FISHERIES, SUSTAINABILITY AND DEVELOPMENT

Fifty-two authors on coexistence and development of fisheries and aquaculture in developing and developed countries

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FOREWORD

Fishes constitute a major part of the aquatic ecosystems that cover about 2/3 of the world. Fisheries provide nutritious food of major importance as well as livelihoods, export incomes, recreation, etc., and could play an important role for development and poverty reduction. However, donors and developing countries have failed fully to take advantage of the potential. Fish stocks are under pressure in most parts of the world. Capture fisheries cannot satisfy the increasing demand for fish and shellfish. Responsible and profitable aquaculture has to be promoted, and changes are urgently needed to make the fisheries sector more sustainable, both ecologically and socio-economically.

How can the unsatisfying status of so many valuable fish stocks all over the world be improved, and the increasing demand for fish and shellfish met in the long run? How can fisheries in developed and developing countries progress in harmony, and at the same time contribute to sustainable development? These and similar questions are the object of a keen international discussion. This book aims at contributing to this discussion, with topical scientific data and an overview of current knowledge. The issue of fisheries is wide, complex and partly controversial. Therefore, a book like this has to present subject matters from different angles. Special attention is paid to fish stock conservation and to fisheries in developing countries.

The Royal Swedish Academy of Agriculture and Forestry recently published an anthology on coexistence and development of agriculture in developing and developed countries, titled *Agriculture, trade and development – Toward greater coherence*. The book was issued in Swedish in 2006 and in English in 2008 (revised version). It was very well received and soon discussions started within the Academy about the possibilities to publish a similar book on fisheries. The original proposal came from Mikael Cullberg, then at the Swedish Board of Fisheries.

The project was funded by the Swedish International Development Cooperation Agency (Sida), the Academy, the Swedish Board of Fisheries, the County Administration of Västra Götaland and the A W Bergsten Foundation. In addition, substantial voluntary work was devoted to the planning, writing and editing of the book. The Academy wishes to express its sincere gratitude for all contributions to the project. A special thanks is

extended to all the authors, who kindly and enthusiastically provided their expertise and experience to the project – on top of all their other commitments – thereby making the book possible.

An editorial committee was set up to run the project. It consisted of Academy Fellows Prof. Per Wramner (chairman) and Prof. Hans Ackefors, with Mikael Cullberg (County Administration of Västra Götaland) as secretary, as well as Antonia Sanchez-Hjortberg (Swedish Board of Fisheries), Joacim Johannesson (Swedish Board of Fisheries) and Johan Sundberg (Sida). Per Wramner, Hans Ackefors and Mikael Cullberg acted as editors of the book, and Ylva Nordin was responsible for the layout. A reference group consisting of representatives from various organisations in the fields of fisheries and environment followed and commented on the work continuously.

The book is aimed at a broad audience with an interest in fisheries in a wide sense, such as politicians, social movements, universities, government agencies, fishers, fish farmers, fisheries organizations and other stakeholders. Several chapters are also appropriate as course literature in various fields of study. The book neither attempts to provide unequivocal answers, nor does it outline definite development paths. Instead, it is aimed at presenting an important and complex area from the perspectives of different expertise and experience. Nevertheless, the final chapter attempts to summarize certain conclusions from the various contributions and discusses possible ways forward.

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Secretary General and Managing Director
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OCEANOGRAPHY AND GLOBAL FISH PRODUCTION

Lars Rydberg

Abstract

Shelf seas and large upwelling areas along the eastern side of the Atlantic and Pacific Oceans occupy 10 percent of the global ocean, but stands for some 80 percent of all marine fisheries. The deep ocean on the other hand, covering some 80 percent of the area, stands for a maximum of 15 percent of the fisheries. Here, the physical reasons (ocean circulation, including upwelling and mixing) behind these large differences in yield are discussed. Nutrient supply from land, and efficient nutrient recirculation due to mixing by tides and winds, enhance primary phytoplankton productivity and fish yields in the shelf seas. A strong upward flux of water and nutrients from intermediate depths boosts productivity and fish yields in upwelling areas.

Introduction

Figure 1 shows the topography of the ocean. The sea occupies some 71 percent of the Earth's surface, totally 361x10^6 km^2. The mean depth is 3,700 meters. The bottoms of the open ocean consist of 4,000–5,000 meters deep basins, separated by deep sea ridges, where melted lava from the inner Earth finds its way to the surface, creating the basis for continental drift. Along these ridges, new bottoms are formed. Horizontal spreading takes place at a rate of a few centimeters per year. The age of the Atlantic deep sea floor is of the order of 100 million years, with a sediment thickness of 100–1,000 meters, increasing from the ridges towards the continents. It means that sediment accumulates by a rain of biogenic wastes (dead plankton and fecal pellets) and terrestrial material, at a rate of 1–10 mm/1,000 years.[1]

The shelf (<200 m deep; Figure 1), situated close to the continents, features massive sediment layers (typically ten kilometers thick). Here, the load of terrestrial material is much larger than in the open ocean. The phytoplankton primary production (PP) is also much higher, as seen from Figure 2, showing PP as determined from satellite data. While ice ages played a major role in building the Arctic and Antarctic shelves, large rivers are responsible for sediment transport and shelf building in equatorial and temperate regions. The extension of the shelves is also sub-

1. Illustrations to the continental drift may be found at the web site of USGS; *http://pubs.usgs.gov/gip/dynamic/dynamic.html*.

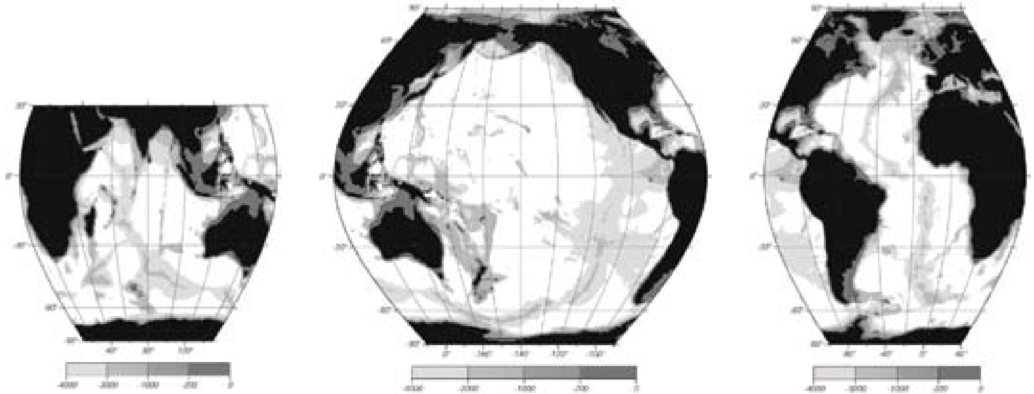

Figure 1. The topography of the global ocean. Shelf waters (< 200 m deep, dark grey) occupy 8 percent of the three oceans, the Indian, the Pacific and the Atlantic. The open ocean consists of deep sea floors with depths of 4,000–5,000 m (white). In between are scattered sea mounts and deep sea ridges of varying depths. Data from ETOPO 30'.
Source: *http://oceanworld.tamu.edu/home/course_book.htm*.

stantially affected by large tertiary sea level variations (typically ±100 m) in relation to today's level. Thus, the North Sea was drowned twice since the latest ice age only. Obviously, the thickness and the quality of the sediments contain very important historical records in relation to PP and the production of fish.

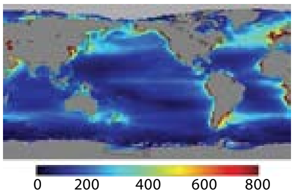

Figure 2. Mean PP (gC $m^{-2}y^{-1}$, 1997–2002) as estimated from satellite determined Chl-a; SeaWiFS data on the OrbView-2 satellite. Primary productivity as estimated from satellite observations tends to give higher PP values than ground truth observations, particularly along the continental margins. Image by Robert Simmons, NASA GSFC Earth Observatory, based on data provided by Watson Gregg, NASA GSFC.

In total, the shelf areas cover 8 percent of the ocean surface, but they account for nearly 50 percent of all marine fisheries. If adjacent deeper coastal waters including some major upwelling areas are added, one will find that more than 80 percent of the marine fisheries originate from just about 10 percent of the ocean. High sea fisheries, beyond the Exclusive Economical Zones (EEZ; more than 370 kilometers from land), make up for the missing 10–20 percent. Thus, the yield per unit area along the coastal boundaries is 10–100 times larger than it is in the open sea. How is that possible? Here, I will elaborate this question from the physical side, by discussing the global ocean circulation and how it relates to long and short term up- and downwelling of nutrients.

Table 1. Fisheries yields (in million tons/year and kg/hectare) and PP (in g Carbon/m²/year) in the three oceans, specified for their high seas, shelves and upwelling areas (average for 2000–2004; data from *www.seaaroundus.org*). Fisheries in the Antarctic and Arctic Oceans (small) are not included, nor are uncontrolled or unreported fisheries (might be several million tons per year, see Anon. 2006). Fisheries yields within EEZ areas deeper than 200 m amounting to about 16 Mtons/year, fall outside the limits of high seas and shelf areas, but are included in the figures for the total ocean.

	Total ocean		High seas			Shelf seas			Upwelling areas		
Ocean	Mtons	kg/ha	Mtons	kg/ha	gC/m^2y	Mtons	kg/ha	gC/m^2y	Mtons	kg/ha	gC/m^2y
Pacific	53	3.11	6.6	0.68	110	26	18.5	≈340	11	16.3	250
Atlantic	21	2.56	1.8	0.34	140	12.5	17	≈430	4.13	9.2	497
Indian	11	1.69	1.4	0.37	120	3	20	-	1.65	10.5	419
Total	**85**		**10**			**41.5**			**16.8**		
Mean		**2.60**		**0.48**	**122**		**18.5**	**≈400**		**13.6**	**341**

The vertical, overturning circulation in the deep water (the Conveyor Belt) and the shallow water thermohaline circulation are of particular importance. The mixing by winds in the surface waters of the ocean and by tides in the shallow waters is also vital, in addition.

First though, some data on the distribution of global fisheries, summarized from the project "The Sea Around Us" at University of British Columbia, Canada. Table 1 shows fisheries yields in the different oceans and their shelf seas and upwelling areas, including the PP, as estimated from satellite data. Marine capture fisheries average 85 Mtons/year, which correspond to 2.6 kg/ha (260 kg/km²). The Pacific Ocean has larger yields than the other oceans, and also larger catch per unit area, while the difference in PP between the oceans is small. In the high seas, outside the EEZ, the yield is only 0.48 kg/ha. In the shelf seas, on the other hand, the yields are much higher, on average 18.5 kg/ha, with maxima of 30–70 kg/ha, e.g. in the Yellow Sea and the North Sea. The upwelling areas, situated on the eastern side of the Atlantic (Canary and Benguela Currents; for positions, cf. Figure 9) and the Pacific (Peru and California Currents) Oceans are also areas of intense fisheries, with yields exceeding 10 kg/ha. However, while the average yields vary with a factor of about 30 (from 0.48 to 18.5 kg/ha), the variations in PP are much smaller (from 122 to 400 gC/m^2y) and although there is a correlation between higher PP and higher yields on average, it is not always so, if comparison is made e.g. between the upwelling areas of the different oceans. This however, may be because PP estimates based on satellite data are so far not particularly accurate.

The vertical (overturning) circulation in the oceans; salinities and temperatures

Deep and bottom water overturning

Figure 3 indicates the main features of the deep water circulation in the oceans, known after Broecker (1991) as the Conveyor Belt. *Deep water* production occurs in the North Atlantic

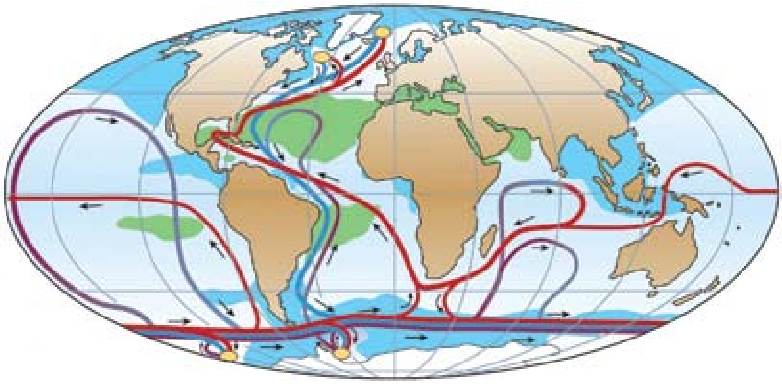

Figure 3. The Conveyor Belt, featuring areas of deep water formation in the North Atlantic, and bottom water formation in the Antarctic Ocean. Areas of high (S>36 psu) and low (S<34 psu) surface salinities are shown in green and dark blue. The colours also indicate surface water stability, where dark blue means high stability and green means low. Green areas are prone to downwelling, indicating that there is formation of "local deep water" taking part in a shallow overturning circulation within the warm water pool. *Source*: Rahmstorf, 2006.

and *bottom water* production in the Antarctic Ocean at rates of 15±12 Mm^3/s and 21±6 Mm^3/s (Ganachaud and Wunsch 2000). These are the only waters that are dense enough (very cold and relatively salty) to reach the largest depths of the ocean. Figure 4 shows a temperature section along the mid-Atlantic Ridge, the position of which is seen in Figure 1. Antarctic bottom water reaches about 40°N, while the Arctic deep water, sinking at 60–70°N (see Figure 4) reaches about 40°S and then turns into the Indian Ocean (Rahmstorf 2006). The bottom water also enters into the deep basins of the Indian and the Pacific Oceans, to be slowly lifted towards the surface and mixed with overlying deep waters.

Lifting of bottom water takes place as a wide-scale upward motion of about five meters a year (Munk 1966), but the local variations are large, affected by mixing at the continental slopes and along deep water ridges (Munk and Wunsch 1998). The deep circulation therefore, has turnover times of about 1,000 years. This circulation also determines the deep water nutrient concentrations and the long term mean fluxes of nutrients. Bottom water formed in the Antarctic, and deep water formed in the North Atlantic during winter, have high nutrient concentrations already when sinking, different from the nutrient depleted surface waters of the open ocean. Figure 5 a, b shows nutrient profiles (phosphate

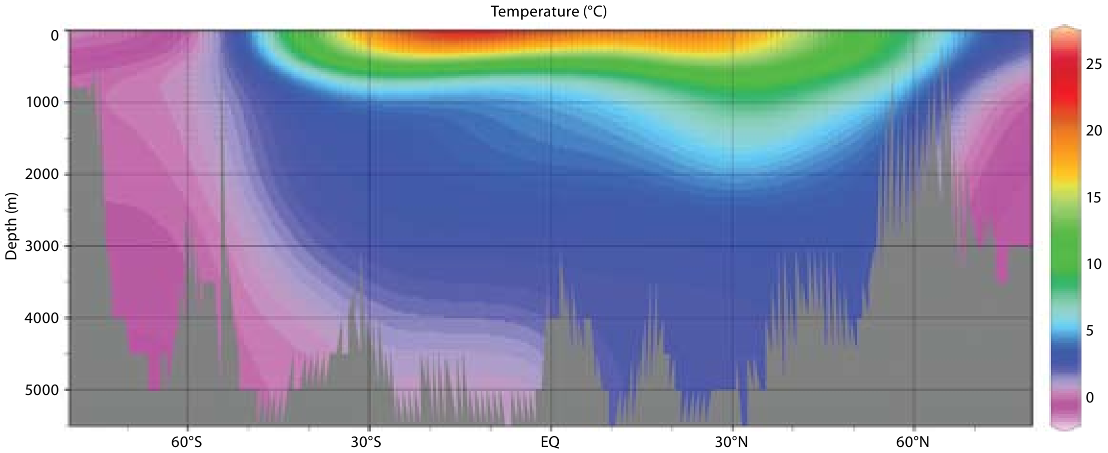

Figure 4. Annual mean temperature in the Atlantic Ocean near the mid-Atlantic Ridge. The figure shows the extension of the shallow warm water pool, the sinking Antarctic bottom water (pink), reaching 40°N and the Arctic deep water, reaching 35°S. The Atlantic deep water continues into the Indian Ocean. Data from WOA05.

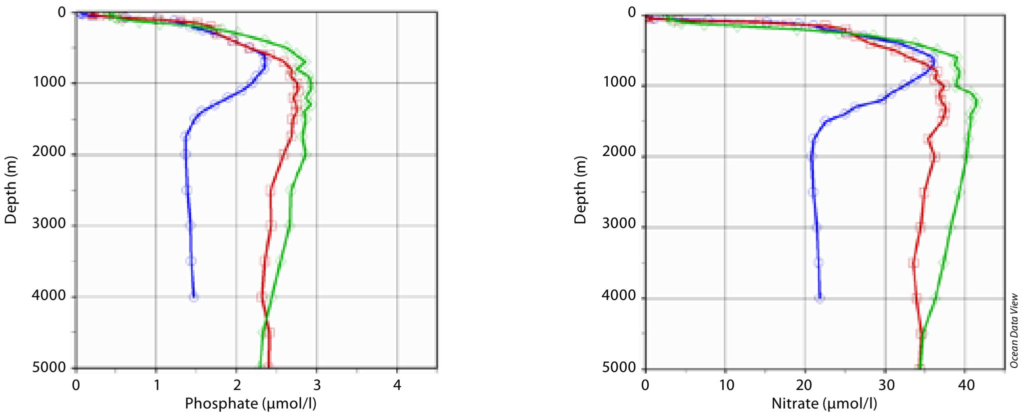

Figure 5a, b. Profiles showing annual mean phosphate (µM; left) and nitrate (µM; right) in the Equatorial Atlantic (blue), Indian (red) and Pacific (green) Oceans, respectively. Maximum nutrient concentrations at depths of 800–1000 m mirror the relatively high consumption of organic matter at those levels. The bottom water concentrations are set by the maximum surface concentrations around the Antarctic continent, where bottom water formation takes place. Lower values in the Atlantic Ocean appear because deep water formation in the Greenland Sea (see Conveyor Belt, Figure 3) takes place at lower surface water concentrations. Data from WOA05.

and nitrate) from the equatorial parts of the three oceans. As seen from these figures, the deep ocean concentrations are very high compared to those of the surface waters. Lower values in the Atlantic deep water indicate younger waters. Contributions from mineralization of sinking organic matter increase the concentrations in the Indian and the Pacific Oceans, while in the Atlantic, the direct access to deep and bottom water precludes higher concentrations in the deep water, while the highest concentrations are found nearer to the surface.

Surface and intermediate water overturning

The shallow water overturning circulation is related to the ocean surface water, particularly the warm waters (Figure 4). Shallow overturning takes place in the upper 1,000 meters, down to temperatures of about 5°C. It involves different areas of sinking (i.e. Rahmstorf 2006), such as those of strong evaporation and weak rainfall, with high salinities and relatively heavy water (20–30°N/S on the eastern side of the oceans), but also intermediate waters of lower temperatures (5–10°C) which descend to the north and south of the warm water fronts (Figure 4). While the high salinity waters sink to a few hundred meters, the latter may reach depths of 1,000 meters or more.

In the equatorial region, the shallow overturning circulation is mainly north-south (i.e. meridional), with a flow away from the Equator at the surface and towards the Equator at depths of some few hundred meters. The Equator and adjacent areas experience upwelling. However, there are also east-west motions involved, because of wind driven surface currents. Overturning in waters >5°C occurs within less than ten years, and involves some 10 percent of the global ocean volume. If the real warm water (>15–20°C; with depths less than 50–200 m) is considered, the turnover times are just about one year. Still, this warm water overturning involves the main part of the surface ocean; Figure 6, showing the annual mean sea surface temperatures (SST) of the ocean, indicates that some 50 percent of the ocean surface has mean SSTs above 15–20°C.

The overturning circulation is also known as *the thermohaline circulation*, because both the temperature and the salinity affect it. Or rather, the circulation is forced by heat and fresh-water fluxes through the sea surface. A net flux of heat into the ocean will cause expansion and a rise of the free surface, driving equatorial surface waters away from the Equator. A net input of freshwater (created by more precipitation than evaporation, which is the case at the Equator) will have a similar effect. Thus, waters in the equatorial oceans will be forced away from the Equator, because of excess heat and excess freshwater input. When reaching the high pressure cells at 20–30°N/S, evaporation is stronger than precipitation and the salinity rises. This can be seen from Figure 7, showing annual mean salinity. In these areas the surface water becomes heavier (because of the salinity increase). It sinks and re-circulates towards the Equator. Because these waters are still warm this occurs within a few hundred meters from the surface.

North and south of the warm water pool

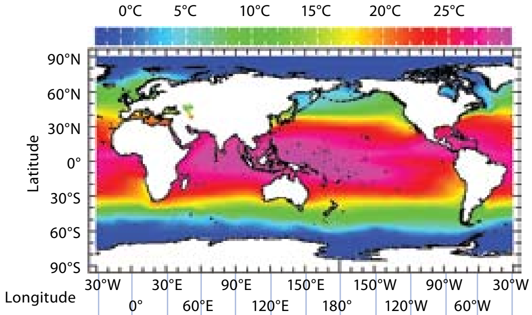

Figure 6. Long term annual mean SST according to WOA 05 data. The eastern upwelling regions are readily seen by the low temperatures in the eastern part of the Atlantic and Pacific Oceans. The surface of the warm water pool (SST>15°C) covers more than 50 percent of the oceans.

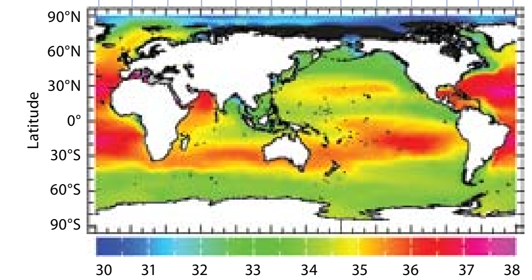

Figure 7. Long term annual mean sea surface salinity according to WOA 05 data. Black indicates S<30 psu, grey S>38 psu. Higher salinity appears in the regions 20–30°N/S due to low precipitation and high evaporation, in connection with the high pressure cells. Low salinities are due to high rainfall and/or large freshwater input from rivers.

(>15–20°C), the surface water cools off and becomes heavier. In these convergences, a more deep-going downwelling takes place. The cold water returns towards the Equator underneath the warm water pool (usually at depths of about 1,000 meters or more). This is also where the highest nutrient concentrations are found (Figure 5). While this returning water is not very sensitive to the wind driven surface currents, the waters in the warm water pool are also partly subject to fast latitudinal redistribution, and to surface water mixing caused by winds (see more below).

The extension of the warm water pool and its overturning circulation is of major importance for PP in the open sea. Nutrient recycling within the pool, as well as input of new nutrients from below through the deep circulation, are important. Figure 2 shows that PP on the Equator is slightly higher, at least in the Pacific. But there is no strong indication of large-scale high PP.

Eastern boundary upwelling

There are large differences in the SSTs between the eastern and the western side of the tropical oceans, where the eastern sides are much cooler (Figure 6). This is because the eastern tropical and subtropical regions of the Atlantic and the Pacific Oceans are subject to persistent upwelling. West of the American and the African continents, the SSTs are more than 5°C lower than in the open ocean. This deep-going upwelling is driven by persistent winds along the coast as illustrated in Figure 8. Here, cold and nutrient rich waters from about 200–300 meters reach the surface. The upwelling regions are highly productive because of the very large nutrient fluxes. These fluxes also create the basis for a high PP (Figure 2), and for the very high fisheries yields (Table 1). The Arabian Sea, in addition, particularly along the coast of South Arabia, is also an area of upwelling-like conditions. The monsoon winds over the Indian Ocean shift from north-east in the northern winter to south-west in the northern summer. The winds are very strong in this area. Deep-going wind mixing creates a more or less continuous entrainment of nutrient rich waters from depths > 100 meters, such that high PP and fisheries yields can also be sustained.

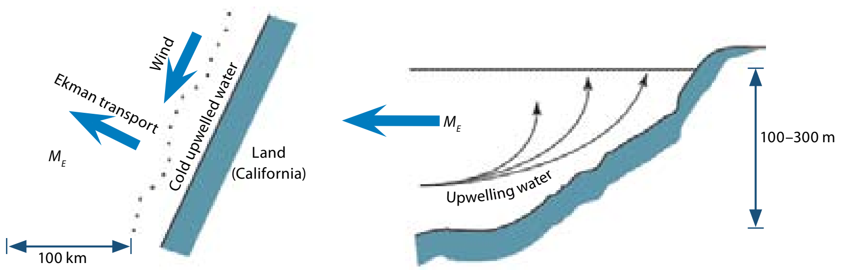

Figure 8. Schematic figure indicating coastal upwelling in the Northern Hemisphere.
Source: *http://oceanworld.tamu.edu/home/course_book.htm*.

Wind driven surface circulation and wind mixing; El Niño

The global wind field is dominated by easterly trade winds, from 30°S–30°N, and the westerlies, north and south thereof. The wind field is more stable over the Southern Hemisphere, while there are large seasonal variations in the Northern Hemisphere, related to changing monsoon circulation. Thus, during the northern summer, the southern trade winds blow across the Equator, creating the southern monsoon, which is particularly strong in the Indian Ocean. Meridional variations in the wind in combination with the frictional force acting on the sea surface and the Earth's rotation create sea surface motions (Ekman drift) which build up meridional sea level variations. These in turn, together with sea level variations due to thermohaline forcing, create the surface currents of the world ocean, as they appear in Figure 9.

The depths to which the ocean currents reach are typically a few hundred meters, with maximum velocities of about 1 m/s at the surface. Maximum transports of 50–100 Mm^3/s appear in the western boundary currents; the Agulhas,

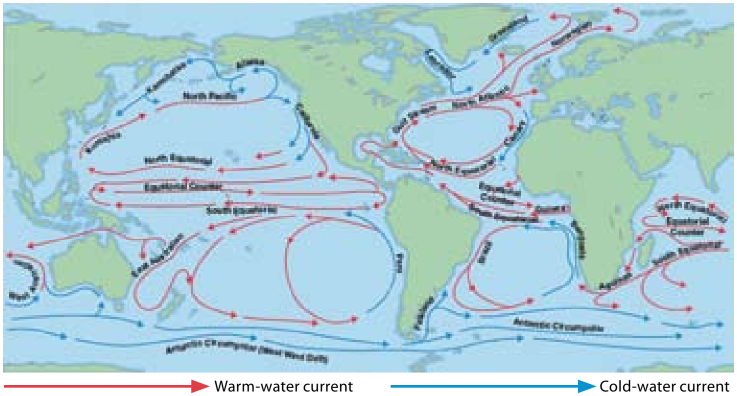

Figure 9. Surface currents of the ocean (blue for cold and red for warm) during the northern winter. During the northern summer, the North Equatorial Current of the Indian Ocean changes to eastward, fuelled by the South Equatorial Current which crosses the Equator northward, then named the Somali Current (*http://cimss.ssec.wisc.edu/sage/oceanography/lesson3/images/ocean_currents2.jpg*).

the Gulf Stream and the Kuroshio (Figure 9). The eastern boundary currents, i.e. the Benguela and Canary Currents, are slower and more widespread, but somehow they return the water that goes pole-ward on the western side of the oceans. Only small amounts of the water take part in the deep overturning circulation.

The east-west currents in the equatorial region also feature high velocities and large fluxes, up to 50 Mm^3/s. In the Indian Ocean (see text, Figure 9), the monsoon shifts also turn the direction of the equatorial surface currents. A more occasional feature is related to ENSO (the El Niño Southern Oscillation). El Niño years, with weaker easterlies, slow down the west-going currents in the Pacific, while the eastward counter current (Figure 9) continues south along the coast of Ecuador and Peru. This hinders upwelling. The eastern Pacific becomes several degrees warmer with a consecutive decrease in PP and fisheries yields. The strong variations in the fisheries for the Peruvian anchoveta (from some few Mtons/year during El Niño years up to 10 Mtons/year during La Niña years) are probably the most vivid example of the importance of the ocean circulation on PP and fisheries. Figure 5, by Sherman *et al.* (this volume), shows warming by LME's, from 1982 to 2006; two LME's out of some 65 have become colder, and these are the California and Peru/Humboldt upwelling regions. This indicates a stronger east-west overturning circulation, bringing more nutrients to the surface.

Hellerman and Rosenstein (1983) calculated global scale up- and downwelling based on the surface Ekman fluxes. These are typically of the order of 10–20 cm/day or 50 m/year in the equatorial regions. As thermohaline forcing drives surface water overturning at similar rates, the combined action can be estimated at 100 m/year.

This means, as mentioned, a turnover time of the order of one year in the uppermost layers of the warm water pool, where fluxes of heat and freshwater on one hand and the wind effect (fluxes of momentum) are of equal importance. However, much faster turnover may be found in relation to wind mixing, caused by strong winds. In the wake of tropical cyclones, upwelling rates of many meters per day have been recorded, and mixing down to more than 100 meters is common. Accordingly high chlorophyll concentrations and PP appear in the wakes.

Tidal mixing

In most shelf areas, the tides are also important for mixing in the surface waters. Tidal friction acts from the bottom upwards, whereas wind-mixing acts from the surface downwards. Thus, tidal mixing results in homogenized waters with rapid recirculation. In the North Sea, with tidal ranges of several meters, mixing by tides homogenize waters out to some 50 meters' depth, and much of the North Sea, with a mean depth of some 50 meters, is mixed from surface to bottom on a daily basis. Therefore, most shelf seas which have strong tides are furnished with efficient mixing to serve for manifold recirculation of nutrients (and high PP) between the bottoms and productive surface water before nutrients (supplied from land) are finally lost to the deep ocean and/or by burial in the sediments.

Discussion and conclusions

Large nutrient supply is conditional for high PP and fisheries yield as well. This may occur outside large rivers, but also in areas with intensive upwelling or deep-going mixing, that bring nutrients from the deep ocean to the surface. An efficient recirculation of nutrients, where dead organic material is not lost to the deep ocean, but re-mineralized on shallow bottoms or within surface waters, may considerably increase the PP. However, mixing by tides and winds is needed to return the mineralized nutrients to the surface, i.e. to where the light is enough to sustain a high PP. In the open ocean most of the nutrients are lost because organic material sinks directly into the deep waters, but on the shelves, the conditions for recirculation are much better. This is why some shelf seas may produce fisheries yields which are up to 100 times larger than those of the open ocean, although the differences in PP, in fact, are moderate (see also Table 1). Gargett and Marra (2002) discuss the relationship between physics (including nutrients) and PP in much more detail. Ryther (1969), Tait (1981), copied by Tait and Dipper (1998) and Pauly and Christensen (1995), to mention a few, have all explored the links between PP and fisheries yield. The works of these authors give more details on the subject, explaining processes and underlying assumptions used and made here.

It is obvious, however, that even if nutrient supply and nutrient recirculation set the limits for the PP, they are not conclusive for the fisheries yields. On the contrary, global fisheries are more or less exclusively responsible for the rate at which fish is produced. Not until man starts exploiting the fish stocks, one can really understand which limits there are to the yields, and to what extent the fish stocks can reproduce themselves. However, because most fish stocks are either fully exploited or over-fished, fisheries yields and production of fish are similar in size. Thus, the heavy fisheries of today mean that man is approaching a stage of extensive ocean aquaculture, with fewer species (the most efficient ones) left for food, and others, at best swimming round in reserves, like wild-life on land where a corresponding development has taken place gradually during thousands of years.

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Photo: Dan Tilander, Swedish Board of Fisheries.

HUMAN IMPACT ON THE AQUATIC ENVIRONMENT

Henrik Österblom

Abstract

Marine ecosystems are substantially influenced by human activities. This human impact comes in various forms and ranges over different temporal and spatial scales. Activities can influence ecosystem dynamics bottom-up by adding nutrients, and they can influence ecosystems top-down, by removing predators. Chemical pollutants, introduced species and climate change can influence all components of the ecosystem. The loss of critical habitats will influence the capacity of ecosystems to respond to human impact. The multitude and magnitude of human impact make it difficult to separate cause and effect, and it is often the cumulative nature of the impact that is leading to the observed response, clearly making it difficult for managers to identify priorities in mitigation measures. Non-linear dynamics in ecosystems even indicate that managers have a limited capacity to restore ecosystems to more desirable states. Increased human impact is to be expected, given increasing demand for seafood and increased intensity of uses in the coastal zone. Reducing human impact in a constructive way remains a global challenge.

Introduction

Human activities influence aquatic environments in ways that can have a substantial impact on the capacity to use the ”ecosystem services” provided by these environments. Ecosystem services can be described as different functions carried out by nature, e.g. protection from erosion, natural purification of water, production of food or carbon uptake. Other less tangible services include cultural services such as spiritual and recreational benefits. In an UN-initiated global assessment of the environmental situation on the planet (the Millennium Ecosystem Assessment), researchers drew the conclusion that more than half (60 percent) of the investigated ecosystem services were declining (MEA 2005). Status and trends for these ecosystem services will influence the possibilities to secure functioning ecosystems and to feed a growing global population with healthy food. Hence, this is not only an environmental issue but also substantially influences human well-being. Fish provides more than 1.5 billion people with almost 20 percent of their intake of animal protein, and 3 billion people with 15 percent (Ababouch, this volume).

Despite the fact that the aquatic environment supplies humanity with a range of important ecosystem services, human influence is substantial in most regions around the world (Burke *et al*. 2001, Revenga *et al*. 2001, GEO 2002, MEA 2005, GEO 2007, Halpern *et al*. 2008). Even if the effects on the marine environment can be traced to specific factors, adequate measures are hampered by the fact that actions need to be taken on land, or in a number of different sectors within different areas of policy. It is primarily the well-studied and well-known impact associated with persistent organic pollutants, which has been significantly reduced in a number of regions (Harremoës *et al*. 2001). However, actions to reduce eutrophication has only had limited effects (Duarte *et al*. 2009), and fisheries policies around the world have still to meet their targets (Pitcher *et al*. 2009).

We have probably only begun to see the effects of climate change on aquatic environments. Even if greenhouse gases were to be reduced dramatically during the coming decades, it will still take a long time before we are able to see the effects. The demand for marine fish protein will increase as a result of more people breaking out of the poverty trap, thereby getting an improved access to healthy food through increased purchasing power.

Healthy aquatic environments contribute, in a substantial way, to the planetary supply of ecosystem goods and services for human well-being, but much work remains to deal with many of the problems. Instead of observing positive results from measures taken, we are increasingly observing the complex and cascading impacts of human activities, such as dramatic changes in ecosystem structure and function due to cumulative impacts from multiple driving forces (e.g. overfishing, eutrophication and climate change: Jackson *et al*. 2001, Scheffer *et al*. 2001, see box).

We face a situation where many actions remain to be taken. We still do not have the knowledge, tools, resources or technologies and institutional structures in place to succeed. The problems are substantial in temperate ecosystems, despite the fact that most countries have elaborate legal frameworks and institutions in place. The challenge is increasing as many developing countries experience rapid economic growth; it is of major importance that they do not repeat the mistakes made by the developed world.

Pollutants

Chemical pollutants are a result of the discharge of heavy metals (e.g. arsenic, mercury, cadmium) or other long-lived compounds that can accumulate in ecosystems (e.g. PCB, dioxins). Discharges from industries, untreated sewage water, pesticide use in the agriculture sector or aquaculture contribute to the problem, as well as the dumping of toxic substances at sea (GEO 2002, UNEP 2006, GEO 2007). Many long-lived chemical pollutants can be transported substantial distances, which e.g. results in high levels of human derived toxins in the Arctic (Barrie *et al*. 1992, Wania and MacKay 1993, Bard 1999). Since many environmental toxins are long-lived, they can be accumulated through the food chain,

Cumulative and historical human impact

The effects from different sectors are clearly inter-related; this cumulative impact makes it difficult to untangle the relative effects of different human induced driving forces, as well as the effects of a changing climate. New studies indicate that the sensitivity of an ecosystem to these multiple stressors can vary depending on a number of factors. Coral reefs in the Caribbean appear much more sensitive to eutrophication than similar reefs in Australia due to the depletion of grazing fish in the Caribbean, which reduces their capacity to counteract the smothering of the reefs from algae (Bellwood *et al*. 2004). There are also indications that larger fish stocks have a better capacity to adapt to a changing climate, than overfished stocks (Brander 2005). The capacity of the ecosystem to deal with this kind of disturbances (i.e. its resilience) may thus be a product of how exposed they are to human activities.

A seminal study on the effects of human activities on coastal ecosystems with a historical perspective (Jackson *et al*. 2001) shows the impact of historical fishing and hunting of marine mammals on the resilience of these ecosystems. The effects from overfishing were not apparent until decades later, due to natural lag effects in the systems. Most of the species that had collapsed due to fishing or hunting had performed important functions in the ecosystem, and in many cases their functions were buffered by similar species, until they too, were overexploited. In Mexico, Australia and North America, giant turtles and dugongs were grazing seagrass beds, thereby contributing to a reduction of organic compounds and nutrients to the sediments. When these grazers were exterminated, the systems became more vulnerable to e.g. eutrophication. There are also indications that historical abundances of oysters and mussels had the capacity to reduce algal blooms and other negative effects of eutrophication (by filtering the water and converting nutrient into biomass). Historical hunting and fishing may thus have led the way for contemporary human impact on aquatic environments.

so that top predators can be especially vulnerable to toxic substances. Mussels and other invertebrates, which filter water for food, can also accumulate high concentrations of toxic substances such as brominated flame retardants (Gustafsson *et al*. 1999).

Under the 1960s and 70s, there were a number of obvious effects from toxic substances documented in marine birds and mammals (Muir *et al*. 1992, Olsson *et al*. 1994, Helander *et al*. 2002). Effects from e.g. PCBs included reduced egg-shell thickness (and hence lower reproduction success) in seabirds, as well as reduced reproduction in marine mammals (due to negative effects on female reproduction organs), which resulted in a targeted effort to reduce the identified compounds, with substantial positive results. Despite these efforts, however, the problems are far from solved; the toxic levels in polar bears and the native population in the Arctic is very high (Bernhoft *et al*. 1997, Deutch *et al*. 2004). A large number of new compounds with potentially toxic characteristics are produced each year and it is practically impossible to determine potential effects on aquatic ecosystems. Even though a large number of toxic compounds have been banned in many countries in the developed world, they are still being used to a large extent, primarily in the developing world.

Untreated sewage water is an important source of health related problems in the developing world. Rapid urbanization, in combination with high initial costs to reduce the amount of untreated water, complicates the potential to implement measures. Pollution from micro-organisms (from untreated sewage water) tends to increase with increasing urbanization, primarily in Asia, Africa and Latin America. For instance, 90 percent of household water in the Caribbean is discharged without any treatment whatsoever (GEO 2002).

Thousands of industries along the Ganges River in India and Bangladesh are active with insufficient capacity for water treatment. The concentrations of e.g. arsenic, cadmium, chrome, mercury and lead exceed the levels acceptable according to health standards with between ten- and hundredfold, in both India and Bangladesh (GEO 2002). Water in China is occasionally unfit for both human consumption and crop watering in many regions, which among other things limits the capacity for food production (World Watch Institute 2006). The agricultural sector is an important cause of chemical pollution of waterways in several countries in Central and South America (UNEP 2006). The rapid expansion of aquaculture in many regions (see below) also results in increased discharge of e.g. antibiotics, with potential negative effects. Most countries in the developed world still face substantial challenges in reducing compounds with unknown effects in marine environments, including pharmaceuticals (e.g. containing hormones) from hospitals and private homes.

Discharge of oil from ships can be an important source of polluting substances, both from cargo and cruise ships. Larger oil discharge accidents commonly get high media attention, but substantial amounts of oil also reach aquatic environments when fuel tanks are cleaned offshore, as well as operational discharges from offshore oil platforms. Marine litter is an additional direct human impact on marine ecosystems (Pruter 1987, Kennish 2002). Plastic particles can result in elevated mortality rates on marine organisms.

Released sediments can be an important source of pollution (UNEP 2006). Forestry, agriculture, infrastructure and other changes in land use result in substantial impacts, primarily in South America, South East Asia and Africa (south of the Sahara). The impact is likely to increase in all these regions during the coming decades. Increased erosion of sediments results in deteriorated water quality, with effects on coastal habitats. Sediments can also smother coral reefs, eelgrass beds and gravel beds, resulting in e.g. negative effects on fish reproduction. The forestry sector in Indonesia contributes to an increased flow of sediments, influencing coral reefs in the region, with negative effects on tourism, fisheries and aquaculture (UNEP 2006).

Eutrophication

Eutrophication in lakes, coastal and offshore ecosystems is a result of high levels of nutrients, which has entered these environments by waterways, sewage treatments plants or from the air, e.g. nitrogen oxides (Nixon 1995, Vitousek *et al.* 1997, Howarth 2008). Modern societies with water toilets can result in excess discharges of nutrients to aquatic environments, but treatment plants offer good opportunities for reducing these discharges. Other such point sources from industries (discharges both to the water and air) are relatively easy to mitigate. Discharges of airborne nutrients, e.g. from traffic, can be substantial (UNEP 2006).

The agricultural sector is often a large source of nutrients and especially modern productive agricultural industries can contribute to large discharges of nutrients to lakes, waterways and coastal ecosystems. Forestry (including bioenergy production) can also be a significant source of nutrient discharge to aquatic environments. These kinds of discharges are normally referred to as diffuse loads, and the effects of measures in these sectors are commonly difficult to trace in aquatic environments due to lag effects (depending on e.g. retention: the capacity of the soil to take up nutrients before they are transported to coastal environments). Although the applications of fertilizers (including nutrients) occur locally, the effects spread regionally or even globally (Vitousek *et al.* 1997). Aquaculture is an additional source of nutrients, although the impact on aquatic environments is often local.

As countries are increasingly becoming industrialized and producing more meat, traditional agricultural production systems are modernized, often resulting in an increased discharge of nutrients. Modernization can also result in an increased use of chemical fertilizers, in combination with straightening of waterways and loss of natural capacity to purify water (e.g. the loss of wetlands and mangrove forests or other coastal habitats which increase retention of nutrients). Human activities have roughly doubled the rate of creation of biologically available nitrogen (although with large regional variation) and over half of the synthetic nutrient fertilizers ever produced was used in the last 15 years (Howarth 2008). More nutrients therefore flow through the systems and the natural capacity to deal with this additional flow is being reduced. The problems associated with eutrophication are likely to increase in a number of regions, especially in Africa and Asia, as a result of the expected increase in agricultural, bioenergy and aquaculture production.

One of the most obvious effects of eutrophication is the overgrowth of waterways, leading to reduced potential for ship transportation and for small-scale hydropower installations (UNEP 2006). Many coastal regions are suffering from excessive growth of algae (influencing e.g. coral reefs with consequences for fish production), changes in food web structure and loss of biodiversity (Howarth 2008). However, there are substantial indications that eutrophication to some extent can have positive effects, e.g. on fish production (Nixon and Buckley 2002). This is because the increased availability of nutrients stimulates an increased production of phytoplankton, in turn stimulating zooplankton production, which transfers into energy for fish (a bottom-up cascading effect). When the organisms from the increased production are decomposing, however, oxygen is consumed. The increased consumption of oxygen in deep waters can result in anoxic conditions, where few (if any) species can survive (Diaz and Rosenberg 1995). Areas with hypoxic conditions are fairly common in North America (Chesapeake Bay and the Gulf of Mexico), Europe (the Black and Baltic Seas) and Japan (Seto inland Sea), and are at least in part thought to be a result of human activities (Diaz and Rosenberg 2008).

The frequency of toxic algal blooms has increased in a number of regions partly as a result of the development of the agricultural sector (and the increased use of chemical fertilizers), but also because of introduced species. Between 1993 and 2003 there was an increase in the number of toxic algal blooms in the South China Sea, from 10 to 86 occurrences per year. Algal blooms influence fish and bottom fauna and can have a substantial social and economic impact (UNEP 2006). The frequency of toxic algal blooms at a global scale has increased during the last centuries, with implications for fish and shellfish production (and revenues), seabirds, human health and the potential for tourism (Burke *et al*. 2001; Hambraeus, this volume).

Climate change and ocean acidification

The effects of climate change are already evident in aquatic ecosystems, with increasing ocean temperatures and melting sea ice in the Arctic (Walther *et al*. 2002, Serreze *et al*. 2007, Eisenman and Wettlaufer 2009) as strong signs of warning. Changes in concentrations of dissolved carbon in the ocean influence the chemistry and pH values of the seas (Caldeira and Wickett 2003). Oceans are the largest active carbon sink on the planet. Approximately one third of anthropogenic emissions are "captured" by the oceans (Takahashi *et al*. 2002). But as the oceans take up more carbon dioxide, they are slowly turning more acidic, which results in negative conditions for marine organisms with limited capacity to adapt to changing conditions (Orr *et al*. 2005). A continued decrease in pH could have enormously negative consequences for a wide range of species, with unknown ecosystem effects (Hoegh-Guldberg 2007).

Ocean acidification probably contributes to the bleaching of corals (Antony *et al*. 2008), which has been observed in a number of regions. Coral bleaching can be temporary, but will decrease the capacity of the corals to reproduce and increase their susceptibility to disease. Several incidents of substantial coral bleaching have occurred during the past ten years and the frequency and intensity of bleaching events appear to have increased. If coral reefs fail to adapt to increasing water temperatures, a substantial reduction of global coral reefs is likely within a few decades (Hoegh-Guldberg *et al.* 2007). Already today, 20 percent of all coral reefs have been lost due to a number of factors and another 20 percent are substantially negatively influenced by numerous forcing factors (MEA 2005). Reef resilience to climate change is also influenced by fishing pressure (as functional diversity of grazing fish is important in the recovery of reefs; Bellwood *et al.* 2004). The loss of coral reefs would have enormous implications for the production of fish, and thereby also for the tens of millions of people who depend on coral reefs for their survival.

Loss of coastal habitats

A number of human activities influence the loss of habitats. Agriculture, forestry and aquaculture all require land and water. Freshwater supply to agricultural and energy production influences the flow of fresh water and sediments to the sea. The rapid urbanization in coastal areas is leading to an increased stress in sensitive habitats.

The need for land, e.g. for food production, has historically been an important driving force for the loss of wetlands (Foley *et al.* 2005, MEA 2005). According to some estimates, around 50 percent of all wetlands have been lost during the 20th century, resulting in a loss of ecosystem services such as protection from erosion and floods, and water purification (MEA 2005). Mangroves serve similar purposes, in addition to protecting the coastal zone from storms, and providing important nursing areas for fish and shellfish. Despite these important functions, mangrove forests are being cut down in order to produce timber and to give room for infrastructure and aquaculture. Mangrove forests line around eight percent of the world's coastlines (Burke *et al.* 2001) and are mainly distributed between 25 degrees on either side of the equator. Even though historical information is missing for many regions, available estimates indicate that between five and 85 percent of mangrove forests have been lost, primarily during the last 50 years. Thailand has lost around 84 percent since the 1950s, and Panama has lost almost 70 percent, only since the 1980s. Substantial losses are also estimated for several countries in Africa (references in Burke *et al.* 2001). Aquaculture is one of the main reasons for the observed decreases, and in some instances, aquaculture also results in pollution, which makes the areas unusable. Fuel and other wood consumption, and clearing of land for tourism infrastructure (beaches and hotels) also contribute substantially to the loss of mangroves. However, there is a trend towards replanting in some regions to reduce the losses. Loss of mangroves can lead to collapses in shrimp and fish stocks, thus causing substantial economic losses.

Seagrass meadows form another type of habitat which is an important nursery area for fish and shellfish. These areas are also important for stabilizing sediments. These ecosystems are, like coral reefs, also influenced by eutrophication, sedimentation, dredging, anchoring as well as aquaculture. Present losses of seagrass meadows are expected to increase, especially in South East Asia and the Caribbean, as a result of human activities (Duarte 2002).

The construction of dams for freshwater supply and energy production influences the flow of water downstream, and thereby the supply of water to coastal habitats. Substantial construction of dams in the developed world was carried out in earlier decades and a similar development is now being observed in developing nations.

Coastal tourism is another important factor influencing coastal habitats, e.g. the construction of hotels and other facilities (golf courses and airports), as well as through direct impacts on coastal environments (visits at sensitive coral reefs, litter). Construction of ports and other infrastructure also influences the extent of natural ecosystems in the coastal zone (UNEP 2006).

The effects of fisheries on food webs

Overfishing appears to have led to decreased diversity in the oceans (Worm *et al.* 2005, 2006). A number of fish stocks seem to be in such a poor state that their recovery is unlikely (Hutchins 2000). As large predators such as tuna and cod are being depleted, it is commonly observed that their prey is increasing, which often is the next resource to use. This phenomenom has been called "fishing down the food web" (Pauly *et al.* 1998), or "fishing through the food web (Essington *et al.* 2006), a process which can further limit the capacity of predatory food fish to recover (as their food is being depleted). However such ecosystem changes can be beneficial for other predators (such as birds and marine mammals), but they can also facilitate the spread of disease (Jackson *et al.* 2001).

These large scale restructurings of food webs are often referred to as regime shifts (Scheffer *et al.* 2001), resulting in the "collapse" of entire trophic levels of an ecosystem and new opportunities for other species, sometimes introduced from other regions, e.g. from ballast waters.

Sometimes, ecosystem changes (e.g. overfishing working in synergy with changes in climate), can lead to chain reactions (cascading effects) through the entire ecosystem. There are indications that overfishing of cod in the Baltic Sea has resulted in an increase of their prey (sprat), a reduction of their zooplankton prey and possibly also an increase in summer phytoplankton (Casini *et al.* 2008) – potentially even contributing to an increased oxygen consumption in deep waters. Analogous indications have been observed in the North West Atlantic (Frank *et al.* 2005). Also, overfishing of the large sharks along the North American east coast resulted in a substantial increase in their prey (rays and smaller sharks) that consume oysters. Increased predation on oysters had consequences for oyster fishermen along the coast (Myers *et al.* 2007).

In addition to the fish that is landed, there is also a "bycatch" of species, made up of unwanted, un-allowed and unprofitable fish. This bycatch is often discarded (thrown over board), a waste of common resources. FAO estimated these discards at 27 million tonnes globally, equal to a third of

Can introduced species "fill the blanks" from overfishing?

Ballast water is transported in ships to stabilize them, but when the water is taken on board it will contain organisms which can be completely different from those where the water is released. When ballast water is exchanged, species from remote regions will intermingle with native species, sometimes leading to dramatic ecosystem changes. These introduced species can cause major problems in the new area where they occur, but there is a range of factors that determine whether introduced species will spread in their new environment or not. In the Black Sea, there is a substantial documentation of how jelly-fish introduced from ballast water were favoured by overfishing and thus were able to spread widely, which had substantial negative economic impact (Daskalov *et al*. 2007). Introduced species without natural predators in their new environment can cause a range of problems. Risks associated with exchange of ballast water can be avoided through regulations on when and where such waters can be released. Using ships with double hulls can avoid impact from accidental release of ballast waters through collision.

the total catch (Alverson *et al*. 1994). However, these estimates are fifteen years old and later estimates indicate that discards have decreased substantially since the initial assessment (Kelleher 2005).

Fishing gear does not only catch fish, but occasionally also turtles, seabirds and marine mammals who are active in the same areas as commercial fishermen. Bycatch of dolphins, albatrosses and other marine mammals and seabirds in longline and drift gillnet fisheries has led to a number of international agreements, which have improved the situation, but many issues remain to solve to reduce bycatch of threatened species.

The total production of fish and shellfish (wild caught and produced in aquaculture) more than doubled between 1970 and 2002, from 65 million tonnes to 142 million tonnes (see Ackefors, this volume). A little more than 100 million tonnes of fish and shellfish are used for human consumption and the remaining 30 million tonnes for fish and animal feed. In 2005, 43 percent of all fish consumed by humans was produced in the aquaculture sector (about 45 million tonnes), compared to only nine percent in 1980 (FAO 2006).

Two scenarios have been presented which estimate the future global demand for fish and fish products by 2020 and 2030 at 170 and 176 million tonnes respectively. The large increase in production is likely to come from aquaculture rather than from catches of wild fish (Delgado *et al*. 2003), since the production of wild fish is unlikely to exceed 85 million tonnes in the future (due to reduced production in many stocks in several regions). These scenarios mean that aquaculture production will have to more than double in the coming decades to meet the expected increasing demand.

Aquaculture production has so far been concentrated to Asia, accounting for 89 percent of the total production in 1999. China alone produced 68 percent of the total. A rapid expansion of aquaculture, using contemporary technology, will require large quantities of wild fish for fishmeal (Naylor *et al*. 2000). The FAO (Food and Agriculture Organization of the United Nations) has also identified the lack of investments, as well as lack of adequate space (on land) and poor freshwater supplies, as important constraints for the future expansion of aquaculture. The FAO scenarios indicate that the price for fishmeal and fish oil is likely to increase (potentially substantially) due to increasing demand from aquaculture. However the model used for the scenarios is sensitive to assumptions on the development of prices and the possibilities to expand the marine fishery to hitherto unexploited species.

A continued large demand for wild fish will lead to an expansion of the fishing effort to greater depths, new areas and the commercial use of additional species. Additional fish stocks will be utilized beyond safe biological reference points, which will increase the risk of unexpected collapse of stocks, with unknown cascading effects and potentially also large-scale reorganizing of the ecosystems. Overfishing and habitat loss has

Improved capacity to catch krill

The increasing demand for feed to aquaculture has already started to become apparent. Norwegian enterprises are preparing for a substantial increase in the Antarctic krill fisheries in order to secure a steady supply of fishmeal to their aquaculture production. Environmental organizations have been expressing concern about the enormous harvesting capacity possible as a result of improved ship-based processing technology. According to some estimates, this development makes it possible for one single ship to catch the equivalent of an entire fleet. Russia has also initiated a restoration of its high-seas fleet, which was active during the 1990s in the Southern Atlantic. Although Atlantic krill catches have been rather constant during the last decades, there was a substantial increase in the requests to catch krill in 2008, compared to the catch levels in earlier years. Announced catches from member states in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) were roughly six times higher than what they had been during the last decade, although still far below the identified precautionary levels (CCAMLR website: *www.ccamlr.org*, Pew Ocean Science Newsletter May 2008).

been identified as key reasons for the observed reduction in productivity in many stocks, and a continued reduction in this potential can have a significant impact on the capacity to catch wild fish during the coming decades.

The impacts of fisheries on habitats

The threats to biological diversity in international waters have been increasingly acknowledged during the past few years. The effects on ecosystems (fish stocks and benthic flora and fauna) can be devastating (UNGA 2006). The knowledge of the diverse and complex deep sea ecosystems has increased rapidly, primarily in the North East Atlantic. Species diversity appears to be especially high at underwater seamounts, where fish abundances are particularly high. These seamounts, typically formed from extinct volcanoes, are found at depths between 1,000 and 4,000 metres, and are defined as such if they rise over 1,000 metres above the bottom. It has been estimated that around 30,000 seamounts exist around the world, but the knowledge of these ecosystems is very limited (Rogers 1994). However, the more we learn about these largely unknown ecosystems, the more we understand their richness, sensitivity and uniqueness. New species are continuously discovered, many of which are endemic to a limited area.

It has become apparent that fisheries on seamounts (bottom-trawling) are particularly damaging, since many of the species caught are very long-lived and late-maturing (often at an age of thirty years or later) making them vulnerable to commercial fishing. Trends in catches of commercial species at seamounts often show a steep increase at the onset of fisheries, followed by a rapid decline. These boom and bust fisheries typically only last between five and ten years before they collapse (Koslow *et al*. 2000). A study of the high seas bottom-trawling fleet shows that the value of the catches only corresponds to the profit from around 300 vessels, where only 100–200 are active full-time (Gianni 2004, Gianni personal communication). The interest of these fishermen is thus impacting on the potentially large values of ecosystem services that are being lost due to destruction of deep-sea habitats.

In addition to bottom-trawling and the more general problem of bycatches, there are a number of damaging fishing methods. Fishing with dynamite or cyanide are effective (and in principle illegal) methods to catch fish around coral reefs, but these methods can lead to irreversible damage to the coral ecosystems that sustain fish populations. However, when the cost of dynamite is around USD 1–2 and the profit is equal to USD 15–40, the incentives are fairly obvious. Despite the short term prospects for a substantial gain, the long term loss can be substantially higher. Negative effects of dynamite fishing is estimated to cost Indonesia at least USD 3 billion in the coming 20 years, and the estimated costs for cyanide fishing in the region is around USD 50 million. A sustainable fishing using hook and line, however, could generate profits at USD 320 million (UNEP 2006).

Pollution, eutrophication, climate change, loss of habitat and fish stocks, are all significantly influencing aquatic environments. In order to compensate for the lost production potential in the seas resulting from these and other factors, aquaculture production has increased, which leads to further deterioration of ecosystem services. We are, however, beginning to understand the scale of human impact, which has led to an increased public awareness and a political will to start dealing with the problems. But much work remains to be done – successful restoration of many of the dramatically changed aquatic ecosystems is unlikely in the near future.

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Giant tiger prawn (*Penaeus monodon*). *Photo*: S. Chaitiamvong.

GLOBAL FISHERIES – THREATS AND OPPORTUNITIES

Hans Ackefors

Abstract

The food web in the sea, with autotrophic plants and a diversity of animals, is the basis of fish and shellfish production. In the open sea, you can distinguish between six trophic levels. The total harvest in sea areas and inland waters of fishes, crustaceans, molluscs and other invertebrates were 142.8 million tonnes in 2005. The capture fisheries amounted to 94.6 million tonnes and aquaculture to 48.2 million tonnes. Marine fish species made up about 84 percent of the harvest, while crustaceans and molluscs made up about seven and eight percent respectively. While crustaceans and molluscs represent about 15 percent by weight, the value share is considered to be between 20 and 30 percent. Most important are shrimps and prawns. The FAO divides the oceans and marine waters into 19 statistical areas. The North-western and South-eastern Pacific are the most productive fishing areas, with 21.3 million and 14.6 million tonnes respectively. This chapter gives information on catches in various subareas of the oceans. Capture fisheries are extremely diversified, and you can distinguish between industrial, recreational, commercial, subsistence and trade fisheries according to the FAO. The world fishing fleets consist of about four million units, with 41 million people employed in fisheries. Overfishing and heavy exploitation are threats to fish and shellfish populations. Many ecosystems world-wide show evidence of substantial fishing down the food web with an average decline of 0.42 trophic levels. Other threats are several types of pollution, caused by run-off from land and activities at sea and in coastal areas. No less than 1.2 percent of the world production of oil is used by fishing vessels.

Introduction

The world is dominated by water, above all marine waters but also freshwater in lakes, rivers, marshlands, etc. Both inland and marine waters are fundamental for all life on earth. The sea areas comprise of 362 million square kilometres. The assessment of inland waters is in the range 1.3–5.3 million square kilometres. It is also estimated that three percent of the total amount of water on earth is freshwater, a large part of which is ice and glaciers.

The production of fish and shellfish is shared by man and various animals. It is estimated that man can only harvest between 10 and 50 percent of the production in various sea areas. Fish, birds and mammals eat fish, and nearly all fish species are cannibalistic. Not only do large cod prey on sprat and herring, they also eat smaller cod, hake, haddock, etc. By investigating the stomach content of fish species in various age groups, it is possible to assess the amount of fish that is consumed.

The production of aquatic food (fish and shellfish) has a qualitative and a quantitative aspect. The marine fatty acids and protein are of utmost importance from the nutritional point of view, together with many other useful substances in aquatic food. In marine areas the phytoplankton organisms are able to produce useful long-chain fatty acids with 20 and 22 carbon atoms. This is the origin of the valuable fatty acids in fish and shellfish. That aspect is stressed in another section of this book.

Aquatic ecosystems provide hundreds of ecological services, apart from the production of food for mankind. To mention a few: freshwater supply, fuel, climate regulation, flood control, waste detoxification, recreational opportunities, transportation media, nutrient cycling, etc. But in this context, the harvest of fish, shellfish and some other animals is the main subject.

When the FAO started to collect statistics on fisheries in 1950, the total capture fisheries in all marine areas amounted to 23 million tonnes. At that time the total world population was about two billion people. Fifty-five years later (2005) the total capture fisheries harvest was 83 million tonnes, an increase by 3.7 times. The world population is about 6.5 billion people or 3.3 times more than in 1950. It looks as if we are on the safe side, but this is an illusion. The World Bank and FAO issued the paper *The Sunken Billions – the Economic Justification for Fisheries Reform* in 2008. Most of our fish populations are fully exploited or overfished and the catches per fisherman or fishing vessel have declined substantially.

The main aim of this chapter is to highlight global fisheries and their contribution as a food source for man, as well as to examine the future prospects and threats for marine living resources. At present the ecosystems in marine and inland water areas produce on average 16.6 kg fish per capita and year. If China is excluded from the statistics, the corresponding figure for the rest of the world is 13.5 kg. In many areas this is the most important source of animal protein, as in parts of Southeast Asia. It is estimated that one billion people are exclusively dependent on fish for animal protein. On average, in the year 2000 the share of animal protein from fish products in Asia (excluding Middle East) was 27.7 percent, in North America 11.5 percent and in Europe 10.6 percent. The global figure is about 16 percent (FAO 2004). It is worth mentioning that the overall share of the total protein intake is less than six percent, and the share of calorie intake from fish and shellfish is only 1–2 percent, worldwide.

The food web in the sea

Marine and freshwater production in seas, lakes and rivers starts with phytoplankton, macroalgae or water plants, which are autotrophic organisms and able to produce organic material (primary production). In addition, bacteria are also capable of producing organic material via various chemical processes.

In pelagic water (all sea water that is not near the seabed), virus, bacteria, phytoplankton, zooplankton, small and large pelagic fish species and marine mammals (above all seals and whales) form a complex food web. In that web, different trophic levels can be distinguished, starting with phytoplankton as level one, zooplankton as level two, small fish as level three and so on, usually referred to as a food chain. In a similar way, communities at the bottom of the sea form food webs, usually starting with phytoplankton produced in the upper part of the open water. Senescent phytoplanktons sink to the bottom and supply energy for organisms living at the seabed. In the bottom community a large number of animals of various sizes also form a complicated food web with animals feeding at different trophic levels. Demersal fish species, such as cod and hake – that eat plankton in the upper water in their juvenile phase – feed on bottom animals, such as crustaceans and molluscs.

The food chain varies very much from the open ocean to the coastal zone, and in upwelling areas (Ryther 1969, Polunin and Pinnegar 2002). In the open ocean, six trophic levels can be distinguished:

1) nanoplankton
2) microzooplankton
3) macrozooplankton
4) megazooplankton
5) planktivores
6) piscivores

In the coastal zone, there are two parallel food chains, both starting with microphytoplankton and nanoplankton. One of the links – the pelagic – continues with 2) macrozooplankton, 3) planktivores, and 4) piscivores. The other link – the benthic one – continues: 2) benthic herbivores, 3) benthic carnivores and 4) piscivores.

The shortest food chain is found in upwelling areas, where it starts with macrophytoplankton. One link simply ends with planktivores (2). The other link goes on with megazooplankton (2) and megazooplanktivores (3).

In aquatic areas, many more animal groups are represented than on land. In this context we refer only to groups harvested by man. Among invertebrates there are hundreds of crustacean species, such as shrimps, lobsters, crabs and various types of molluscs such as mussels, clams and oysters. There are three other important molluscan groups, viz. the cephalopods (squids, cuttlefish and octopus). In many tropical waters many other invertebrates, like cucumbers, sea-urchins and jellyfish are also harvested by man.

Vertebrates harvested by man are mammals (above all seals and whales) and a large number of fish species. Even various types of reptiles, such as turtles and crocodiles are caught. Fish catches make up the bulk of what man takes from sea areas and inland waters.

Overview of exploited resources in fisheries and aquaculture

The total harvest of fishes, crustaceans, molluscs and various aquatic organisms (invertebrates) was 142.8 million tonnes in 2005. The capture fisheries in marine and freshwater areas amounted to 94.6 million tonnes. Fishes made up 85.5 percent, while crustaceans, molluscs and invertebrates made up 6.4 percent, 7.6 percent and 0.5 percent, respectively. The aquaculture harvest amounted to 48.2 million tonnes of which 30.3 million tonnes of fish, nearly four million tonnes of crustaceans, 13.5 million tonnes of molluscs including cephalopods, and 0.9 million tonnes of other invertebrates.

In capture fisheries, the bulk of fish species were marine fishes, with 71.0 million tonnes (87.7 percent), followed by freshwater fishes; 8.2 million tonnes (10.1 percent) and diadromous fishes; 1.7 million tonnes (2.1 percent). The latter group consisted mostly of salmonids. In aquaculture on the other hand, the bulk of the harvest was freshwater fishes 25.8 million tonnes (85.1 percent), followed by diadromous fishes; 2.9 million tonnes (9.5 percent), while marine fishes only amounted to 1.6 million tonnes (5.4 percent).

A considerable and important part of the harvest (mainly in sea areas) consists of aquatic plants. The main part was cultivated, 14.8 million tonnes (91.9 percent), and only 1.3 million tonnes (8.1 percent) were taken in capture fisheries.

Thus, together the total harvest of aquatic plants and aquatic animals was 158.8 million tonnes in 2005 (Table 1). According to preliminary figures the corresponding amount was 160 million tonnes in 2006.[1]

Table 1. Total world production of various aquatic organisms in 2005 in marine and freshwater areas (FAO 2007b), figures in 1,000 tonnes.

	Fishes		Crustaceans		Molluscs		Misc. aquatic organisms		Total	
	Kton	%	Kton	%	Kton	%	Kton	%	Kton	%
Capture	79569	85.3	6013	6.4	7204	7.6	467	0.5	94559	100
Aquaculture	30301	62.9	3961	8.2	13499	27.9	438	0.9	48199	99.9
Total	**111176**	**78.0**	**9974**	**7.0**	**20653**	**14.4**	**905**	**0.6**	**142758**	**100**

	Freshwater fishes		Diadromous fishes		Marine fishes		Total	
	Kton	%	Kton	%	Kton	%	Kton	%
Capture	8199	10.1	1714	2.1	70962	87.7	80875	100
Aquaculture	25778	85.1	2880	9.5	1643	5.4	30301	100
Total	**33977**	**30.6**	**4594**	**4.1**	**72605**	**65.3**	**111166**	**100**

	Aquatic plants	
	Kton	%
Capture	1306	8.1
Aquaculture	14790	91.9
Total	**16096**	**100**

	Aquatic plants	Aquatic animals	Total
Capture	1306	94559	95865
Aquaculture	14790	48199	62989
Total	**16090**	**142758**	**158848**

1. In this chapter, statistics are from various FAO publications. Please note that there are slight differences between the figures in various FAO issues (2007a, 2007b and 2007c). Most authors use the term "catch" when they mean landing or yield and this is true for this chapter also. The reason for using the term "landing" is that large catches are discarded at sea. "Production" is sometimes erroneously used meaning fish landings or catches. Production means all plant and animal material which is produced in a certain area and during a certain time limit, e.g. per year. Only a fraction of this can be harvested by man.

In 2005 global marine capture production reached 83.7 million tonnes (FAO 2007a). The highest and lowest catches in the past ten years (1996–2005) coincided with the fluctuating catches of Peruvian anchoveta, a species notoriously influenced by the El Niño effects on the oceanographic conditions of the Southeast Pacific. Catches of this small pelagic fish ranged from 1.7 million tonnes in 1998 to 11.3 million tonnes in 2000, whereas global total catches (marine and freshwater) excluding anchoveta remained relatively stable, between 83.6 and 86.5 million tonnes. The estimated first-hand value of global capture fisheries production was some USD 84.9 billion in 2004. About 60 percent of the total landings (marine and inland waters) in 2005 were taken by ten countries (Table 2). The world landings amounted to 94.6 million tonnes.

The total amount of fish and shellfish landed in 2005 from marine waters was 83.7 million tonnes. The marine fish species made up about 83 percent of the total landings, while crustaceans and molluscs made up 6.6 and 8.1 percent, respectively. The diadromous fish species (salmonids mainly) represented only 1.6 percent (FAO 2007a). The three latter groups, however, are cultivated to a large extent in marine areas, and the total harvest of those is comparatively more important than the total fishery harvest (see below).

Table 2. Marine and inland capture fisheries of the top ten producer countries in 2005, with a yield of 55.8 million tonnes, corresponding to about 60 percent of the world catch (FAO 2006a).

Country	Catch by country	Percentage of total catch
China	17.0	18.2
Peru	9.4	10.1
United States of America	4.9	5.3
Indonesia	4.4	4.7
Chile	4.3	4.6
Japan	4.1	4.4
India	3.5	3.8
Russian Federation	3.2	3.4
Thailand	2.6	2.8
Norway	2.4	2.6

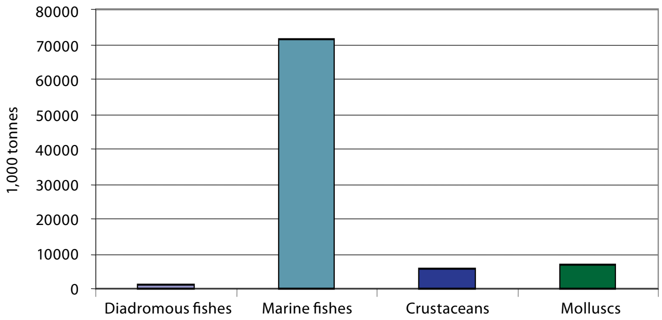


Figure 1. World production in marine areas in 1,000 tonnes in 2005. The total world capture of fish and shellfish species in marine areas in 2005 was 83.4 million tonnes. The landings of marine fishes were 71 million tonnes, diadromous fish species 1.7 million tonnes, crustacean species 5.6 million tonnes and molluscan species 6.8 million tonnes (FAO 2007a).

Important species and fisheries in marine areas world wide

There are hundreds of marine fish species caught in the three oceans and in adjacent coastal and brackish waters. The total amount of fish landed in 2007 was 69.7 million tonnes. Marine fish species are classified by FAO into groups of species, not based on taxonomic division. Pelagic species belonging to the herring group (group B-35) dominate the catch, amounting to about 23 million tonnes or 32 percent of the total landings. Next is a plethora of miscellaneous pelagic fishes (B-37); 11.2 million tonnes (16 percent). Catches of cod, hake and haddock (B-32) amounted to 9.4 million tonnes (13 percent). Miscellaneous coastal fishes (B-33) amounted to 7.0 million tonnes (nearly 10 percent), followed by large pelagic fishes; tuna, bonito and billfish (group B-36). The total landings were six million tonnes or little more than eight percent. The group B-34, consisting of miscellaneous demersal fishes, amounted to 3.2 million tonnes or 4.5 percent. Finally three groups; B23 (salmon, trout and smelt), B-31 (flounder, halibut and sole) and B-38 (shark, ray and chimaera) amounted each to 0.9-0.8 million tonnes, a little more than one percent in each group.

The most important group is ***herring-like fish (B-35)***. The various stocks of herring, sardines and anchovies are caught in many areas of the world. The anchoveta (= Peruvian anchovy, *Engraulis ringens*) outside the Peruvian and Chilean coasts

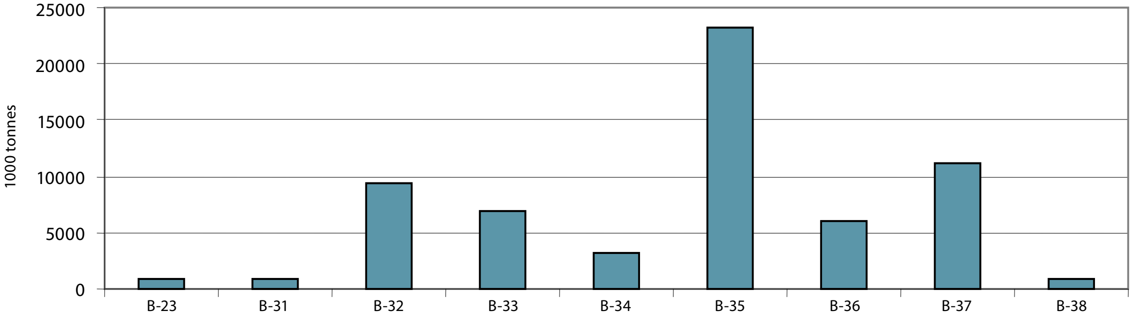


Figure 2. Important groups of fish species caught in marine areas in 2005 (FAO 2007a). The total harvest of marine fish species was 70 million tonnes from the three oceans together. In addition to this 1.5 million tonnes were produced in aquaculture. The total landings of fish, including crustacean and mollusc, were close to 85 million tonnes in 2005.

The FAO divides the marine fish landings into groups:

B-23 – salmon, trouts, smelts
B-31 – flounders, halibuts, soles
B-32 – cods, hakes, haddocks
B-33 – miscellaneous coastal fishes
B-34 – miscellaneous demersal fishes
B-35 – herrings, sardines, anchovies
B-36 – tunas, bonitos, billfishes
B-37 – miscellaneous pelagic fishes
B-38 – sharks, rays, chimaeras

in the southeast Pacific was outstanding in catches amounting to more than 10 million tonnes, nearly 45 percent of the total catches in the group. This is an upwelling area with very high productivity. Anchoveta is rather unique; it feeds as adult on phytoplankton, and is thus very close to trophic level one. Since 1972 the catches have fluctuated widely since the waters are influenced by the current El Niño. Due to this, catches have been only around one million tonnes every 8–10 years. Anchoveta is mainly used for production of fishmeal and fish oil. This species and the famous Atlantic herring (*Clupea harengus*) were for many years the most important species from the profitability viewpoint.

The catches of Atlantic herring were nearly 10 million tonnes and consisted of Atlanto-Scandic herring in the Norwegian Sea and Barents Sea, and Bank herring in the North Sea and adjacent areas. Due to over-exploitation in the 1960s and 1970s, the catches are now in the order of two million tonnes. But still the species is considered one of the most important with regard to economic return. It is consumed in many different ways; fresh, salted, smoked, fermented, etc.

Within this group there are many other herring-like species, such as many species of sardines, some of them as big as herring and highly appreciated. Other stocks are used for fishmeal and fish oil production. Sardines also occur in other areas, such as the upwelling zones of the West African coast and west of South America. An important species is also European sprat (*Sprattus sprattus*), mainly caught in the northeast Atlantic including the Baltic. The total catch is around 600,000–700,000 tonnes. The species is used both for human consumption and fishmeal production. When the species is canned the product is given various commercial names as "Anchovy" and "Sardine".

The group ***miscellaneous pelagic fishes (B-37)*** is of great importance in all three oceans. Capelin (*Mallotus villosus*) has been caught in the range of 0.7–1.6 million tonnes during the last decade on both sides of the Atlantic, but mostly in the northeast Atlantic. At present the stock in the northeast Atlantic is very small. It is important for industrial fisheries, as it is used for the production of fishmeal and fish oil, and for cod as an important prey. Another species targeted by industrial fisheries is Atlantic horse mackerel (*Trachurus trachurus*), for fishmeal production. The Atlantic mackerel (*Scomber scombrus*) is a valuable food fish which is landed in the order of 0.7 million tonnes, mostly on the eastern side of the Atlantic. In the southeast Atlantic outside Africa, Cape horse mackerel (*T.capensis*) is caught in the range 350,000–400,000 tonnes.

There is a great number of fish species in this group that are caught in various parts of the Pacific, such as Japanese jack mackerel (*T. japonica*) with catches around 0.3 million tonnes, and chub mackerel (*S. japonicus*) which is caught in the range of 1.5–2.0 million tonnes. The latter is caught in many parts of that ocean, including in the eastern central part of the Atlantic and the Pacific. In both the Atlantic and the Pacific, dolphinfish (*Coryphaena hippurus*) are caught. Another important species, mainly in the northwest Pacific, is bigeye scad (*Selar crume-*

nophthalmus). In the western central Pacific many species belonging to the family Carangidae are fished. Many amberjack species (*Seriola* spp.) are caught in the northwest Pacific as well as various pomfret species (*Pampus* spp.). The catches amounted to 0.4 million tonnes. Finally, it should be mentioned that barracudas (*Sphyraena* spp) are caught in tropical areas of the Atlantic and the Pacific.

The group ***various cod species (B-32)*** comprises all demersal species, i.e. which as adults mainly feed on bottom animals, but also on pelagic fish species. The total yield is 9.4 million tonnes. The cod stocks in the Atlantic are well-known food fishes. Atlantic cod (*Gadus morhua*) and two hake species, whiting (*Merlangius merlangus*) and haddock (*Melanogrammus aeglefinus*), occur in the Atlantic, while Alaska pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*) occur in the Pacific. Apart from these most species are of little significance, except blue grenadier (*Macruronus novaezelandiae*) in the southwest Pacific. Alaska pollock is next to anchoveta the world's most common fish species in commercial catches. As the Pacific cod differs in muscle texture from the Atlantic cod, it is considered inferior.

The cod used to be the backbone of food fishes in the Atlantic. It is still important with a yield of 860,000 tonnes in 2004. However, catches have decreased conspicuously since the 1950s and 1960s. In the northwest Atlantic, cod catches decreased from 1.4 million tonnes in the 1960s to 55,000 tonnes in 2002 (FAO 2005). In the northeast Atlantic, catches dropped from 1.7 million tonnes in the 1970s to about 800,000 tonnes in 2004 (FAO 2005). Hence, total catches have dropped from more than three million tonnes to less than one million. There used to be 18 different stocks of cod in the Atlantic. Many of those stocks have been over-exploited, some of them to the extent that they have disappeared, as in the case of what used to be the world's largest stock outside Newfoundland. Now the stock in Barents Sea is the largest, and still gives a large yield.

Next to cod is haddock (*Melanogrammus aeglefinus*) with a yield of 325,000 tonnes, and Argentine hake (*Merlucccius hubbsi*) with catches of 480,000 tonnes. But other species, such as whiting and European hake (*M. merluccius*), both with yields varying from 40,000 to 107,000 tonnes, are important food species. A main component in the industrial fisheries in the Atlantic is blue whiting (*Micromesistius poutassou*), which nowadays is the most prominent species for fishmeal and fish oil production in the northern Atlantic, followed by sandeel (*Amodytes* spp.) and previously capelin (*Malotus villosus*). However, capelin stocks are at present in a bad shape (2007).

Alaska pollock (*Theagramma chaleogramma*) is found in the northern Pacific. Some years, when the stock of anchoveta (*Engraulis ringens*) has declined, it has been the most commonly caught species world-wide. In 2004 the catch was 2.7 million tonnes, mainly in the northeast Pacific. The Alaska pollock is sold as a cheaper alternative to Atlantic cod. The second cod species in the Pacific is of minor importance, the Pacific cod (*Gadus macrocephalus*), with a yield of 373,000 tonnes. Finally it is worth mentioning the blue grenadier (*Macruromus novaezelandiae*) in the southwest Pacific, with catches in the order of 160,000–324,000 tonnes per year.

Within the group ***miscellaneous coastal fishes (B-33)*** are hundreds of species, of which only a few will be mentioned. They occur in the warmer parts of the three oceans, mainly the Indian Ocean and the Pacific. Usually warmer seas contain many more species than cold areas, which means smaller catches of many species instead of larger catches of fewer species. In total the yield of this group is about seven million tonnes, used as both food fish and industrial fish.

Well-known fish species are mullets (Mugilidae), of which the three most important together yield around 600,000 tonnes, mainly in the Indian Ocean, but also in the inland waters of the Asian continent. Catches of groupers and sea basses of the family Serranidae are about 250,000 tonnes in total from the Indian Ocean, the northwest Pacific, and the western central Atlantic. Various species of croakers that are common in the northwest Pacific and in the Indian Ocean yield more than one million tonnes per year. Species like Bombay duck (*Harpadon neherus*), sea catfishes belonging to the family Ariidae, and emperors belonging to the family Lethrinidae, together yield 600,000 tonnes. These are caught in the Indian Ocean and Eastern Central Pacific.

Porgies and other seabream species belonging to the family Sparidae in the northwest Pacific, as well as Okhotsk atka mackerel (*Pleurogrammaus azorners*), are fairly well-known, each group yielding little more than 200,000 tonnes in the northwest Pacific. Large quantities of yellow croaker (*Larimichthys polyactis*) are also caught in the northwest Pacific, exceeding 300,000 tonnes in 2004.

Typical industrial fish species in this group belong to the genus *Ammodytes*. In the northeast Atlantic sandeels nei yielded 390,000 tonnes in 2004 and Pacific sandiance (*Ammodytes personatus*) 293,000 tonnes.

The group ***tuna, bonito and billfish (B-36)*** thrive above all in the vast areas of trade-winds biome and westerlies biome, usually at a long distance from the coastal areas of the continents. The species within this group are all large pelagic fishes which are able to swim long distances to get prey. These areas are characterized by low primary production with very small phytoplankton, and therefore a long food chain is formed. Their small prey fishes feed on trophic level three or four, and thus the tunas themselves are on trophic levels four or five.

A world-wide species is skipjack tuna (*Katsuwomus pelamis*) which make large jumps through the water surface into the air, when chasing small pelagic fishes. In 2004 more than two million tonnes were caught of this beautiful fish, which occurs in all three oceans, from the eastern central Atlantic to various parts of the Pacific and also in the western Indian Ocean. Apart from this species, great quantities are harvested of southern bluefin tuna (*Thunnus maccoyil*) in the tropical areas of Atlantic, the Pacific and the Indian Ocean – about 1.23 million tonnes. The catches of Japanese Spanish mackerel (*Scomberomorus brasiliensis*) amounted to 439,000 tonnes, the largest yield taken in the northwest Pacific. Large catches were also taken of frigate and bullet tunas (*Auxis thazard*), narrow-barred mackerel (*S. commerson*), albacore (*T. alalunga*) and kawakawa (*Euthynnus affinis*), mainly in various parts of the Pacific. Catches were in the order of 200,000 tonnes for each species. An odd species, the blue marlin (*Makrira nigricans*), is well-known from the novel *The Old Man and the Sea* by Earnest Hemingway, .

In the group ***miscellaneous demersal fishes (B-34)*** the total amount of catches is 3.2 million tonnes. Half of this quantity comes from one species, largehead hairtail (*Trichiurus lepturus*), which is fished mainly in the northwest Pacific. The species reaches a length of two metres or more. Together with other hairtail fish species the harvest was nearly 1.6 million tonnes in 2004. In the Atlantic, the characteristic red fishes from deep water belong to this group, the *Sebastes* species, above all beaked redfish (*Sebastes mentella*). Catches were in the order of 150,000 tonnes. The angler, or monk, (*Lophius piscatorius*) is also well-known, nowadays one of the most expensive fishes for the consumer. The catch quantity was 59,000 tonnes, mainly in the Atlantic but also in the Mediterranean Sea. Other characteristic species are the tilefishes nei (Branchiostegidae) which are caught in quantities of 74,000 tonnes in the northwest Pacific.

The group ***shark, ray, chimaera (B-38)*** consists mainly of cartilage fishes. Within this group 112 various species are registered, the most common being different species of shark, ray, skate and manta. Usually rather small amounts are caught of each species, normally no more than 20,000–30,000 tonnes, but in most cases between 100 and 2,000 tonnes. In many cases there is no specific species given in the statistics; species are lumped together, as is the case of species of the genus *Raja* with trivial names of *Raja* rays nei. They occur in all three oceans, some species in the warmer part of the ocean, others in temperate areas. Great quantities are taken in the Indian Ocean and the western central Pacific. The total catch in this group was in 2004 about 800,000 tonnes.

Flounder, halibut, sole (B-31) is an important group of fishes, of which the total catch is 875,000 tonnes, and most species are high-priced. Number one in the catch statistics is Greenland halibut (*Reinhardtius hippoglossoides*), harvested at a quantity of 112,000 tonnes, while the catch of the larger Atlantic halibut (*Hippoglossoides hippoglossoides*) was only 4,600 tonnes. Next in catch quantity is the European plaice (*Pleuronectes platessa*) with 88,000 tonnes, also caught in the Atlantic. Other catches in the Atlantic are common sole (*Solea vulgaris*) (40,000 tonnes), also caught in the Mediterranean Sea, and European flounder (*Platichthys flesus*) with a catch quantity of 23,000 tonnes.

In other areas may be mentioned yellowfin sole (*Limanda adspers*), which is caught in the northeast Pacific at a quantity of 63,000 tonnes. Several other highly appreciated flatfishes, such as common dab (*Limanda limanda*), lemon sole (*Microstomus kitt*), Dover sole (*Solea vulgaris*) and turbot (*Psetta maxima*), are harvested in quantities from 15,000 tonnes down to 6,000 tonnes.

Salmon, trout, smelt (B-23) groups the various salmon species in the Pacific dominate. Three of these species are very abundant in the fishery, chum (or keta, or dog) salmon (*Onchorhynchus keta*), pink (or humpback) salmon (*O. gorbuscha*) and sockeye (or red) salmon (*O. nerka*), with catches in 2004 of 354,000, 266,000 and 142,000 tonnes respectively. The other Pacific species, chinook salmon (*O. tshawytscha*), masu (or cherry) salmon (*O. masou*) and coho (silver) salmon (*O. kisutch*), are caught in much smaller quantities. In comparison, Atlantic salmon (*Salmo salar*) is fished at a quantity of only 3,000–4,000 tonnes. The latter species is nowadays farmed in large quantities both in the Atlantic and in the Pacific (outside Chile). The total capture fishery for this group comprised 879,000 tonnes in 2004.

Important crustacean and molluscan species on a world wide basis

The crustaceans made up 6.0 million and the molluscs 7.2 million tonnes in the fishery yield, which corresponds to 6.4 and 7.6 percent respectively, of the total marine catches in 2005 (see Figure 3, cf. Table 1). But the value of this harvest is considered to represent between 20–30 percent of the total value of capture activities. Later on we will see that for certain groups the yield from aquaculture largely exceeds capture fisheries.

Crustaceans

Within the group ***Crabs and sea-spiders (B-42)***, the swimming crabs of the genus *Portunus* dominate. Gazami crab (*Portunus tuberculatus*) yielded 347,000 tonnes in the northwest Pacific, while the blue swimming crab (*P. pelagicus*) yielded 200,000 tonnes in the western central and southwest Pacific. Large quantities of *Brachyura* crabs are caught in various parts of the Pacific, but not recorded at species level. In fact, this group gave about 340,000 tonnes in 2004. Blue crab (*Callinectes sapidus*) was caught to an amount of 89,000 tonnes along the Atlantic coast outside

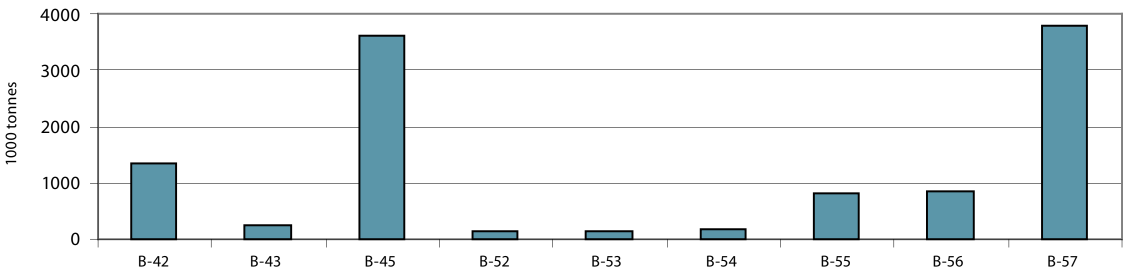


Figure 3. The landings of crustaceans and molluscan species in marine areas in 2005 in 1,000 tonnes. B-42 Crab, sea-spiders: 1.3 million tonnes. B-43 Lobsters, spiny-rock lobsters: 0.2 million tonnes. B-45 Shrimps and prawns: 3.6 million tonnes. B-52 Abalones, winkles, conches: 0.14 million tonnes. B-53 Oysters: 0.15 million tonnes. B-54 Mussels: 0.19 million tonnes. B-55 Scallops, pectens: 0.8 million tonnes. B-56 Clams, cockels, arkshells: 0.9 million tonnes. B-57 Squid, cuttlefish, octopus: 4 million tonnes.

the USA. This crab is famous because it is usually sold as "soft crab"; it is not sold until it moults and the customer has no problem peeling off the "shell". Large catches (69,000 tonnes) are also taken of crabs belonging to the genus *Chinoecets* (tanner crabs). Finally it could be mentioned that the edible crab (*Cancer pagurus*) is caught in the eastern north Atlantic to an amount of 46,000 tonnes.

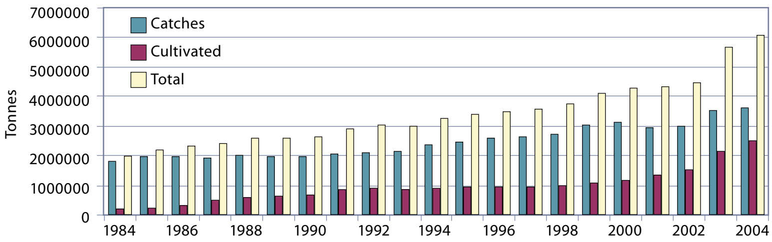


Figure 4. The total world production of shrimp in 2004 was about six million tonnes. Forty-three percent of all shrimp was cultivated while 57 percent was caught in fisheries. As shown for the years 1984–2004, capture fisheries reported higher values than aquaculture harvest (Ackefors 2009).

Species in the group ***Lobsters, spiny-rock lobsters (B-43)*** are among the most valuable animals from the sea. The total yield is only 233,00 tonnes. The most expensive species is the European lobster (*Homarus gammarus*), of which the total catch is only about 3,000 tonnes in the northeast Atlantic and in the Mediterranean. The American lobster (*H. americanus*) is caught in quantities 25–30 times larger than the European lobster. In 2004 the catch was 80,000 tonnes in the East Coast of the US and Canada. In many tropical areas the spiny lobsters dominate. The Caribbean spiny lobster (*Palinurus argus*) yielded 39,000 tonnes in 2004, mainly in the western central part of the Atlantic.

The group ***Shrimps, prawns (B-45)*** is the largest crustacean group with a yield of 3.6 million tonnes in 2004. It is dominated by middle and small shrimps, but the highest economical revenue comes from the large tropical shrimps of genera *Penaeus* and *Metapenaeus*. Roughly the smaller and middle sized shrimps amounted to 2.8 million tonnes and the larger tropical shrimps to 0.8 million tonnes. The latter species are farmed in large quantities, 2.6 million tonnes in 2004. Together the yield from the large tropical shrimps amounted to 3.6 million tonnes. The total harvest from farming and capture fisheries was a little more than six million tonnes.

The catches of the large tropical shrimps were dominated by giant tiger prawn (*P. monodon*) with a yield of 216,000 tonnes in 2004, in the Indian Ocean and the western central part of the Pacific. Banana prawn (*P. merguensis*) yielded 91,000 tonnes in the same areas, while northern white shrimp (*P. setiferus*) gave 56,000 tonnes in the western central Atlantic.

Among the middle sized and smaller shrimps is the Northern prawn (*Pandalus borealis*) which yielded the most of all shrimp species at a quantity of 446,000 tonnes on both sides of the North Atlantic. Another small shrimp is Southern Rough shrimp (*Trachypenaues curvirostris*) which yielded 299,000 tonnes. Many shrimp species are caught in smaller quantities, one of which is the Common shrimp (*Crangon crangon*), the catches of which amounted to 39,000 tonnes.

Molluscs

Abalones, winkles, conches (B-52) is a group of gastropods with comparatively small yields. The total harvest in the world was 139,000 tonnes in 2004. Number one among the species was the whelk (*Buccinum undatum*), which was caught in the northeast Atlantic, followed by stromboid conches (*Strombus* spp.), with a yield of 25,000 tonnes taken in the western central Atlantic. Horned tuban (*Turbo cornutus*) is taken in the northwest Pacific; the quantity harvested was 18,000 tonnes. Various types of gastropods were taken in different sea areas, of at a quantity of 24,000 tonnes.

Of ***Oysters (group B-53)***, the total capture harvest is only 152,000 tonnes. The largest catch was reported for the species American cupped oysters (*Crassotrea virginica*), of which most of the harvest, or 101,000 tonnes, was taken in the western central part of the Atlantic. The oyster group is mostly cultivated (see below).

The ***Mussel group (B-54)*** comprises one species, for which the large harvest is cultivated. According to the statistics most of the 190,000 tonnes in the capture fishery of blue mussel (*Mytilus edulis*) (122,000 tonnes) were taken in the northeast Atlantic. The Mediterranean mussel (*Mytilus galloprovincialis*) was harvested at an amount of 42,000 tonnes (see cultivation below).

The ***Scallop, pecten group (B-55)*** constitute an important mollusc fishery with a yield of 800,000 tonnes in 2004. Within the group there are several important species; most important for fisheries is the American sea scallop (*Placopecten magellanicus*) with a yield of 325,000 tonnes in the north and central Atlantic on the American side. About the same size harvest came from the northwest Pacific of the species yesso scallop (*Patinopecten yessoensis*). In the northeast Atlantic the harvest of Great Atlantic scallop (*Pecten maximus*) amounted to 49,000 tonnes.

The ***Clams, cockles, arkshells group (B-56)*** yields about 850,000 tonnes. One of the most important species from the northwest Atlantic outside the US is ocean quahog (*Arctica islandica*) with a harvest in the fisheries of 162,000 tonnes. In the same area the Atlantic surf clam (*Spisula solidissima*) was fished at the same magnitude. In the Indian Ocean and the western central part of the Pacific, clams of the genera *Anadara* and *Paphia* were harvested in quantities of about 100,000 tonnes.

Squid, cuttlefish, octopus (B-57) is an important group of species harvested to a quantity of nearly four million tonnes. This group consists of many species in the oceans, once conceived as the great nutritional reserve for mankind. In the 1970s it was considered that many stocks of these species could yield as much as the whole fish catch in the world, but their dispersal over great areas and above all their occurrence in deeper water make them difficult to harvest.

Various species of squids, belonging to the families Loliginidae and Ommastrephidae, are harvested to a quantity of 800,000 tonnes (2004). The main fishing area is the northwest Pacific with China as the fishing nation. This is also the case for cuttlefish of various species within the families Sepilidae and Sepiolidae. However these are also fished in certain areas of the Atlantic and the Mediterranean, including the Black Sea. They were harvested to a quantity of 400,000 tonnes. Octopuses belonging to the family Octopodidae were also mainly fished in the southwest Pacific to a quantity of more than 300,000 tonnes. In the same area Wellington flying squid (*Nototodarus sloani*) was fished to a quantity of more than 100,000 tonnes.

Shellfish species are usually farmed to greater quantities than they are fished. Only squid, cuttlefish and octopus are fished in great quantities with practically no aquaculture production. Aquaculture production will be described in another section of this book, but as a comparison a diagram with information from FAO 2007a and 2007b is shown in Figure 5. Fishing is most important in four of the groups, and aquaculture in four. Among the crustaceans (B-45), the aquaculture production of certain groups of shrimps is much larger than capture production. This is true for the big tropical species of the genus *Penaeus*. For all species of mussel, oyster and clam (B-52–56) aquaculture production is generally extremely important and fishing of minor importance. For squid, cuttlefish and octopus the production takes place almost exclusively in fisheries.

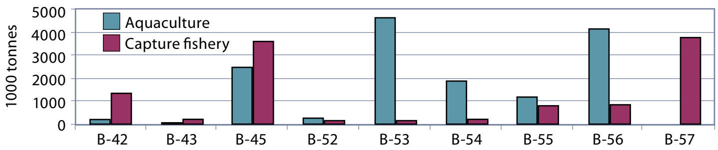


Figure 5. The relation between aquaculture and capture production of shellfish in 2005 according to the FAO (2007a, b).

Groups of species:

B-42 – crabs, sea-spiders

B-43 – lobsters, spiny-rock lobsters

B-45 – shrimps and prawns

B-52 – abalones, winkles, conches

B-53 – oysters

B-54 – mussels

B-55 – scallops, pectens

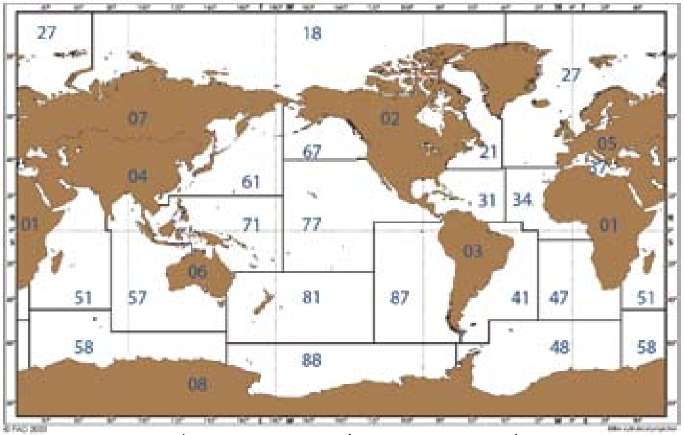
B-56 – clams, cockles, arkshells

B-57 – squids, cuttlefishes, octopuses

Catches in the oceans – an overview

The FAO divides the oceans and the marine waters into 19 statistical areas (Figure 6). In addition, all freshwater areas on the continents are classified into eight statistical areas inland. In both cases all catches are reported for these areas.

The production of fish and shellfish in marine areas was 83.2 million tonnes in 2005, which is 3.7 times higher than the yield in the beginning of 1950s (Table 3). From the 1950s and onwards, the harvest increased yearly from less than 20 million tonnes to about 60 million tonnes in the beginning of the 1970s, when the catch curve seemed to level out. Since then catches have increased moderately with setbacks certain years. The trend in fisheries has been strongly influenced by variations in the anchoveta (*Engraulis ringens*) catches



Freshwater areas		Marine areas in the Atlantic		Marine areas in the Indian Ocean		Marine areas in the Pacific Ocean	
01	Africa	18	Arctic Sea	51	Indian Ocean Western	61	Pacific Northwest
02	North America	21	Atlantic Northwest	57	Indian Ocean Eastern	67	Pacific Northeast
03	South America	27	Atlantic Northeast	58	Indian Ocean Antarctic	71	Pacific Western Central
04	Asia, inland waters	31	Atlantic Western Central			77	Pacific Eastern Central
05	Europe, inland waters	34	Atlantic Eastern Central			81	Pacific Southwest
06	Oceania, inland waters	41	Atlantic Southwest			87	Pacific Southeast
07	Former USSR area, inland waters	47	Atlantic Southeast			88	Pacific Antarctic
08	Antarctica, inland waters	48	Atlantic Antarctic				

Figure 6. FAO classification of marine and freshwater areas.

off Peru and Chile, which has dominated world catches periodically. The variation is wide, from about 1.5 million to more than 11 million tonnes per year. Alaska pollock is second in the catches of the oceans, mainly in the northwest Pacific with total catches in the Pacific in the order of 5–6 million tonnes.

The northwest and southeast Pacific ranked as the most productive fishing areas in 2005 with 21.3 million and 14.6 million tonnes respectively, followed by the western central Pacific (10.8 million tonnes) and the northeast Atlantic (9.6 million tonnes). As shown in Table 3, other areas are much less productive.

Figures for total catches in 2005 for each geographical area of the three oceans are given in Figure 7. The landings from the three most productive areas amounted to 66.6 million tonnes or 78.3 percent of the world harvest that year, when the total harvest was 85.1 million tonnes.

Whereas catches on average increased in all areas from the period 1950–1959 until 1970–1979, overall catches have decreased from 1990–1999 in some areas, and increased in others. For single years it is impossible to draw any conclusions from such figures. When analyses are made for a single stock, it is very obvious that there are dramatic negative changes of cod stocks in the northwest Atlantic.

Total catches include fish, crustaceans and molluscs including cephalopods. Figure 8 demonstrates that fish catches made up a large share of the total catches in most areas (see also Table 4). In the eastern part of the Atlantic fish catches

Table 3. The oceans are divided into 16 marine areas according to FAO (2005, 2006a) excluding the three areas of the Arctic Ocean (see Figure 6). The table shows the marine catches with average values 1950–1959, 1970–1979, 1990–1999, and values for 2004 and 2005. Figures in million tonnes (FAO 2005 and 2006).

Area	1950–59	1970–79	1990–99	2004	2005
NW Atlantic (21)	2.6	3.7	2.4	2.4	2.2
NE Atlantic (27)	6.7	11.2	10.4	10.0	9.6
WC Atlantic (31)	0.7	1.5	1.8	1.6	1.5
EC Atlantic (34)	0.4	3.1	3.5	3.4	3.5
Mediterannean Sea, Black Sea (37)	0.8	1.2	1.5	1.5	1.4
SW Atlantic (41)	0.2	0.9	2.3	1.8	1.8
SE Atlantic (47)	0.8	2.8	1.6	1.7	1.6
W Indian Ocean (51)	0.7	1.8	3.7	4.3	4.4
E Indian Ocean (57)	0.5	1.6	4.1	5.5	5.1
NW Pacific (61)	6.7	15.2	22.3	21.4	21.6
NE Pacific (67)	0.6	2.2	3.0	3.1	3.2
WC Pacific (71)	1.0	2.4	8.5	10.9	10.8
EC Pacific (77)	0.4	1.1	1.5	1.5	1.6
SW Pacific (81)	0.05	0.3	0.8	0.7	0.7
SE Pacific (87)	0.6	6.9	14.9	15.4	14.6
All areas	**22.8**	**55.9**	**82.3**	**85.2**	**83.7**

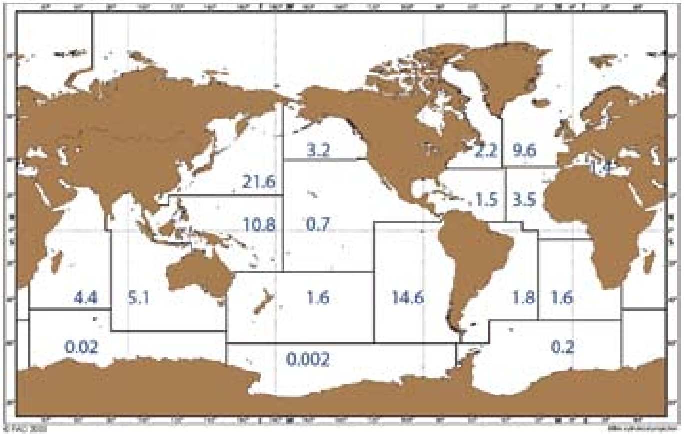


Figure 7. World landings of fish and shellfish from the FAO marine areas in 2005, expressed in million tonnes (FAO 2007a).

were 94–99 percent of total catches, while in the western parts the shares varied from 44 to 67 percent. The tendency is the same in the eastern and western parts of the Pacific, with 94–97 percent and 73 to 88 percent respectively. Except for the Antarctic, the shellfish catches (crustaceans and molluscs) seem to be more important in the western parts of the ocean areas. In the Indian Ocean the shellfish catches make about 10 percent.

The most important crustacean catches as shares of the total are taken in the northwestern and western central parts of the Atlantic and in the northwestern part of the Pacific (Figure 8, see also Table 4). In all three areas shrimp catches dominate. The largest total catches – 2.7 million tonnes – are taken in the northwest Pacific.

The largest catches of molluscs (excluding cephalopods) are taken in the northwestern and western central parts of the Atlantic with percentage figures of 28.9 to 13.5 (Figure 8). However, as the total catches are much smaller than in e.g. the northwestern Pacific, the greatest amount of those species is taken in that area. In 2005 no less than 1.4 million tonnes were harvested there (Table 4).

Squid, including octopus and cuttlefish, is mostly caught in the south-western Atlantic, northwestern Pacific, western central Pacific and southeastern Pacific (Figure 8). In the northwestern Pacific the catches amounted to 1.6 million tonnes (Table 4).

Northwest Atlantic

The total surface is 6.3 million km^2 of which the shelf area is 1.3 million or 2.1 percent. The catches are characterized by a rather high yield of crustaceans (0.5 million tonnes) and molluscs (0.6 million tonnes), together about 55 percent of the total yield. The fishery catches were

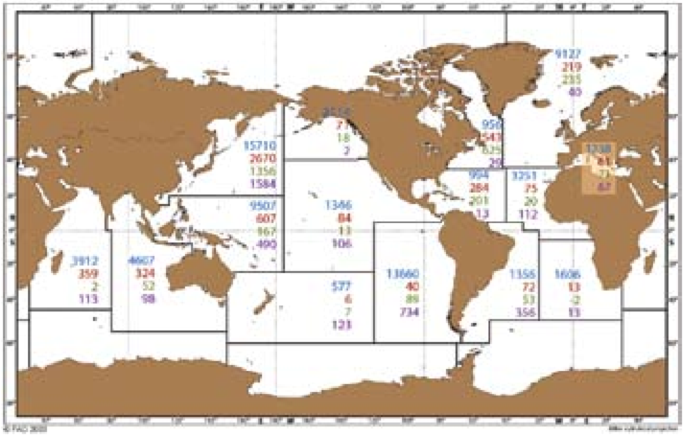


Figure 8. Fish, crustacean, mollusc (excl. cephalopods) and cephalopod catches in 2005 (expressed in thousands of tonnes).

Blue: Fish **Red:** Crustaceans **Green:** Molluscs **Purple:** Cephalopods

Table 4. Landings of fish, crustaceans, molluscs and cephalopods sea areas in 2005 (FAO 2007a). The total marine catch (landing) that year was 83.7 million tonnes. The inland catch (mainly freshwater) was 9.5 tonnes. Total harvest was hence nearly 93.3 million tonnes (FAO 2007a). All figures are expressed in 1,000 tonnes.

Area	**Fish**		**Crustacean**		**Mollusc**		**Cephalopod**		**Total**	
	Kton	%	Kton	%	Kton	%	Kton	%	Kton	%
NW Atlantic	956	44.5	543	25.1	625	28.9	29	1.3	2160	99.8
NE Atlantic	9127	94.9	219	2.3	235	2.4	40	0.4	9622	100
WC Atlantic	995	66.7	284	19.0	201	13.5	13	0.9	1492	100.1
EC Atlantic	3251	94.0	75	2.2	20	0.5	112	3.2	3458	99.9
Mediterannean Sea; Black Sea	1238	86.1	61	4.2	71	4.9	67	4.6	1438	99.8
SW Atlantic	1356	73.8	72	3.9	53	2.9	356	19.3	1837	99.9
SE Atlantic	1606	98.5	13	0.8	–		13	0.8	1633	100.1
W Indian Ocean	3912	89.2	359	8.2	2	0.06	113	2.6	4388	100.1
W Indian Ocean	4607	90.6	324	6.3	52	1.0	98	1.9	5086	99.8
NW Pacific	15710	73.7	2670	12.5	1356	6.3	1584	7.4	21320	99.9
NE Pacific	3114	97.1	71	2.2	18	0.6	2	0.06	3208	100
WC Pacific	9507	88.1	607	5.6	167	1.5	490	4.5	10794	99.7
EC Pacific	1346	86.9	84	5.4	13	0.8	106	6.8	1549	99.9
SW Pacific	577	80.8	6	0.8	7	1.0	123	17.2	714	99.8
SE Pacific	13660	93.8	40	0.3	89	0.6	734	5.0	14569	99.7
All areas	**70962**		**5428**		**2909**		**3880**		**83179**	

0.9 million tonnes or 42 percent. The total yield in 2005 was 2.6 million tonnes. The fish stocks were severely depleted in the late 1980s and early 1990s by a combination of heavy fishing and cold water conditions (FAO 2005). Demersal fisheries remain either closed or operating under strict regulatory limitations. The most striking issue is the declining gadoid resources on Georges Bank. In 1992 certain cod populations collapsed, such as on the Grand Bank. In some years the catches of cod species were above 2,000 tonnes but in later years the catches have dropped to less than 1,000 tonnes. The species was replaced by skates (*Raja* spp.) and other species. Greenland halibut (*Reinhartius hippoglossoides*) has recovered and made up about 50 percent of the large catches of demersal fish species, that totalled 116,000 tonnes. The catches of the pelagic Atlantic herring have also dropped from nearly one million tonnes in late 1960s to about 200,000 tonnes. The yield of menhaden (*Brevoortia tyrannus*) is in the order of 200,000 tonnes.

Crustacean species, such as American lobster (*Homarus americanus*), Northern prawn (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*), have increased very much since the gadoid predators have decreased. American lobster catch was about 80,000 tonnes. The Gazami crab (*Portunus tuberculatus*) and swimming crab (*P. pelagicus*) are important, as well as the blue crab (*Callinectes sapidus*). The catches surpassed 400,000 tonnes. Among the molluscs, the blue mussel (*Mytilus edulis*) and American sea scallop (*Placopecten magellanicus*) are important. Another important species is Great Alantic scallop (*Pecten maximus*) with catches up to 50,000 tonnes. Among the squid species the northern shortfin squid (*Illex illecebrosus*) dominates in the catches with a yield of 25,000 tonnes in 2004.

Northeast Atlantic

The total area is 14.3 million km^2 of which 18.9 percent or 2.7 million km^2 is shelf area. The catches peaked in 1976 with 13 million tonnes. Nowadays catches have declined to 10–11 million tonnes per year. In 2004 catches dropped to less than 10 million tonnes. The yield is dominated by fish species (94.4 percent). The most valuable species are cod, haddock and herring. The catches of cod species (cod, haddock, whiting, etc.) have fluctuated around four million tonnes. The catches of cod have decreased to less than one million tonnes. When these species decline, the fisheries shift to lower-valued species, such as sandeel (*Ammodytes* spp.) and blue whiting (*Micromesistius poutassou*), used in the production of fishmeal and fish oil. Catches of sandeel have fluctuated around one million tonnes. Catches of Atlantic herring and particularly capelin (*Mallotus villosus*) have shown greater short term variability than those of many other species. The herring catches went down at the end of 1960s and remained low in the 1970s, with a heavily regulated fishery. Total catches of flatfish species have fluctuated around 250,000 tonnes. The Northern prawn (*Pandalus borealis*) is an important species in the Skagerrak, around Iceland and outside Greenland.

Western Central Atlantic

The area is 15 million km^2, of which 12.7 percent or 1.9 million km^2 is shelf area. Catches are comparatively small; 1.6 million tonnes in 2004. 69 percent were fish species, 18 percent crustaceans and 11 percent molluscs. Squid catches are very small. The fish species are dominated by Gulf menhaden (*Brevoortia patronus*), with catches in the order of 500,000 tonnes. Fishes from seven families dominate small pelagic catches as e.g. flying fish (Exocoetidae), herring and sardines (Clupeidae), anchovy and anchoveta (Engraulidae), jacks, bumpers and scads (Carangidae), halfbeaks (Hemiramphidae), needlefish (Belonidae) and mullet (Mugilidae). The round sardinella (*Sardinella aurita*) is an important species with a catch of 140,000 tonnes in 2004. Catches have varied over time.

Eastern Central Atlantic

The total area is 14.2 million km^2, of which 4.6 percent or 0.65 million km^2 is shelf. Catches were 3.4 million tonnes in 2004. More than 95 percent is various fish species. In contrast to the other side of the Atlantic, crustacean and molluscan species represented less than five percent in that year. About half of the catches were from the herring group, mostly sardines and anchovies. The European pilchard (*Sardina pilchardus*) makes the largest contribution, followed by other species such as the round sardinella (*Sardina aurita*) and European anchovy (*Engraulis encrasicolous*). But even *Sardinella* species are important. The Senegalese hake (*Merluccius senegalensis*) and European hake (*M. merluccius*), together with other cod species, contributed to yields around 30,000 tonnes. The crustacean species were mainly shrimps, with the pink shrimp (*Penaeus notialis*) and deepwater rose shrimp (*Parapenaues longirostris*) as the dominating species. Catches of those species were nearly 50,000 tonnes in all. Catches of cephalopod species have varied, but totalled 74,000 tonnes in 2004.

The Mediterranean and the Black Sea

The Mediterranean Sea is a semi-enclosed sea measuring 3.3 million km^2, which is 0.8 percent of the total world marine surface. It is an oligotrophic sea area with moderate catches. Together with the Black Sea, catches were 1.5 million tonnes in 2004, 85 percent of which was fish, 8.2 percent molluscs, 3.3 percent cephalopods and 2.9 percent crustaceans. Small pelagic species account for approximately 50 percent of the catches. Anchovy (*Engraulis encrasicolous*) dominated the catches followed by the sardine (*Sardina pilchardus*). Catches of sprat and sardinella species are also notable. The prominent large pelagic species are bluefin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*). Both species are used for fattening in fish farms. Catches of the latter species were in the order of 15,000 tonnes. Bluefin tuna yielded 23,000 tonnes in 2004, whereas catches of horse mackerel (*Trachurus mediterraneus*) and chub mackerel (*Scomber japonicus*) were in the order of 25,000 tonnes. There were more than 100 demersal species that made up about 40 percent of the catches.

Among fish species may be mentioned European hake (*Merluccius merluccius*) with catches of 50,000 tonnes in the middle of 1990s, red mullets (*Mullus* spp.), whiting (*Merlangius merlangus*), and anglerfishes (*Lophius* spp). Important crustaceans are red shrimp (*Aristeus antennatus*), deepwater rose shrimp (*Parapenaeus longirostris*) and Norway lobster (*Nephrops norvegicus*), but also lobster (*Homarus gammarus*) and crabs of various species occur. Among clams, striped venus (*Chamela gallina*) dominated the catches with a yield of 55,000 tonnes in 2004. The cephalopod catches were mainly *Octopus* spp. and cuttlefish (*Sepia officinalis*).

Southwest Atlantic

The total area is 17.7 million km^2 with 1.96 million km^2 shelf area or 13.4 percent. The catches are comparatively small. In 2004 the yield was 1.7 million tonnes, dominated by fish catches (82.5 percent), the rest being crustaceans (4.9 percent), molluscs except cephalopods (3.4 percent) and cephalopods (9.3 percent). Cod fishes and cephalopods are the dominating groups in the catches. Catches of Argentine hake (*Merluccus hubsii*) peaked at the end of the 1960s and in the 1990s with catches around 500,000 tonnes, but the catches declined around the year 2000 and increased again to 480,000 tonnes in 2004. Consequently, this species is the most important in the area. Other important demersal species are Patagonian grenadier (*Macuronus magellanicus*) and blue whiting (*Micromesistius austalis*), with catches around 200,000 and 100,000 tonnes respectively. This means that three species made up about 55 percent of the whole fish catch. Other fish species are Argentine croaker (*Umbrina canosai*), stripped weakfish (*Cynoscium striatus*) and other weakfish species, the whitemouth croaker (*Micropogonias furniere*). The total catch of those species was more than 200,000 tonnes. There are also small pelagic species of importance as the Brazilian sardinella (*S. brasiliensis*) – 50,000 tonnes in 2004 – and Argentine anchovy (*Engraulis anchoita*) – 40,000 tonnes in 2004. In the middle of the 1970s, the sardinella gave catches above 200,000 tonnes.

An important fishery in this area is for squids, the dominant species being the Argentine shortfin squid (*Ilex argentinus*). The catch was very high in 1999, with a yield of 1.5 million tonnes. In 2004 the catches had decreased to 130,000 tonnes. The Patagonian squid (*Loligo gahi*) reached a maximum in 1989 at 89,000 tonnes. In 2004 catches were reduced to 30,000 tonnes. The shrimp fishery gives catches around 50,000 tonnes, most importantly the Argentine red shrimp (*Pleoticus muelleri*) with catches fluctuating from 6,700 to 79,000 tonnes during the past ten years.

Southeast Atlantic

This section of the Atlantic covers the waters adjacent to the coastlines of Angola, Namibia and South Africa and extends well into high seas to the south and west. The area is 18.4 million km^2 with less than 0.5 million km^2 (or 2.7 percent) shelf area. The total catch is of the same magnitude as in the southwest, about 1.7 million tonnes. Catches were slightly over three million tonnes in 1950, but have declined since then. Fish catches amounted to 98.6 percent of the 1.7 million tonne catch in 2004. There are minor catches of shrimps, very few molluscan species and some squid fishery. But the economic revenue of those groups is comparatively high in coastal fisheries. Catches are dominated by small pelagic sardine and anchovy species, horse mackerel and cape hakes. There are six taxonomic groups of small pelagic species: South African pilchard (*Sardinops sagax*), South African anchovy (*Engraulis capensis*), sardinellas (*Sardinella aurita* and *S. maderensis*), Whitehead's round herring (*Etrumeur whiteheadi*), Cape horse mackerel (*Trachurus capensis*) and Cuene horse mackerel (*T. trecae*).

In the area, there are several well-known species with rather small catches such as croakers (*Pseudolihus* spp.), porgies, or sea breams (*Pterogymnus* spp.), Pargo sea breams (*Pagrus* spp), bigeye grunt (*Barchydeutereus auritus*), steenbras (*Lithognathus mormyrus*), mullet species (*Mugulidae*), red pandora (*Pagellus belottii*), etc.

Several crustacean species support valuable fisheries in the coastal area, e.g. red crab (*Chaceon maritae*). Among the shrimps and prawns may be mentioned deepwater rose shrimp (*Parapenaeus longirostris*) and the striped red shrimp *(Aristeus varidens*) with varying catches from year to year in the order of 2,000 to 5,000 tonnes. Catches of Cape rock lobster (*Jasus lalandii*) and Southern spiny lobster (*Palinurus gilchristi*) have dwindled and are nowadays in the order of 2,000 to 3,000 tonnes. Among the molluscan species may be mentioned Chokka squid (*Loligo vulgaris reynaudii*) and Perlemoen abalone (*Haliotis midae*). Squid catches have varied much over time from less than 3,000 tonnes to 7,000 tonnes, while abalone catches are in the order of 400–500 tonnes.

Western Indian Ocean

The surface area is in the order of 30 million km^2, and no less than 6.3 percent or 1.9 million km^2 is shelf areas. The total catch is 4.1 million tonnes, 88.3 percent of which is various fish species, and 8.9 percent crustaceans. Minor quantities of molluscan species of clam, scallop and mussel are caught, but cephalopod catches were 2.7 percent or 112,000 tonnes. The FAO (2005) describes the problems in characterizing the catches from this area. First of all many catches are under the group "Marine fishes nei", i.e. the fish caught are not identified as to species. Secondly some catches are unreported, a fact which might well be true for other areas as well. A third difficulty is that catches may have been taken outside the FAO area 51 but landed there.

Reported nominal catches averaged slightly over one million tonnes per year during the 1960s, increased to approximately 2.6 million tonnes per year during the 1980s and reached a peak of 4.2 million tonnes in 2002. Of the 153 categories of species type catches reported in 2002, 21 landings categories presented 80 percent of the catch. Ignoring the aggregate group "Marine fishes nei" (not elsewhere included) at 16.5 percent, skipjack tuna (*Katsuwonus pelamys*) was the most abundant single reported category (9.3 percent of the total reported catches) followed by Indian oil sardine (*Sardinella longiceps*), 9.2 percent; sciaenids, 6.2 percent; yellowfin tuna (*Thunnus albacares*), 5.7 percent; hairtails and scabbardfishes nei (Trichiuridae), 3.0 percent; shrimps (Natantia), 3.0 percent; Bombay duck (*Harpadon nehereus*), 2.4 percent; and pelagic percomorphs (Perciformed), 2.3 percent (FAO 2005).

This description does not include catches in the four subareas which are already included in the above mentioned figures; 1) Eastern Arabian Sea, Pakistan, India and the Maldives, 2) the Persian Gulf and Gulf of Oman, 3) the Red Sea and Gulf of Aden, and 4) coastal East Africa (Somalia to Mozambique).

FAO (2005) reports catches for selected species from 1950 to 2002, namely Indian mackerel (*Rastrelliger brachysoma*), pelagic Percomorphs nei, Indian oil sardine, Clupeoids nei, Bombay duck or bummalo, croakers, drums nei, other redfishes, narrow-barred Spanish mackerel, skipjack tuna, yellowfin tuna, other tunas, giant tiger prawn (*Penaeus monodon*), Natantian decapods nei, *Penaeus* shrimps nei and other shrimps. The actual catch of other shrimps was no less than 370,000 tonnes in 2004. Indian oil sardine (*Sardinella longiceps*) has increased to 374,000 tonnes, with an even higher peak at 456,000 tonnes in 2001. Various species of redfish peaked in 2002 with 450,000 tonnes. This is also an extremely important catchment area for tuna species, with catches for the ten species amounting to more than one million tonnes. Among the shrimp species, giant tiger prawn recently gave catches of 100,000 tonnes or above.

Eastern Indian Ocean

The area is about 30 million km^2, with a total shelf area of 2.4 million km^2 or about 8 percent. The main fisheries are coastal and concentrated to the various shelf areas. But there are also high seas resources, especially tunas, mostly exploited by the distant-water fishing fleets. As in most developing countries, a large part of the fish catches is not identified; in fact about 44 percent of marine fishes. Eighty-nine percent of the catches consists of fish species, 6.5 percent of crustaceans, 0.8 percent of molluscan species except cephalopods, and 2.1 percent of cephalopods. In addition to that 1.5 percent is various invertebrates.

Of the five million-tonne fish catches, miscellaneous coastal fish species (FAO group 33) made up 584,000 tonnes in 2004. A large part of those catches consisted of croakers (Scienidae), sea catfishes nei and ponyfishes (Leiogntahidae). Herrings, sardines and anchovies (group 35) made up 432,000 tonnes with prominent catches of anchovy (*Stolephorus* spp.) and Indian oil sardine (*Sardinella longiceps*). Tunas, bonitos and billfishes (group 36) comprised 434,000 tonnes. The latter group consists of at least ten important species, among them the skipjack tuna (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus alabacares*).

Shrimps and prawns are important among the crustaceans with a catch of 230,000 tonnes in 2004. Those species and the tunas make a large contribution to the export value.

Northwest Pacific

This is the most productive of the FAO areas. Some years reported catches have been almost 25 million tonnes. In 2004 catches amounted to 21.6 million tonnes, with 72.5 percent fish species, crustaceans 12.3 percent, molluscs except cephalopods 6.3 percent and cephalopods 7.6 percent. The total surface area is 19 million km^2, with the third largest shelf area of 3.6 million km^2 or 18.9 percent of the total area.

Japanese pilchard (sardine) (*Sardinops melanostichus*) and Alaska pollock (*Theragra chalcogramma*) are the most abundant fish species. In 1988 the catches of Japanese pilchard were 5.4 million tonnes. By 1998 the catches had fallen to 296,000 tonnes. They have continued to fluctuate, but have remained low. In 2004 the catches were 230,000 tonnes. The Alaska pollock (*Theregra chalcogramma*) also had a peak catch in 1988, with a yield of 5.1 million tonnes. In 2004 the catch was 1.2 million tonnes.

The Japanese anchovy (*Engraulis japonicus*) had a peak catch in 1998 of two million tonnes, but catches have slowly declined since then. The largehead hairtail (*Trichiurus lepturus*) increased to almost 1.4 million tonnes in 2000–2002. The chub mackerel (*Scomber japonicus*) decreased from 1.6 million tonnes in 1996 to 870,000 in 2002, but increased again to more than one million tonnes in 2004.

In the Pacific there is also a herring species (*Clupea pallasii*) with fluctuating catches from 450,000 to 250,000 tonnes, and a Pacific cod species with catches around 100,000 tonnes in this area. There are six different salmon species (Table 5).

The Japanese flying squid (*Todarodes pacificus*) is the most common squid species with a catch of 448,000 tonnes in 2004. Another important mollusc is the Yesso scallop (*Patinopecten yessoensis*) with a yield of 317,000 tonnes in the same year. Shrimp and prawns are extremely important, with catches over 1.5 million tonnes

Table 5. The two most common salmon species in the Pacific Ocean are pink and chum salmon, followed by sockeye. These three species made almost the whole yield of the Pacific salmon species, which was 730,000 tonnes in 2004.

Species	Area NW	Area NE	Total
Pink (= Humpback); *Onchorhynchus gorbuscha*	104	139	243
Chum (= Keta, Dog); *O. keta*	256	65	321
Masu (= Cherry); *O. masou*	0.9		0.9
Sockey (= Red); *O. nerka*	12	119	131
Chinook (= Spring, King); *O. tshawytsch*	0.4	12	12.4
Coho (= Silver); *O. kisutch*	2	21	23
Total	**375.3**	**356**	**731.3**

in 2004. The small species Akiami paste shrimp (*Acetes japonicus*) gave nearly half of that amount or 680,000 tonnes. The crab species are also important, among them Gazami crab (*Portunus tribuberculatus*) with a catch of 350,000 tonnes. The total crab yield was 700,000 tonnes.

Northeast Pacific

This is a less productive area compared to the Northwest Pacific. The total yield was 3.1 million tonnes in 2004. The main part of the catches or 96.8 percent was fish, while 2.4 percent was crustaceans, 0.6 percent molluscs (other that cephalopods), and 0.02 percent cephalopods. The area is 8 million km^2 of which 16 percent or 1.3 million km^2 is shelf area.

Alaska pollock (*Theagra chalcogramma*) made the largest contribution, about half of the total catches or 1.5 million tonnes. Another important cod species is the North Pacific hake (*Merluccius *productus*) with a yield of 340,000 tonnes in 2004. The salmon catches are important (see Table 5) at 356,000 tonnes in this area. The largest flatfish stock in the area is sea yellowfin sole (*Pleronectes asper*). The catch was 83,000 tonnes. The yield of Pacific halibut (*Hippoglossus stenolepis*) was 43,000 tonnes. Catches of Pacific herring (*Clupea pallasii*) fluctuate between 50,000 and 100,000 tonnes. Pacific ocean perch (*Sebastes alutus*) is rather important with a total catch of 21,000 tonnes and sable fish (*Anoplopoma fimbris*) with a catch of 26,000 tonnes.

Western Central Pacific

This FAO statistical area covers 33.9 million km^2, the shelf area of which is 19.5 percent or 6.6 million km^2. These shelf areas are rich in demersal resources, including penaeid shrimps, and small pelagic resources, while the oceanic waters of the Pacific have rich tuna resources. The total catches were 11 million tonnes in 2004, of which 87.5 percent consisted of fish species, 5.9 percent crustaceans, 1.6 percent of molluscs (non-cephalopods), and cephalopods 4.4 percent. In addition to that various invertebrates were caught.

A large part of the catches was unidentified fish species. The second most important group was the tuna, mainly skipjack tuna (*Katsuwonus pelamis*) with catches at 1.4 million tonnes and yellowfin tunas (*Thunnus albacares*) at 365,000 tonnes. They are an important export commodity. The next important group is miscellaneous pelagic fishes belonging to group 37, e.g. jacks, scads (560,000 tonnes) and mackerels. Next to that is species from group 35: herrings, anchovies (*Stolephorus* spp.) and sardine (*Sardinella gibbosa*) (156,000 tonnes) and other sardine species of the same genus.

The shrimp species are very important, with total catches of 446,000 tonnes in 2004. The catches in the Arafura Sea are dominated by the genera *Penaues* and *Metapenaues*. The major species is the banana shrimp (*P. merguensis*) and various species of the genus *Matapenaeus*, particularly *M. endeavour* and *M. ensis*. In the northern territory of Australia, the banana shrimp, white shrimp (*P. indicus*) and many other species are exploited. In the region the spear fishery for rock lobster (*Panulirus ornatus*) is important. The squids (*Loligo* spp.) fishery is also of great importance and the catches are in the order of 160,000 tonnes.

Eastern Central Pacific

The FAO statistical area 77 covers a total area of 48.9 million km^2, but the total shelf area is comparatively small, only 0.8 million km^2 or 1.6 percent of the total area. The catches are relatively small, comprising only 1.7 million tonnes, of which 82.2 percent is fish catches, while crustaceans amount to 4.3 percent, molluscs to 1.5 percent and cephalopods 8.9 percent.

The area is well-known for the fluctuations in the sardine fishery (*Sardinops caeruleus*). Since the mid-1930s, the catches have swelled and then collapsed. There was a peak in the early 1940s, with yearly catches of 900,000 tonnes. They dropped to 690,000 in 1950 and to a record low of 320,000 in 1953. During the past ten years, catches have fluctuated between 360,000 and 680,000 tonnes.

The last figure was the catch in 2004. The collapse in the late 1940s was partly compensated for by the abundance of California anchovy (*Engraulis mordax*). Nowadays the catches of that species are small, but in 1980 they were almost 900,000 tonnes. Together the catches of these small pelagic species increased to a record high in 2002, when the total catch was 907,000 tonnes. The main part of the catches was the California sardine (pilchard). Other important species in off-shore waters far from the coast have been the Pacific anchoveta (*Cetengraulis mysticetus*) and the Pacific thread herring (*Opisthonema libertate*), both species with catches around 40,000–50,000 tonnes. The main midsize pelagic species are chub mackerel (*Scomber japonicus*) and Pacific jack mackerel (*Trachurus symmetricus*).

Tunas and other large pelagics belonging to group 36 yield high catches in the area. In 2002 catches were 556,000 tonnes. The main species are yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), skipjack tuna (*Katsuiwonus pelamis*) and albacore (*Thunnus alalunga*). In the area various species of swordfish are also caught.

Shrimp and prawn catches are also of importance, around 50,000 tonnes. More than 15 species are caught from the genera *Penaeus*, *Xiphopenaeu*, *Trachypenaeus*, *Heterocarpus*, *Pandalus*, *Pandalopsis* and others. Catches of squids are in the order of 150,000 tonnes and highly variable. The most abundant species is the jumbo flying squid (*Dosidicus gigas*). Another important species off California is the inshore squid (*Loligo opalescens*).

Southwest Pacific

The total surface area is 27.7 million km^2 but the shelf area is only 0.4 million km^2 or 1.4 percent of the total area. It is a very deep sea and Australia has been a pioneer in developing profitable deep-water trawl fisheries. The sea area borders eastern Australia and surrounds New Zealand. The catches are comparatively low with only 0.7 million tonnes in 2004. 78.9 percent consists of fish species, 0.8 percent of crustaceans, 1.0 percent of molluscan species except cephalopods. The latter group comprises 19 percent.

Well-known are the mesopelagic species orange roughy (*Hoplostethus atlanticus*) and hoki (*Macruronus novaezelandiae*). The latter species, also named blue grenadier, was caught at a quantity of 154,000 tonnes. Another important species is the southern blue whiting (*Micromesistius australis*) with catches of 42,000 tonnes. The species are caught over depths of 250–600 m. Greenback horse mackerel (*Trachurus declivis*) was very abundant in catches in the late 1980s and early 1990s but has now decreased to catches of 23, 000 tonnes. The above mentioned orange roughy, which is a deepwater species, has also previously been much more abundant, but in 2004 the catches were only 26,000 tonnes. Finally it is worth mentioning that very large catches are taken of Wellington flying squid (*Nototodarus sloani*). In 2004 the catches were 108,000 tonnes.

Southeast Pacific

The sea area outside South America in the Pacific is well-known for its high catches of the Peruvian anchoveta (*Engraulis ringens*), another species with variable catches. During the last ten years catches have fluctuated between 1.7 million tonnes (1996) and 11.3 million tonnes (2000). Peru takes the largest part of the catches followed by Chile. Smaller amounts are also taken by Ecuador.

The statistical area comprises 30 million km^2 and the continental shelf area is approximately 0.5 million km^2 or 1.7 percent of the total area. Of the catches 94.2 percent consists of fish species, 0.2 percent of crustaceans, and 0.7 percent of molluscs. No less than 4.5 percent of the catches is cephalopods. In addition some invertebrates are caught.

World fisheries – characteristics

Capture fisheries are extremely diversified, comprising a large number of types of fisheries that are categorized by different levels of classification. On a broad level, capture fisheries can be classified as *industrial, small-scale* or *artisanal* and *recreational*. A more specific level includes reference to the fishing area, gear and the main target species, such as the North Sea herring purse seine fishery, Gulf of Mexico shrimp trawl fishery, southern ocean Patagonian toothfish longline fishery and others. While capture fisheries encompass thousands of fisheries on a global scale, they are often categorized by the capture species, the fishing gear used and the level at which a fishery is managed nationally and/or regionally.

At the end of 2004, the world fishing fleets comprised about four million units, of which 1.3 million were decked vessels of various types, tonnage and power, and 2.7 million were undecked (open) boats (FAO 2007c). The decked vessels were concentrated in Asia, with about 86 percent of the total. 7.8 percent were found in Europe, 3.8 percent in North and Central America, 1.3 percent in Africa, 0.6 percent in South America and 0.4 percent in Oceania.

Types of fishing vessels

The FAO distinguishes three different categories of fishing vessels; trawlers, seiners and line vessels.[2]

Trawls are conical fishing nets that are dragged along the bottom of the sea or in midwater at a specified depth. They are actively pulled through the water behind one or more trawlers. A trawler may also operate one or more trawl nets simultaneously (double-rig and multi-rig). There are many variants of trawling gear, according to local traditions, bottom conditions, and how large and powerful the trawling boats are. Trawlers can be small open boats with only 30 horsepowers or large factory vessels with 10,000 horsepowers. Trawl variants include beam trawls, large-opening mid-water trawls and large bottom trawls, such as “rock hoppers” that are rigged with heavy rubber wheels that let the net crawl over the rocky bottom.

A *seine* is a large fishing net hung vertically in the water by attaching weights along the bottom edge and floats along the top. Seine nets are

2. ***Trawlers***: beam trawler, otter trawler, pair trawler, side trawler, stern trawler, freezer trawler, wet fish trawler.
Seiners: American and European purse seiner, seine netter, tuna purse seiner, gillnetter, get netter, lift netter.
Line vessels: jiger, pole and ling, trollers, longliners, midwater liners, freezer longliner, factory longliners, wet fish longliners.

usually long flat nets like a fence that are used to encircle a school of fish, with the boat driving around the fish in a circle. There are two main types of seine nets:

The *purse seine* has a number of rings along the bottom, with a rope passed through them. When pulled, the rope draws the rings close to one another, preventing the fish from swimming down to escape the net. A *Danish seine* consists of a conical net with two long wings with a bag where the fish collect. Drag lines extend from the wings, and are long so they can surround an area. It is similar to a small trawl net, but the wire warps are much longer. The seine boat drags the warps and the net in a circle around the fish. The motion of the warps herds the fish into the central net. Danish seiner vessels are usually larger than purse seiners, though they are often accompanied by a smaller vessel.

Longline fishing uses a line with baited hooks attached at intervals by means of branch lines. Longlines are classified mainly by where they are set in the water column. This can be at the surface (pelagic), or at the bottom (demersal). Lines can also be set by means of an anchor, or left drifting. Hundreds or even thousands of baited hooks can hang from a single line. Swordfish, tuna, halibut, sablefish and many other species are commonly targeted by longliners.

The technological development in fishing devices and gears has been enormous, especially since World War II. Electronic devices have been constructed to localize the fish schools and to handle fishing gears. Modern vessels are able to take large catches with a limited crew. The FAO classifies the main categories of fishing gears:

1. Surrounding nets (including purse seines).
2. Seine nets (including beach seines).
3. Trawlnets (including bottom trawl, beam trawl, otter trawl, pair trawls and midwater trawls.
4. Dredgers.
5. Liftnets.
6. Falling gear (including cast nets).
7. Gillnets and entangling nets (including set and drifting gillnets, trammel nets).
8. Traps (including pots, stow or bag nets, fixed traps).
9. Hook and lines (including handlines, pole and lines, set or drifting long lines, trolling lines).
10. Grappling and wounding gears (including harpoons, spears arrows, etc.).
11. Stupefying devices.

In 2004, fishery and aquaculture production activities provided direct employment to some 41 million people world-wide (FAO 2007c). The largest number of fishermen and aquaculture workers were in Asia (88 percent of the world total) followed by Africa (6.9 percent), Europe (3.6 percent), North and Central America (2.1 percent each), South America (1.7 percent) and Oceania (0.1 percent). The shares closely reflect the population of the different continents, the share of the population economically active in agriculture and the relative predominance of labour-intensive fisheries and economics in Africa and Asia.

As the full potential of wild fisheries resources has been achieved – and often "lost" through over-fishing – the main objective and

DEFINITIONS

Industrial fisheries are capital-intensive, using relatively large vessels with a high degree of mechanization. Normally advanced fish finding and navigational equipment is used. Such fisheries have a high production capacity, and the catch per unit effort is normally relatively high. In some areas of the world, the term "industrial fisheries" is synonymous with fisheries for species that are used for reduction to fishmeal and fish oil (e.g. the trawl fishery for sandeel in the North Sea or the Peruvian purse seine fishery for anchoveta).

Small-scale fisheries are labour-intensive fisheries that use relatively small crafts (if any), and little capital and equipment per person on board. The vessels are often family-owned, but may be commercial or for subsistence. Fuel consumption is usually low. "Small-scale" is often equated with artisanal fisheries.

Artisanal fisheries are typically traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amounts of capital, relatively small fishing vessels, making short fishing trips, close to shore, mainly for local consumption. In practice, the definition varies between countries, e.g. from hand-collection on the beach or a one-person canoe in poor developing countries, to more than 20 m large trawlers, seiners, or long-liners over 20 m in developed countries. Artisanal fisheries can be subsistence or commercial, providing for local consumption or export. Artisanal fisheries are sometimes referred to as small-scale fisheries. In general, though by no means always, relatively low-level technology is used. Artisanal and industrial fisheries frequently target the same resources which may give rise to conflicts.

Recreational (sport) fishing refers to harvesting fish for personal use, leisure, pleasure and challenge (e.g. as opposed to profit or research). Recreational fishing does not include sale or trade of all or part of the catch.

Commercial fisheries are undertaken for profit and with the objective to sell the harvest on the market, through auction halls, direct contracts, or other forms of trade.

Subsistence fisheries: the fish caught are shared and consumed directly by the families and kin of the fishermen, rather than being bought by intermediaries and sold at the market. Pure subsistence fisheries are rare, as part of the landings are generally sold or exchanged for other goods or services.

Traditional fisheries were established long ago, usually by specific communities that have developed customary patterns of rules and operations. Traditional fisheries reflect cultural traits and attitudes and may be strongly influenced by religious practices or social customs. Knowledge is transmitted between generations by word of mouth. They are usually small-scale or artisanal.

emphasis in capture fisheries development strategies has changed from increasing harvest (an objective during the first three quarters of the last century) to establishing a more sustainable and optimal use of the available fisheries resources (particularly since the UN Conference on Environment and Development, UNCED, the "World Summit" in 1992). The same path has been followed by aquaculture where the development from the 1950s to the 1990s emphasized technology development, intensification, and larger harvests. Concerns about the environmental management and sustainability appeared essentially during the 1990s.

For centuries, open access was the norm in capture fisheries. Fishermen considered it their right to fish in any part of the oceans, except the narrow borders of territorial waters along the coastline of each coastal state. It is now widely recognized that the fishing of wild fish should be strictly controlled, to guarantee the sustainability of the fish stocks. Most countries introduced a 200-mile exclusive zone in 1976. It was regulated on a world-wide basis in 1982 through the UN Convention on the Law of the Sea (UNCLOS). This is a prerequisite for an effective, ecosystem-based management of marine fisheries and aquaculture, and essential to achieving the long-term development of fisheries (FAO 2007c).

Is over-fishing a threat to fish and shellfish populations?

It would be easy to say "yes" to this question. However, the answer must be defined in more detail. The debate has been going on for many years. Recently many papers have been published which deal with this question, e.g. Essington *et al.* (2006), Pauly (2007) and Hilborn (2007). One of the questions that are raised in these publications is the concept of trophic index. The catches of the high-trophic level fishes are decreasing from year to year. Will this ultimately lead to the collapse of many valuable fish populations which are harvested by mankind? Will top predators such as large groundfish species (cod, haddock, etc.) and pelagic tuna species disappear? The concept of "fishing down marine food webs" indicates that species lower down the food chain are fished, and ultimately plankton and jelly fish will be harvested, as indicated by Pauly (2007).

How to avoid over-fishing? Hilborn (2007) describes two divergent views of the status and future of the world's fisheries. One group, largely represented by academic Marine Ecologists, sees almost universal failure of fisheries management and prescribe the use of marine protected areas as the central tool of a new approach to rebuilding the marine ecosystems of the world. However, the fishery scientists as well as many academic scientists see a more complex picture, with many failures but also numerous successes for the management procedures that are at present applied by various regional fisheries bodies and the European Union.

According to Hilborn (2007), the first view, the one with the marine protected areas concept, is very pessimistic and partly inaccurate. The academic Marine Ecologists project that, at the current rate of exploitation, all the world's

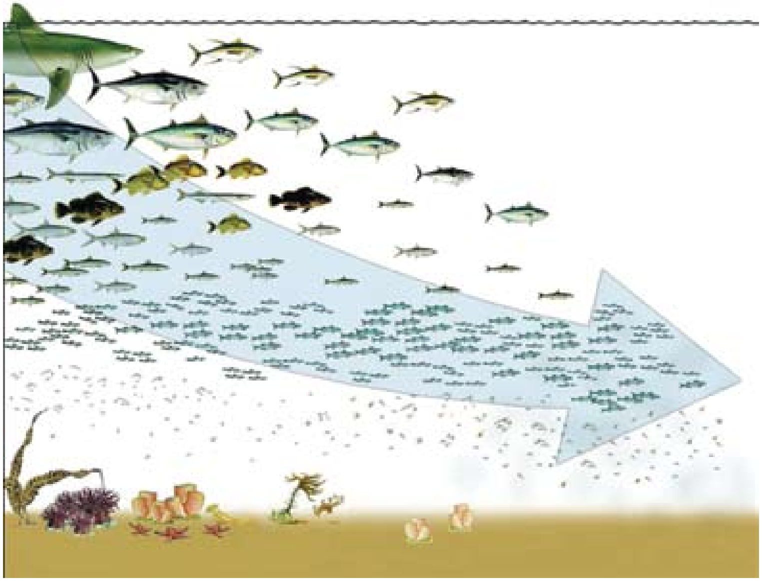


Figure 9. Fishing down marine food webs means that the fisheries (blue arrow), having at first depleted the more vulnerable large fish at the top of various food chains, must then target smaller fish, finally targeting very small fish and invertebrates, including jellyfish. In some parts of the world, the fisheries have indeed gone all the way down the food chain and even jellyfish may be taken in the future. The bottom invertebrates at the lower left part of the graph disappear because of trawling, which leave large mud beds in their wake (from Pauly 2007).
Design: Daniel Pauly; artist Aque Atanacio, Los Baños, Philippines.

wild stocks will have collapsed by 2048. A collapse is defined as a situation where the catch, in any year, falls below 10 percent of the highest recorded catch (using world catch statistics from 1950 compiled by the FAO). In 2003 this group estimated that 29 percent of the stocks were already collapsed. This, of course, is a very conspicuous statement. Many examples could be given which support this theory, e.g. the collapse of cod stocks in the Northwest Atlantic in 1992, and the jack mackerel (*Trachurus symmetricus*) in the California current. But obviously stocks can collapse and recover. This is the case for the bonito (*Sarda chiliensis lineolata*) which fluctuates greatly in abundance and has collapsed three times and subsequently recovered in the past 50 years, according to this definition of collapse.

It is true that the key to sustainability of a fishery is good governance. Unfortunately there are many stocks which are managed in a non-sustainable manner, because there is no real governance. There are several reasons for this. Building larger vessels puts pressure on management agencies to allow larger catches, in order to pay back investment costs. Industrial fisheries are therefore difficult to regulate. This is why the most important action at present seems to regulate access to fishery resources by a more efficient method. Various types of tenure could be good management tools e.g. in regional and local fisheries. One of the key problems is the mismatch between fishing capacity, demand for fish and the productive capacity of the resource to produce the supply.

Hilborn (2007) emphasises that the management of fisheries is different in rich countries with strong central government in contrast to countries without a strong central government, and in international and distant-water fisheries. The first category of countries usually has a more elaborate management system. In the second category without a strong government there might be chaos and fisheries managers can do little on a national scale. If senior government officials allow foreign fleets or unlicensed fishermen to fish in their waters, there is little hope of sustainability. International fisheries (high seas fisheries) management has failed totally, despite the existence of numerous regional fisheries management organisations.

Essington *et al.* (2006) investigated the concept of "fishing down the food web", by using statistical methods. They analysed trends in fisheries landings in 48 large marine ecosystems worldwide. Fishing down the food web was widespread, and was by far the most common underlying force in the declines of the mean trophic level of landings. Only nine ecosystems showed declining catches of upper trophic level species, compared with 21 ecosystems that exhibited either no significant change or significant increases in upper trophic level catches when fishing down the food web was occurring.

Many ecosystems worldwide show evidence of substantial fishing down the food web with an average decline of 0.42 trophic levels. (A decline in mean trophic level of >0.15 is considered to be evidence of ecologically significant fishing down the food web.) It is obvious that the index of past and present trophic levels is an indicator of overfishing, but every stock has to be analysed separately in order to measure the consequences.

Taking into account the total catches in all ecosystems world wide, the mean trophic level was stable from 1950 to 1956, declined from 3.44 to 3.16 between 1956 and 1986, and has remained stable since 1986. Analyses of lower trophic level catches in these ecosystems confirm that declining mean trophic level was associated with rapid increases in lower trophic level catches except for certain instances in which high trophic level catches declined. The data identifying the trophic level decline as the most common process underlying fishing down the food web, representing more than two-thirds of all studied cases.

It is quite obvious in many fisheries that trawling tends to overexploit fish stocks. The ultimate result of this may be that large sizes of the fish species (older fish) tend to become fewer and fewer. In the end only small specimens will remain. This was the case when the population of cod was investigated in various sites off the Swedish westcoast. The only site with large specimen was in an area where trawling was not permitted (Svedäng *et al.* 2002).

Bottom trawls change the seabed structure. Therefore fishing with bottom trawl is contentious in many countries. We know that in many areas, like the North Sea, nearly every single square metre is trawled at least once a year.

However, it is less clear whether trawling is destructive on soft-bottom habitats (Essington *et al.* 2006). On the contrary, it could stimulate production of target species. However, in other investigations it is clear that the soft bottom is very disturbed. In the deep furrows of the bottom, oxygen free areas are formed with hydrogen sulphide development, which was seen in the Baltic (Andersson and Jonsson 2003). It is also obvious that in some hard bottom areas, trawling can destroy valuable bottom species such as corals.

Energy consumption in fisheries

The energy consumption in fisheries was investigated in 2000 for 250 fishery units in 20 countries (Tyedmers *et al.* 2005). The authors compared the amount of fuel used by the fishing vessels with the catches. The protein content and its energy value were used as a reference in all comparisons. They distinguished between various types of fisheries, e.g. the fuel consumption for purse seine, trawls, etc. The overall conclusion was that in the purse seine fishery, the fuel consumption was only 50 litres per tonne fish caught, while in other fisheries for shrimps, tunas and swordfish, the corresponding figure was 2,000 litres. The explanation was mainly that the fishing vessels were forced to travel large distances, and that the populations of fish species were not very dense. But in the purse seine fishery, close to the coast, there were dense schools of menhaden and herring.

The authors also made comparisons with the energy content in the fuel and in the catch. For the total fisheries the ratio between energy in the fuel and in the edible (protein) part of the catch was 12.5. Comparisons were made with the food production on land. The conclusion was that some food production on land required less energy and others more.

Table 6. Production of various types of food and the energy required versus the protein content in the product (Tyedmers *et al.* 2005).

Type of food production	Energy ratio fuel versus edible protein content in the product
Global fishery (average value)	12.5
Chicken	4.0
Pig	7.1
Cow (beef)	20.3
Egg	40.0
Milk	7.1

This comparison can be criticised. The authors did not consider the fat content (oil) in the fish product. Not only the protein in the fish, but also the useful fatty acids, make a great contribution to the nutritional value of some fish species. Of course, the same thing can be said for the food produced on land. Comparisons in this would become more complicated.

Tyedmers *et al.* (2005) also made other comparisons with the energy consumption in fisheries. They concluded that the world fleet in the year 2000 consumed 50 billion litres of fuel which corresponds to 620 litres of fuel per tonne catch. This means that for each tonne of fuel consumed the catch was 1.9 tonnes of fish and shellfish. Furthermore, the total fuel consumption of all fishing vessels in the world corresponded to 1.2 percent of the total world consumption of oil!

Finally the emission of carbon dioxide (CO_2) was calculated for 250 fishery units in 20 countries, with a total world catch of 80.4 million tonnes in 2000. The emission from the world fleet was 134 million tonnes CO_2 in that year, which corresponds to 1.7 tonnes CO_2 per tonne of fish landed.

Life cycle analyses were made for fisheries by comparing the energy used in all links from fishery in the Baltic to the dinner table (Ziegler 2001). Results showed that fishing dominates all included categories of environmental impact (global warming potential, eutrophication potential, acidification potential, aquatic ecotoxicity, photochemical ozone creation potential). Fishing is responsible for 75 percent of the total energy consumption in the life cycle of the product, mainly due to the onboard diesel consumption. The remaining 25 percent of the energy used was due to the transport from retail store to the household and the preparation at home measured together as environmental impact. However, the differences between gillnet and trawl fishery were considerable, since the fuel consumption in trawl fishing is much higher.

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ACCELERATED WARMING AND EMERGENT TRENDS IN FISHERIES BIOMASS YIELDS

Kenneth Sherman, Igor M. Belkin, Kevin D. Friedland, John O'Reilly and Kimberly Hyde

Abstract

Since 1995, international financial organizations have extended explicit support to developing coastal countries for assessing and managing goods and services using the modular approach at the Large Marine Ecosystem (LME) scale. At present, 110 countries are engaged in LME projects along with five UN agencies and USD 1.8 billion in financial support from the Global Environment Facility (GEF) and the World Bank. Sixteen LME projects are presently focused on introducing an ecosystems approach to the recovery of depleted fish stocks, restoration of degraded habitats, reduction and control of pollution, conservation of biodiversity, and adaptation to climate change. In recognition of the observational evidence of global warming from the Fourth Assessment Report of the IPCC (2007), and the lack of information on trends in global warming at the LME scale where most of the world's marine fisheries biomass yields are produced, we undertook a study of the physical extent and rates of sea surface temperature trends in relation to fisheries biomass yields and SeaWiFS derived primary productivity of the world's LMEs.

Introduction

The heavily exploited state of the world's marine fisheries has been well documented (FAO 2004, Garcia and Newton 1997, González-Laxe 2007). Little, however, is known of the effects of climate change on the trends in global fisheries biomass yields. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change stated with "high confidence" that changes in marine biological systems are associated with rising water temperatures affecting shifts in pelagic algae and other plankton, and fish abundance in high latitudes (IPCC 2007). The Report also indicated that adaptation to impacts of increasing temperatures in coastal systems will be more challenging in developing countries than in developed countries due to constraints in adaptive capacity. From a marine resources management perspective, the eight regions of the globe examined by the IPCC (i.e. North America, Latin America, Europe, Africa, Asia, the Australia and New Zealand region and the two Polar regions), are important fisheries areas, but at a scale too large for determination of temperature trends relative to the assessment and management of the world's marine fisheries biomass yields produced

1 East Berling Sea
2 Gulf of Alaska
3 California Current
4 Gulf of California
5 Gulf of Mexico
6 Southeast U.S. Continental Shelf
7 Northeast U.S. Continental Shelf
8 Scotian Shelf
9 Newfoundland-Labrador Shelf
10 Insular Pacific-Hawaiian
11 Pacific Central-American Coastal
12 Caribbean Sea
13 Humboldt Current
14 Patagonian Sea
15 South Brazil Shelf
16 East Brazil Shelf
17 North Brazil Shelf
18 West Greenland Shelf
19 East Greenland Shelf
20 Barents Sea
21 Norwegian Sea
22 North Sea
23 Baltic Sea
24 Celtic-Biscay Shelf
25 Iberian Coastal
26 Mediterranean Sea
27 Canary Current
28 Guinea Current
29 Benguela Current
30 Agulhas Current
31 Somali Coastal Current
32 Arabian Sea
33 Red Sea
34 Bay of Bengal
35 Gulf of Thailand
36 South China Sea
37 Sulu-Celebes Sea
38 Indonesian Sea
39 North Australian Shelf
40 Northeast Australian Shelf-Great Barrier Reef
41 East-Central Australian Shelf
42 Southeast Australian Shelf
43 Southwest Australian Shelf
44 West-Central Australian Shelf
45 Northwest Australian Shelf
46 New Zealand Shelf
47 East China Sea
48 Yellow Sea
49 Kuroshio Current
50 Sea of Japan
51 Oyashio Current
52 Okhotsk Sea
53 West Bering Sea
54 Chukchi Sea
55 Beaufort Sea
56 East Siberian Sea
57 Laptev Sea
58 Kara Sea
59 Iceland Shelf
60 Faroe Plateau
61 Antarctic
62 Black Sea
63 Hudson Bay
64 Arctic Ocean

Figure 1. Large Marine Ecosystems for the world and linked watersheds. Large Marine Ecosystems are areas of the ocean characterized by distinct bathymetry, hydrography, productivity, and trophic interactions. They annually produce 80 percent of the world's fish catch. They are national and regional focal areas of global effort to reduce the degradation of linked watersheds, marine resources, and coastal environments from pollution, habitat loss, and over-fishing.

principally in 64 LMEs (Figure 1). These LMEs, in coastal waters around the globe, annually produce 80 percent of the world's marine fisheries biomass (Figure 2).

Large Marine Ecosystems are areas of an ecologically based nested hierarchy of global ocean biomes and ecosystems (Watson *et al*. 2003). Since 1995, LMEs have been designated by a growing number of coastal countries in Africa, Asia, Latin America, and eastern Europe as place-based assessment and management areas for introducing an ecosystems approach to recover, de-

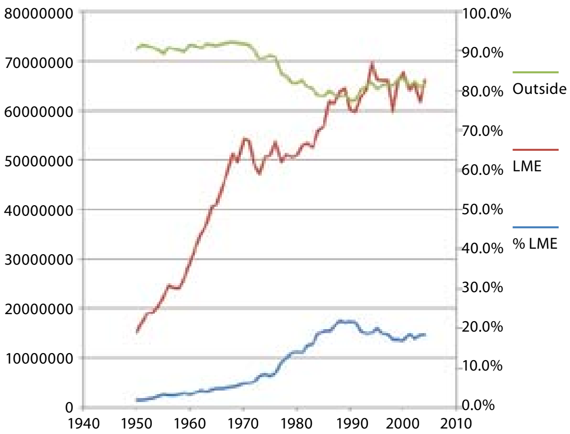


Figure 2. Annual global marine fisheries biomass yields in metric tons of the world's LMEs. Green line = percentage of the world catch. Red line = the biomass yield trend in all LMEs together. Blue line = biomass yield trend from areas outside LMEs. From the University of British Columbia's Sea Around us Project.

velop, and sustain marine resources. The LME approach to the assessment and management of marine resources is based on the operationalization of five modules, with suites of indicators for monitoring and assessing changing conditions in ecosystem: 1) productivity, 2) fish and fisheries, 3) pollution and ecosystem health, 4) socioeconomics, and 5) governance (Duda and Sherman 2002). The approach is part of an emerging effort by the scientific community to relate the scale of place-based ecosystem assessment and management of marine resources to policy making and to tighten the linkage between applied science and improved management of ocean resources within the natural boundaries of LMEs (COMPASS 2005, Wang 2004).

Methods

Fisheries biomass yields are not presented here as representative of individual fish stock abundances. They are representative of fisheries catches and are used here to compare the effects of global warming on the fishery biomass yields of the World's LMEs. The comparative analysis of global temperature trends, fisheries biomass yields, and primary productivity is based on available time-series data at the LME scale on sea surface temperatures, marine fisheries biomass yields, and Sea WiFS derived primary productivity values.

LME sea surface temperatures (SST)

Sea surface temperature (SST) data is a thermal parameter routinely measured worldwide. Subsurface temperature data, albeit important, are limited in the spatial and temporal density required for reliable assessment of thermal conditions at the Large Marine Ecosystem (LME) scale worldwide. The U.K. Meteorological Office Hadley Center SST climatology was used in this analysis (Belkin 2008), as the Hadley data set has a resolution of one degree latitude by one degree longitude globally. A detailed description of this data set has been published by Rayner *et al.* (2003). Mean annual SST values were calculated for each 1°x1° cell and then were area-averaged by annual 1°x1° SSTs within each LME. Since the square area of each trapezoidal cell is proportional to the cosine of the middle latitude of the given cell, all SSTs were weighted by the cosine of the cell's middle latitude. After integration over the LME area, the resulting sum of weighted SSTs was normalized by the sum of the weights, that is, by the sum of the cosines. Annual anomalies of annual LME-averaged SST were calculated. The long-term LME-averaged SST was computed for each LME by a simple long-term averaging of the annual area-weighted LME-averaged SSTs. Annual SST anomalies were calculated by subtracting the long-term mean SST from the annual SST. Both SST and SST anomalies were plotted using adjustable temperature scales for each LME to depict temporal trends. Comparisons of fisheries biomass yields were examined in relation to intervals of 0.3°C of increasing temperature.

LME primary productivity

The LME primary productivity estimates are derived from satellite borne data of NOAA's Northeast Fisheries Science Center, Narragansett Laboratory. These estimates originate from SeaWiFS (satellite-derived chlorophyll estimates from the Sea-viewing Wide Field-of-view Sensor), Coastal Zone Color Scanner (CZCS), a large archive of *in situ* near-surface chlorophyll data, and satellite sea surface temperature (SST) measurements to quantify spatial and seasonal variability of near-surface chlorophyll and SST in the LMEs of the world. Daily binned global SeaWiFS chlorophyll *a* (CHL, mg m^{-3}), normalized water leaving radiances, and photosynthetically available radiation (PAR, Einsteins m^{-2} d^{-1}) scenes at 9 km resolution for the period January 1998 through December 2006 were obtained from NASA's Ocean Biology Processing Group. Daily global SST (°C) measurements at 4 km resolution were derived from nighttime scenes composited from the AVHRR sensor on NOAA's polar-orbiting satellites and from NASA's *Modis Terra* and *Modis Aqua* sensors. Daily estimates of global primary productivity (PP, gC m^{-2} d^{-1}) were calculated using the Ocean Productivity from Absorption and Light (OPAL) model, a derivative of the model first formulated in Marra *et al*. (2003). The OPAL model generates profiles of chlorophyll estimated from the SeaWiFS chlorophyll using the algorithm from Wozniak *et al*. (2003) that uses the absorption properties in the water column to vertically resolve estimates of light attenuation in approximately 100 strata within the euphotic zone. Productivity is calculated for the 100 layers in the euphotic zone and summed to compute the integral daily productivity (gC m^{-2} d^{-1}). Monthly and annual means of primary productivity (PP) were extracted and averaged for each LME. Significance levels (alpha=0.01 and 0.05) of the regression coefficients of the nine years of Sea WiFS mean annual primary productivity data were determined using a t-test according to Sokal and Rohfl (1995). Time series trends plotted for each LME are available online (*www.lme.noaa.gov*).

Fisheries biomass yield methods

Prior to the *Sea Around Us Project*, projections of marine fisheries yields at the LME scale were largely defined by the range of vessels exploiting a given resource (Pauly and Pitcher 2000). UNCLOS[1] obliges countries to manage fisheries within EEZs[2], and hence to derive fisheries

1. UNCLOS = UN Convention of the Law of the Sea.
2. EEZ = Exclusive Economic Zone.

yields at national level (Prescott-Allen 2001). The national reporting is compatible with a transboundary scaling of yields to support the emergence of ecosystem-based management at the LME scale (Sherman *et al*. 2003, Pauly *et al*. 2008). The time series of fisheries biomass yields (1950–2004) used in this study are based on the time-series data provided at the LME scale by the *Sea Around Us Project* at the University of British Columbia (Pauly *et al*. 2008). The method used by the project to map reported fishery catches onto 180,000 global spatial cells of ½ degrees latitude and longitude was applied to produce profiles of 54-year mean annual time-series of catches (biomass yields) by 12 species or species groups for the world's LMEs (Pauly *et al*. 2008, Watson *et al*. 2003). In addition, plots on the status of the stocks within each of the LMEs according to their condition (e.g. undeveloped, fully exploited and overexploited) in accordance with the method of Froese and Kesner-Reyes (2002), and illustrated by Pauly *et al*. (2008), were used to examine trends in yield condition among the LMEs. Fisheries biomass yields were examined in relation to warming trends for 63 LMEs for the period 1982 to 2004. Fisheries biomass yield trends were plotted for each LME using the LOESS smoothing method (tension=0.5) and the emergent increasing and decreasing patterns examined in relation to LME warming data (Cleveland and Devlin 1998). Observed trends were compared to earlier studies for emergent spatial and temporal global trends in LME fishery biomass yields.

Results

Comparative SST clusters

The LME plots of SST and SST anomalies are presented in two sets of four plates, with each set containing a total of 63 figures: four plates for SST and four plates for SST anomalies 1957–2006. These can be viewed at *www.lme.noaa.gov*. The Arctic Ocean LME was not included in this analysis because of the perennial sea ice cover. Other Arctic LMEs also feature sea ice cover that essentially vanishes in summer, thus making summer SST assessment possible. The 1957–2006 time series revealed a global pattern of long-term warming. However, the long-term SST variability since 1957 was not linear over the period. Specifically, most LMEs underwent cooling between the 1950s and the 1970s, replaced by a rapid warming from the 1980s until the present. Therefore we re-calculated SST trends using only the last 25 years of data (SST data available at *www.lme.noaa.gov*, where SST anomalies are calculated for each LME.

The most striking result is the consistent warming of LMEs, with the notable exceptions of two, the California Current and Humboldt Current. These LMEs experienced cooling over the last 25 years. Both are in large and persistent upwelling areas of nutrient rich cool water in the Eastern Pacific. The SST values were partitioned into 0.3°C intervals to allow for comparison among LME warming rates. The warming trend observed in 61 LMEs ranged from a low of 0.08°C for the Patagonian Shelf LME to a high of

1.35°C in the Baltic Sea LME. The relatively rapid warming exceeding 0.6°C over 25 years is observed almost exclusively in moderate- and high-latitude LMEs. This pattern is generally consistent with the model-predicted polar-and-subpolar amplification of global warming (IPCC 2007). The warming in low-latitude LMEs is several times slower than the warming in high-latitude LMEs. In addition to the Baltic Sea, the most rapid warming exceeding 0.96°C over 25 years is observed in the North Sea, East China Sea, Sea of Japan/East Sea, and Newfoundland-Labrador Shelf and Black Sea LMEs.

Comparisons of warming were made among different temperature clusters of LMEs.

1) ***Super-fast warming*** LMEs, D(SST) >0.96°C–1.35°C
2) ***Fast warming*** LMEs, D(SST) 0.67°C–0.84°C.
3) ***Moderate warming*** LMEs, D(SST) >0.3°C–0.6°C.
4) ***Slow warming*** LMEs, D(SST) 0.0°C–0.28°C.

If super-fast warming LMEs are combined with fast warming LMEs (0.67°C to 1.35°C), 18 are warming at rates two to four times higher than the global air surface temperature increase of 0.74°C for the past 100 years as reported by the IPCC (2007) (Figure 3).

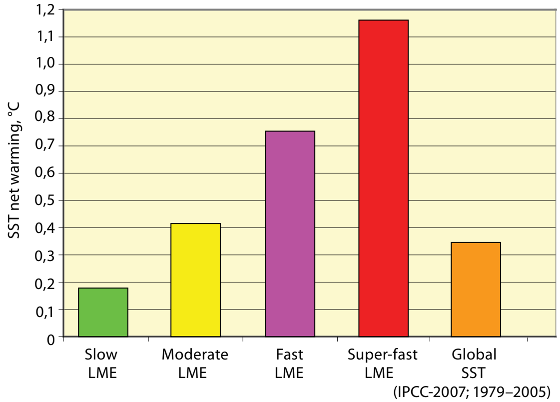


Figure 3. Comparison of SST warming rates in Large Marine Ecosystems 1982–2006 (Belkin 2009). The fast and super-fast warming LMEs (purple and red bars respectively) warmed approximately two to four times faster than the global ocean as a whole (orange bar), while the slow LMEs (green bar) warmed more slowly than the global ocean. All estimates of warming rates are based on the best available global SST climatology produced by the U.K. Meteorological Office, Hadley Centre.

Primary productivity

No large scale consistent pattern of either increase or decrease in primary productivity was observed. Of the 64 LMEs examined, only four 9-year trends were significant ($P<0.05$). Primary productivity declined in the Bay of Bengal, and increased in the Hudson Bay, Humboldt Current and Red Sea LMEs. The general declining trend in primary productivity with ocean warming reported by Behrenfeld (2006) was limited to the Bay of Bengal LME. No consistent trend among the LMEs was observed. However, as previously reported (Chassot *et al*. 2007, Nixon *et al*. 1986, Ware and Thomsom 2005) fisheries biomass yields did increase with increasing levels of primary productivity ($P<0.001$) in all 63 LMEs, and for LMEs in each of the warming clusters (Figure 4).

Fisheries biomass yield trends

The effects of warming on global fisheries bio-

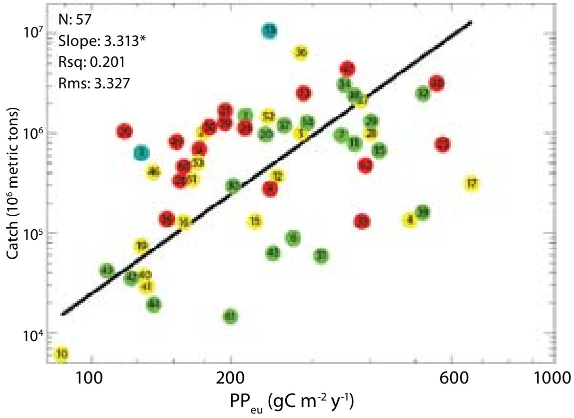


Figure 4. Positive correlation of 5-year mean annual fisheries biomass yield with 9-year mean annual primary production in fast warming (red), moderately warming (yellow) and slower warming (green) LMEs. The two blue circles represent cooling LMEs. P<0.001.

mass yields were non-uniform in relation to any persistent global pattern of increasing or decreasing yields. The relationship between change in LME yield and SST change was not significant; the slight suggestion of a trend in the regression, was influenced by the data for the Humbolt LME. The results on trends in fisheries biomass yields divided the LMEs into two groups. Increasing yields were observed in 31 (49.2 percent) and decreasing trends in 32 (50.8 percent) of the LMEs. Differences were similar in fast warming (eight increasing, ten decreasing) and moderate warming LMEs (ten increasing, eight decreasing). In the slower warming LMEs, most (14) were undergoing increasing biomass yields and six were in a decreasing condition.

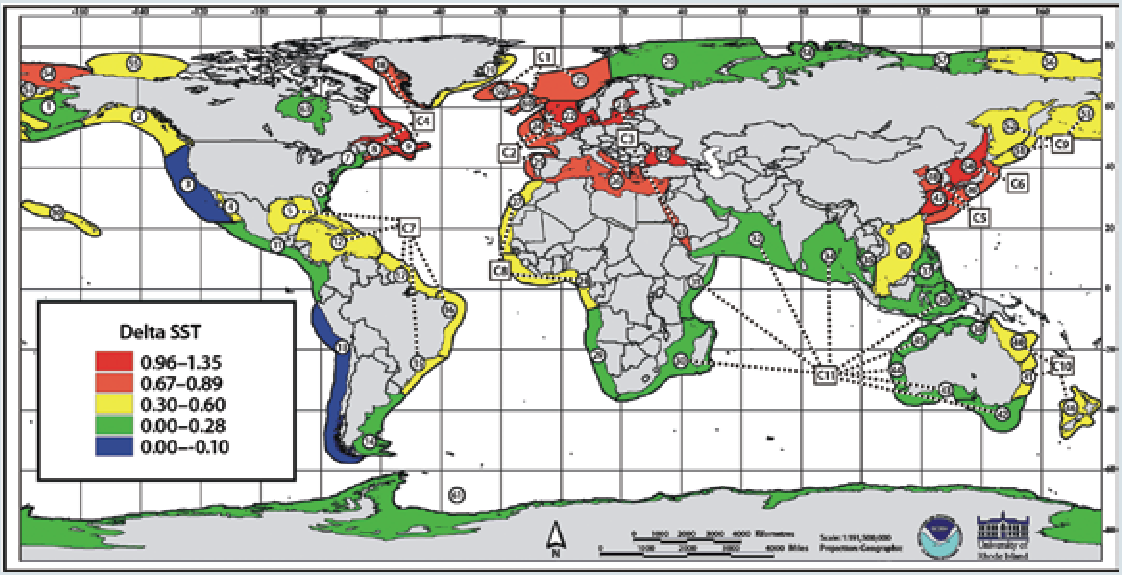
Linear warming trends from 1982 to 2006 for each LME were distributed in distinct global clusters, 1) the fast warming LME clusters were in the Northeast Atlantic, African and Southeast Asian waters; 2) the moderate warming LMEs were clustered in the Atlantic and North Pacific waters; and 3) the slow warming LME clusters were located principally in the Indian Ocean, and also in locations around the margins of the Atlantic and Pacific Oceans (Figure 5).

Comparative fisheries biomass yields in relation to warming

Fast warming European LMEs

In the *Norwegian Sea*, *Faroe Plateau*, and *Iceland Shelf*, the fisheries biomass yield is increasing. These three LMEs account for 3.4 million tons, or five percent of the world biomass catch, (Figure 6). This cluster of LMEs is influenced from bottom-up forcing of increasing zooplankton abundance and warming hydrographic conditions in the northern areas of the North Atlantic, where stocks of herring, blue whiting and capelin are benefiting from an expanding prey field of zooplankton (Beaugrand and Ibanez 2004, Beaugrand *et al.* 2002) supporting growth and recruitment of these three species. The warming trend in the Norwegian Sea driving the increase in biomass of herring, capelin and blue whiting yields has been reported by Skjoldal and Saetre (2004). On the Faroe Plateau LME, Gaard *et al.* (2002) indicate that the increasing shelf production of plankton is linked to the increased

SST WARMING IN LARGE MARINE SYSTEMS, 1982–2006



Warming clusters of LMEs in relation to SSTs, 1982–2006

Fast warming: **C1** Northern European cluster; **C2** Southern European; **C3** Semi-enclosed European seas; **C4** of the NW Atlantic; **C5** Fast warming East Asian LMEs; **C6** Kuroshio Current and Sea och Japan/East sea LMEs.

Moderate warming: **C7** Western Atlantic LMEs; **C8** Eastern Atlantic LMEs; **C9** NW Pacific; **C10** SW Pacific. Several non-clustered LMEs are moderate warming: NE Australia, Insular Pacific Hawaiian, Gulf of Alaska, Gulf of California, South China Sea, East Greenland Shelf.

Slow warming: **C11** Indian Ocean and adjacent waters. Non-clustered, slow warming LMEs include the U.S. Northeast Shelf, the U.S. Southeast Shelf, the Barents Sea, East Bering Sea, Patagonian Shelf, Benguela Current and Pacific Central American coastal LMEs.

Figure 5. Map showing Warming Clusters of LMEs in relation to SSTs, 1982–2006.

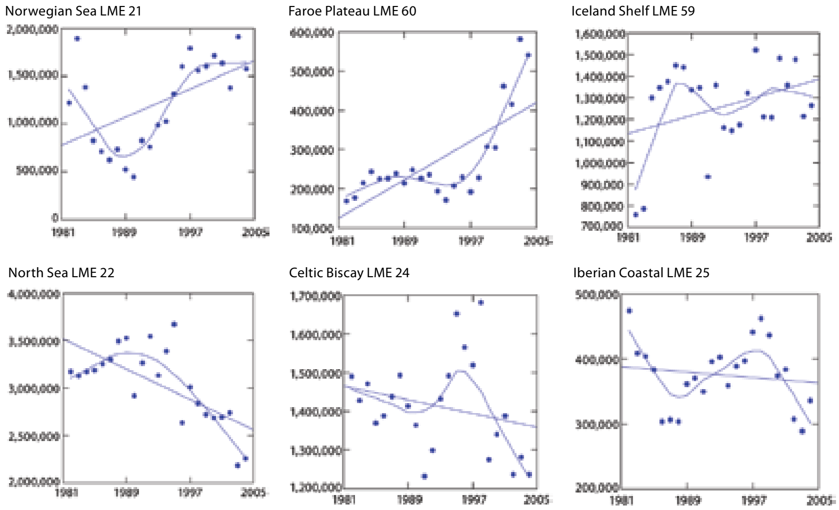


Figure 6. Fast Warming LMEs and biomass yield trends for the increasing European Northern (Cluster 1): Norwegian Sea LME, Faroe Plateau LME, Iceland Shelf LME – and the declining European Southern (Cluster 2) biomass yield trends: North Sea LME, Celtic Biscay LME and Iberian Coastal LME.

production of fish and fisheries in the ecosystem. Astthorsson and Vilhjálmsson (2002) have shown that variations of zooplankton in Icelandic waters are greatly influenced by large scale climatic factors, and that warm Atlantic water inflows favor zooplankton that supports larger populations of capelin that serve as important prey of cod. The productivity and fisheries of all three LMEs are benefiting from the increasing strength of the sub-Polar gyre bringing warmed waters to the LMEs of the region generally in the northern northeast Atlantic and contributing to decreasing production and fisheries yields in the relatively warmer southern waters of the northeast Atlantic (Richardson and Schoeman 2004).

In southern Europe three LMEs, the *North Sea*, *Celtic Biscay*, and *Iberian Coastal* LMEs in fast warming clusters are experiencing declines in biomass trends representing 4.1 million metric tons (6.4 percent) of the mean annual global biomass yield (Figure 6). It has been reported that zooplankton abundance levels in the three LMEs are in decline, reducing the prey field for zooplanktivores (Beaugrand *et al.* 2002, Valdés and Lavin 2002, Valdés *et al.* 2007). Although we did not detect any significant decline in primary productivity in the three LMEs, the declining phytoplankton level in the region (Richardson and Schoeman 2004) is consistent with the declines in primary productivity in warming ocean waters reported by Behrenfeld (2006). The fisheries biomass yields of 80 percent of the targeted species are in an overexploited or fully exploited condition, suggesting that the observed decline in biomass yield of pelagic species is related to both heavy exploitation and warming.

The three semi-enclosed European LMEs, the *Mediterranean*, the *Black Sea*, and the *Baltic Sea*, and the adjacent area of the *Red Sea*, are surrounded by terrestrial areas and are fast warming, with heavy fishing as a dominant feature. The four LMEs contribute 2.4 million metric tons (3.7 percent) of the mean annual global biomass yield. In three European LMEs, the fisheries biomass trend is decreasing, while in the Red Sea it is increasing. In the case of the Black Sea, the fisheries biomass is severely depleted, with 85 percent of fisheries stocks overexploited due to heavy fishing and a trophic cascade (Daskalov 2003). In the Baltic Sea, Red Sea and Mediterranean Sea LMEs, 78 percent of the stocks are in a fully exploited condition. Mixed species dominate in the Red Sea, where 88 percent of the species fished are fully exploited and 10 percent are overexploited. It appears that heavy exploitation is the dominant driver of the biomass trends observed in all four LMEs.

Fast warming clusters of the Northwest Atlantic (C4) LMEs and the Asian (C5, C6) LMEs

The three LMEs in this region contribute 1.1 million metric tons (1.7 percent) to the global biomass yield. In two LMEs of the Northwest Atlantic, the downward trends in fisheries yield have been attributed to the cod collapse in the *Newfoundland-Labrador Shelf* (Rice 2002), and to the cod collapse and collapse of other demersal fisheries in the *Scotian Shelf* LME from excessive fishing mortality (Choi *et al.* 2004, Frank *et al.* 2005). In the *West Greenland Shelf* LME, where the cod stock has collapsed from excessive fishing mortality, there is a recent increase in the landings of shrimp and other species (Aquarone and Adams 2008b).

Fast warming LMEs of East Asian Seas

The 7.5 million metric tons biomass yields of the *Yellow Sea* and *East China Sea* LMEs constitute 11 percent of the global yield. In both LMEs, yields are increasing. The principal driver of the increase is food security to accommodate the needs of the People's Republic of China and Korea (Tang 2003, Tang 2006, Tang and Jin 1999, Zhang and Kim 1999). Biomass yields are dominated by heavily fished "mixed" species. Seventy percent or more of the species constituting the yields are fully exploited or overexploited, suggesting that the principal driver of increased biomass yields is full exploitation rather than global warming.

The fast warming *Kuroshio Current* and *Sea of Japan/East Sea* LMEs show declining fisheries trends. They contribute 1.9 million metric tons (2.9 percent) to the global marine fisheries yield. For these two LMEs, exploitation levels are high with 90 percent of the species in a fully exploited to overexploited condition. The fisheries are also subjected to periodic oceanographic regime shifts affecting the abundance of biomass yields (Chavez *et al.* 2003). Among the fast warming East Asian Seas LMEs, no analysis has been conducted for the ice-covered *Chukchi Sea* LME, as the data is limited and of questionable value.

Moderate warming Western (C7) and Eastern Atlantic (C8) LMEs, and LMEs of the Asian Northwest Pacific region

A large cluster of moderately warming LMEs can be found in the Trade Winds region of the Atlantic Ocean. This is an important cluster of LMEs contributing 5.1 million metric tons (7.9 percent) to the mean annual global biomass yield. Five LMEs are clustered in the Western Atlantic, and two in the Eastern Atlantic. In the West Atlantic Ocean, the *Gulf of Mexico* LME fisheries biomass yields are decreasing, while in the *Caribbean*, *North Brazil*, *East Brazil*, and *South Brazil Shelf* LMEs fisheries biomass yields are increasing.

The fisheries biomass yield trends in the Atlantic Ocean region appear to be driven principally by heavy exploitation rather than climate warming. The Caribbean, North Brazil, and East Brazil Shelf LMEs are in a fully exploited and over-exploited fisheries condition equal to or greater than 88 percent of the stocks. In the South Brazil Shelf, 60 percent of fisheries are fully exploited or overexploited. The East Brazil Shelf and South Brazil Shelf LMEs are dominated by small pelagics and/or "mixed species".

The two LMEs of the Eastern Atlantic are important sources of food security to the over 300 million people of West African countries adjacent to the LMEs. The *Canary Current* and the *Guinea Current* are showing increasing trends in biomass yield with "mixed species" dominant (Heileman 2008). The fisheries stocks in both LMEs are at risk. Oceanographic perturbations are also a source of significant variability in biomass yields in the Guinea Current (Hardman-Mountford and McGlade 2002, Koranteng and McGlade 2002) and in the waters of the Canary Current LME (Roy and Cury 2003; *www.thegef.org*, IW Project 1909).

Three LMEs, the *Sea of Okhotsk*, the *Oyashio Current*, and the *West Bering Sea*, contribute 2.3 million metric tons (3.5 percent) to the mean annual global biomass yield. They are in a condition where 78 percent of the fisheries stocks are overexploited. The Oyashio Current and the West Bering Sea LMEs show decreasing trends in fisheries yields. In the Sea of Okhotsk, the biomass yields are dominated by targeted table fish including pollock and cod. The increasing yield trend in the Sea of Okhotsk LME is related principally to a high level of overexploitation (Shuntov *et al*. 1999).

Moderately warming Southwest Pacific LMEs (C10) and other non-clustered, moderately warming LMEs

The three moderately warming LMEs, two on the east coast of Australia (*Northeast* and *East Central Australia* LMEs) and the *New Zealand Shelf* LME, contribute 0.4 million metric tons (0.7 percent) to the mean annual global biomass yield. Biomass yields are decreasing in the Australian LMEs, whereas they are increasing in the New Zealand Shelf LME under the present condition of full exploitation. Whether their conditions are the result of top-down or bottom-up forcing is not clear. However, Individual Transferable Quota (ITQ) management to promote the recovery and sustainability of high priority fisheries stocks is in place. Stewardship agencies in Australia and New Zealand have implemented management actions for the recovery and sustainability of the overexploited species.

Six moderately warming LMEs occur in separate locations. Taken together they contribute 7.7 million metric tons (11.8 percent) to the mean annual global biomass yields. In the Pacific, landings are too low in the moderately warming *Insular Pacific Hawaiian* LME to draw any conclusion on biomass yield. In the moderate warming *Gulf of Alaska* LME, the overall 25-year fisheries biomass trend is decreasing. However, this LME shows evidence of a relatively recent upturn in yield, attributed to increases in biomass of Alaska Pollock and Pacific salmon populations in response to climate warming (Overland *et al*. 2005).

The biomass of the moderately warming *Gulf of California* LME is in a declining trend. The dominant biomass yield in this LME is from small pelagics and "mixed species", suggestive of top-down fishing as the principal driver of the decline. The *South China Sea* fisheries biomass yields are increasing. The dominant biomass yield of the LME is of "mixed species" and the level of exploitation is high with 83 percent fully exploited and 13 percent overexploited. In this case, high population demand for protein by the adjacent countries contributes to drive the biomass yield upward.

The Arctic region's *Beaufort Sea* LME, landings data are unavailable. The moderate warming *East Greenland Shelf* fisheries biomass yields are increasing with capelin, redfish and shrimp dominant; following the earlier collapse of cod and other demersal species. The role of global warming in relation to cause and effect of increasing yields is not known.

Slow warming Indian Ocean and adjacent LMEs (C11)

The ten LMEs of the Indian Ocean, *Arabian Sea*, *Bay of Bengal*, *Indonesian Sea*, *Agulhas Current*, *Somali Current*, *North Australia*, *West Central Australia*, *Northwest Australia*, *Southeast Australia* and *Southwest Australia* LMEs are in the slow range of climate warming and their biomass trends are all increasing. This group of LMEs contributes 8.6 million metric tons, or 13.2 percent of the global biomass yield. The slow warming is consistent with the IPCC forecast of slow but steady warming of the Indian Ocean in response to climate change (IPCC 2007). While biomass yields are increasing, the landings adjacent to developing countries are composed primarily of mixed species and small pelagics (Heileman 2008) and the stocks are predominantly fully exploited and/or overexploited, suggesting that top-down fishing is the predominant influence on the condition of biomass yield.

In the adjacent Southwest Pacific waters, the slow warming *Sulu-Celebes* and *Gulf of Thailand* LMEs contribute 1.8 million metric tons (2.8 percent) to the mean annual global biomass yield.

The consistent pattern of increasing yields of the Indian Ocean LMEs adjacent to developing countries is driven principally by the demand for fish protein and food security (Ahmad *et al*. 1998, Dwivedi and Choubey 1998). In the case of the five LMEs adjacent to Australia, the national and provincial stewardship agencies are promoting stock recovery and sustainable management through ITQs. The fisheries stocks in the LMEs adjacent to developing countries are under national pressure to further continue to expand the fisheries to provide food security for the quarter of the world's population inhabiting the region. Given the demands on fisheries for food security for the developing countries bordering the Indian Ocean, there is a need to control biomass yields and sustain the fisheries of the bordering African and Asian LMEs.

Other slow warming LMEs

This includes the Northwest Atlantic and the United States East Coast, Barents Sea, East Bering Sea, Patagonian Shelf, Benguela Current, and Pacific Central American Coastal LMEs.

There is slow warming taking place in the Northeast US Shelf and in the Southeast US Shelf. The LMEs contribute 1.0 million metric tons (1.6 percent) to the mean annual global marine biomass yield. For both LMEs, the declines are attributed principally to overfishing (NMFS 2006). For these two LMEs and the Gulf of Mexico, the Gulf of Alaska, the East Bering Sea, Chukchi Sea, Beaufort Sea, Insular Pacific Hawaiian Islands, and the Caribbean, the United States has underway a fisheries stock rebuilding program for increasing the spawning stock biomass of overfished species (NMFS 2007).

For several of the slow warming LMEs bordering the Arctic including the Laptev Sea, Kara Sea, East Siberian Sea and Hudson Bay, biomass yield data is at present incomplete and is not included in the trend analyses. In the case of the *Barents Sea* LME, there is a decreasing biomass trend attributed to the overexploited condition of many fish stocks inhabiting the LME. During the present warming condition, variability in ice cover has an important influence on biomass yields (Matishov *et al*. 2003).

Four widely separated LMEs, the *East Bering Sea*, the *Patagonian Shelf*, *Benguela Current*, and *Pacific Central American* LMEs are located in slow warming waters. Together they contribute 3.3 million metric tons (5.1 percent) to the mean annual global biomass yield. In the North Pacific Ocean, the slow warming East Bering Sea has an overall decline in fisheries biomass yield. However, in recent years there has been an upturn in yield, attributed to climate warming and increases in biomass of Alaska Pollock and Pacific Salmon populations (Overland *et al*. 2005). In the Southwest Atlantic Ocean Patagonian Shelf LME, increasing biomass yields are reflective of a very high level of fisheries exploitation, overshadowing any climate change effects, where 30 percent of fisheries are fully exploited, and 69 percent are overexploited. The increasing biomass trends of the Pacific Central American Coastal LME are the result of high levels of exploitation driven principally by the need for fish protein and food security of the adjacent developing countries and secondarily by oceanographic regime shifts (Bakun *et al*. 1999).

The biomass yields of the Benguela Current (BCLME) along the southwest African coast are in a declining trend. The living resources of the BCLME have been stressed by both heavy exploitation and environmental perturbations during the past 25 years (van der Lingen *et al.* 2006). The south-westward movement of sardines (*Sardinella*) populations from the coastal areas off Namibia to southeastern South Africa has been attributed to recent warming. The southerly migration has disrupted the Namibian fisheries. A further southerly movement of sardines and anchovies from the vicinity of island colonies of African penguins off South Africa led to a decrease in availability of small pelagic fish prey of penguins resulting in a 40 percent penguin population decline (Koenig 2007).

Discussion

Emergent trends

From the analysis, we conclude that in four LME cases the warming clusters of LMEs are influencing 7.5 million metric tons or 11.3 percent of the world's fisheries biomass yields. The first and clearest case for an emergent effect of global warming on LME fishery yields is in the increasing biomass yields of the fast warming temperature clusters affecting 3.4 million metric tons (5.0 percent) of global yields for the Iceland Shelf, Norwegian Sea, and Faroe Plateau LMEs in the northern Northeast Atlantic. Warming in this region has exceeded levels expected from entering the warm phase of the Atlantic Multidecadal Oscillation (Trenberth and Shea 2006). The increase in zooplankton is related to warming waters in the northern areas of the Northeast Atlantic (Beaugrand *et al.* 2002) leading to improved feeding conditions of three zooplanktivorous species that are increasing in biomass yields. Herring, blue whiting, and capelin yields are increasing in the Iceland Shelf and Norwegian Sea LMEs, and blue whiting yields are increasing in the Faroe Plateau LME.

The second case is in the contrasting declines in biomass yields of the fast warming cluster of more southern Northeast Atlantic waters including the North Sea, the Celtic-Biscay Shelf, and Iberian Coastal LME where declines in warm water plankton (Valdés *et al.* 2007) and northward movement of fish (Perry *et al.* 2005) are a negative influence on 4.1 million metric tons (6.3 percent) of the mean annual global biomass yields. Recent investigations have found that SST warming in the northeast Atlantic is accompanied by increasing zooplankton abundance in cooler more northerly areas, and decreasing phytoplankton and zooplankton abundance in the more southerly warmer regions of the northeast Atlantic in the vicinity of the North Sea, Celtic-Biscay Shelf and Iberian Coastal LMEs (Richardson and Schoeman 2004). Due to tight trophic coupling fisheries are adversely affected by shifts in distribution, reduction in prey and reductions in primary productivity generated by strong thermocline stratification inhibiting nutrient mixing (Behrenfeld *et al.* 2006).

In the third case, recent moderate warming of the Gulf of Alaska, and slow warming of the

East Bering Sea are supporting increasing levels of zooplankton production and recent increasing biomass yields of Alaska Pollock and Pacific Salmon (Grebmeier *et al*. 2006, Hunt *et al*. 2002, Overland *et al*. 2005).

The biomass yields of the fourth case are more problematic. Biomass yields of all ten LMEs (8.6 million metric tons, 13.2 percent) around the western and central margin of the *Indian Ocean* are increasing. The increasing yields of the five LMEs adjacent to developing countries, the Agulhas Current, Somali Current, Arabian Sea, Bay of Bengal and Indonesian Sea, are dominated by mixed species and small pelagic species, driven by the fish protein and food security needs of nearly one quarter of the world's population inhabiting the bordering countries of Africa and Asia (Heileman and Mistafa 2008). The overexploited condition of most species is at present masking any gains in biomass yield that may be attributed to the slow and steady warming of waters predicted for the Indian Ocean by the IPCC (2007) and observed during the present study. In contrast, the slow warming five Australian LMEs on the eastern margin of the Indian Ocean are driven principally by economic considerations and are closely monitored by governmental stewardship agencies that practice an adaptive management system of Individual Transferable Quotas (Aquarone and Adams 2008a). Taken together, the 8.6 million metric tons mean annual biomass yield of the Indian Ocean LMEs are critical for food security of the heavily populated adjacent countries. In this region there is a need to exercise a precautionary approach (FAO 1995) to recover and sustain the fisheries in the LMEs of east Africa and Asia, in the slow warming clusters.

Precautionary cap and sustain action

From a global perspective 38.2 million metric tons or 58 percent of the mean annual 2001–2006 biomass yields are being produced in 29 LMEs adjacent to developing countries. This vital global resource is at risk from serious overexploitation. Given the importance for sustaining 58 percent of the world's marine fisheries biomass yield, it would be prudent for the GEF supported LME assessment and management projects to immediately cap the total biomass yield at the annual 5-year mean (2000–2004) as a precautionary measure and move toward adoption of more sustainable fisheries management practices.

The management strategies for protecting the 26.8 million metric tons or 42 percent of global marine biomass yields in LMEs adjacent to the more developed countries have had variable results ranging from highly successful fisheries biomass yield recovery and sustainability actions for stocks in LMEs adjacent to Australia, New Zealand, the United States, Norway, and Iceland to the less successful efforts of the European Union and LMEs under EU jurisdiction in the Northeast Atlantic (Gray and Hatchard 2003). An ecosystem-based cap and a sustainable adaptive management strategy for groundfish, based on an annual overall total allowable catch level and agreed TACs for key species is proving successful in the management of the moderately warming waters of the Gulf of Alaska LME and slow warming East Bering Sea LME Alaska Pollock and Pacific Salmon stocks, providing evidence that cap and sustainability strategies can serve to protect fisheries biomass yields (NPFMC 2002, Witherell *et al*. 2000).

In LMEs where primary productivity, zooplankton production and other ecosystem services are not seriously impaired, exploited, overexploited and collapsed stocks as defined by Pauly and Pitcher (2000) can be recovered, where the principal driver is excessive fishing mortality and the global warming rates are moderate or slow. The principal pelagic and groundfish stocks in the slow warming US Northeast Shelf ecosystem have been targeted for rebuilding from the depleted state of the 1960s and 1970s by the New England Fisheries Management Council and the Mid Atlantic Fisheries Management Council. In collaboration with NOAA-Fisheries and the results of productivity and fisheries multi-decadal assessment surveys, it was concluded that the principal driver of the declining trend in biomass yield was overfishing. Reductions in foreign fishing effort in the 1980s resulted in the recovery of herring and mackerel stocks.

Further reductions in US fishing effort since 1994 initiated recovery of spawning stock biomass of haddock, yellowtail flounder and sea scallops. Similar fish stock rebuilding efforts are underway in all ten of the LMEs in the US coastal waters (NMFS 2007).

From our analysis, it appears that the emerging increasing trends in biomass yields can be expected to continue in fast warming LMEs of the northern North Atlantic (Iceland Shelf, Faroe Plateau, Norwegian Sea) and the moderate and slow warming LMEs of the northeast Pacific (Gulf of Alaska, East Bering Sea and the U.S. Northeast Shelf). The countries bordering these LMEs (U.S., Norway, Faroe Islands) have in place sufficiently advanced ecosystem-based capacity to support adaptive assessment and management regimes for maintaining sustainable levels of fishery biomass yields.

Since many countries lack the capacity for conducting annual assessments of a large number of marine fish species, and since the effects are uncertain of climate warming in the observed slow warming and increasing fisheries biomass yields of LMEs adjacent to east Africa and south Asia along the margins of the Indian Ocean, it would be prudent for the bordering countries to take precautionary action to protect present and future fishery yields with a cap-and-sustain strategy aimed at supporting long term food security and economic development.

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TRENDS IN GLOBAL MARINE FISHERIES – A CRITICAL VIEW[1]

Dirk Zeller, William Cheung, Chris Close and Daniel Pauly

Abstract

Individual fisheries are generally perceived as one fleet exploiting one or several target species. Their welfare then depends on the relation between the size of each fishery relative to the size of population(s) it exploits, which 'stock assessments' are supposed to evaluate and 'fisheries management' is supposed to adjust. The vision of fisheries that will be presented here, however, is that of a global system spanning all oceans. It is the result of an expansion which began in Europe, North America and Japan over a century ago, and which is now being completed by largely uncontrolled industrial fleets operating in the deepest waters of the Southern Oceans.

The major consumer countries, mainly the EU, the United States and Japan, are largely unaffected by the local depletion these fleets induce, in spite of globally declining catches, buffered as they are by an integrated global market that causes a large and increasing fraction of world fish catches to be consumed in countries other than those where the catches are being made. This global fishery, fed by enormous subsidies in developed countries and 'subsidized' by the need for foreign exchange in developing countries, has a substantial impact on marine ecosystems, with the biomasses of large and mid-sized target species and associated organisms generally reduced by one order of magnitude a few decades after a fishery opens. This effect can be detected by declining trends of the mean trophic level of fisheries landings, a process now known as 'fishing down food webs'. We briefly review, in the context of Large Marine Ecosystems (LMEs), the work documenting this global phenomenon, which implies that fisheries gradually 'spread' from a few targeted species contributing the bulk of the catch to a situation where essentially all palatable taxa are targeted, with each taxon ('diversity') contributing a small part ('evenness') of the total catch. This is demonstrated through the application of an indicator ('BA-DAP index'), derived from work by R.M. Warwick, applied here for the first time to the time series of LME catch data for 1950 to 2004. It can be anticipated that the form of interaction with marine megafauna and their supportive ecosystems demonstrated here will lead in the next decades to a succession of local extirpation, followed potentially by global extinctions, just as early hunters exterminated the megafauna of newly accessed continents or

1. This chapter is updated from material presented at the 5th ICEF: Environmental Future of Aquatic Ecosystems Conference, Zürich, 23–29 March 2003; and Pauly *et al*. (2008).

islands. Confronting the ecosystem impact of this exploitation system will require a new mode of thinking on how humans and marine wildlife can co-exist on Earth.

Yes, we can and do exterminate our prey

Notwithstanding humans' alleged 'biophilia' (Wilson 1993), it is now well established that hunters, given the means and the opportunity, will exterminate the animals they hunt. Understanding the underlying processes is important, as they provide a framework for understanding the war of extermination presently waged against smaller and mid-size mammals in Africa ('bushmeat'; Bowen-Jones 1998) and against large fishes in the world ocean, the latter process being commonly known as 'fishing'.

Perhaps the best studied, and most illustrative of these wars of extermination, was conducted 13,000–12,000 years ago by 'Clovis' hunters in North America, so named after the site where the first of their magnificent fluted arrow and spear points were found. Notwithstanding a long tradition stating the contrary, the Clovis hunters were probably not the 'First Americans', these probably having been coastal people, who may have relied on fishing for their subsistence (Dalton 2003). The Clovis people, on the other hand, were apparently the first to tackle the large mammals of the interior. Both archaeology and model studies confirm that their expansion and population growth, and their decimation of 30 species of large and slow-reproducing mammals of North America (mastodon, giant ground sloth, giant armadillo, western camels, etc.), proceeded in the form of a wave lasting from 800 to 1,600 years (Alroy 2001). Given the human live span, and the difficulty of all societies, but especially of preliterate ones, to convey quantitative information on past animal abundances across generations (Pauly 1995), this time span was sufficient for the Clovis hunters living past the crest of this wave to fail to realize what their ancestors had done and lost (Alroy 2001).

The full realization and understanding of this event is prevented by those who, contrary to the rather strong evidence provided by a multitude of Clovis points embedded in fossil bones, still argue that this megafauna extinction was driven by climate change. Can we truly deny events which happened to coincide precisely with the arrival of the Clovis hunters and which are supposed to have eliminated, in a few centuries, species that had endured millions of years of environmental change, including glaciations that entombed North America under two kilometers of ice? We shall return to this theme of denial, as it also precludes informed debate about the impact of industrial fisheries.

There is good evidence of a similar hecatomb about 46,000 years ago in Australia, in this case associated with the very first arrival of *Homo sapiens*, and which exterminated the larger representatives of the marsupial fauna that had evolved on that continent, again over millions of years (Roberts *et al.* 2001). Need we stress that there are, here as well, those who say it is some environmental fluctuation that is to blame?

Then there is the extermination of the large, ostrich-like moa in what is now New Zealand, by Polynesians, the ancestors of the present day Maori, who arrived in the late 13th century, and who took approximately 100 years to exterminate 11 species that required millions of years to evolve (Holdaway and Jacomb 2000). In this case, it seems, few are claiming it is the 'environment' that did it.

In Africa, on the other hand, where humans co-evolved with large mammals, the latter survived until recently, by being wary of bipedal primates carrying sticks. Indeed, it is only recently that guns, globalization and human population growth have combined to disrupt this evolved balance, and that the hunting of mammals of all sizes, and the local and international trade of 'bushmeat' are now emptying African terrestrial ecosystems of all but the smallest rodents and insectivores (Bowen-Jones 1998, Brashares *et al.* 2004). Here again, the events are too close and easy to trace to their causes for the 'environment' to be blamed.

Why all this in a contribution devoted to fisheries, i.e., the killing of fish from waters, rather than mammals on land? One reason is obviously to pre-empt ultimately sterile debates about the recent, massive biomass declines in various large marine ecosystems (see e.g. Christensen *et al.* 2003 for the North Atlantic) being due to anything but overfishing (see also Jackson *et al.* 2001 and Worm *et al.* 2006). Thus, we shall ignore those who deny that fishing impacts on the underlying resources, and that observations of low fish biomass are due either to scientists being incompetent at detecting or catching the fish in question (as in the 'Trawlgate' case described by Malakoff 2002), or the fish having moved elsewhere (Bigot 2002), or because of some regime shift (Steele 1998).

The other reason for using hunting to frame a discussion of world fisheries is to suggest that the very approach we use to define fisheries may in fact be misleading. We are used to discussing fisheries in terms of their target species, e.g., the 'North Sea cod fishery', or the 'Greenland shrimp fishery', but these labels, which seemingly package distinct, separable set of attributes, are as misleading as identifying giant armadillo, or mastodon hunts by the Clovis hunters. Fact is, these hunters killed all large, slow moving targets they encountered, and ended up, once these were gone, with a species assemblage composed mainly of small mammals (with the large bison, moose and bears among the few exceptions), and whose components were much harder to get close to, and less rewarding to hunt. In fact, given these hunting patterns, Alroy (2001) found that in his simulations, "the only way to prevent a size-selective mass extinction is to assume that humans strongly prefer to hunt small game".

Similarly, when fishing starts in a new area, it is the large fishes that go first, given that they can be readily caught in the first place. Large fishes are relatively easier to catch than small fishes, and tend to provide a better return on energy expanded, be it in form of muscle power (rowing boats, reeling hooked fish), or in terms of financial return on fuel costs; large fish usually fetch higher prices than an equivalent weight of small fish, the latter being often used only for fishmeal, when not discarded (Pauly *et al.* 2002). Large fish, with their low natural mortalities and relatively high age at first maturity (Pauly 1980, Froese and Binohlan 2000), cannot sustain much fishing pressure and they decline (Denney *et al.* 2002, Cheung *et al.* 2007), forcing the fishers either to move on to smaller fishes, and/or to other, previously unexploited areas. As larger fish tend to have higher trophic levels than smaller fish – indeed, the latter are usually the prey of the former – this process, now called 'fishing down marine food webs', invariably leads to declining trends in the mean trophic level of fisheries landings (Pauly *et al.* 1998a).

This suggestion was initially challenged (Caddy *et al.* 1998), but subsequent work, summarized in Table 1, shows the 'fishing down' phenomenon to be ubiquitous. For the various countries/areas covered in that table, 'fishing down' implies a transition from fisheries targeting large fish (e.g. northern cod) to fisheries targeting smaller fishes (e.g. capelin), or invertebrates (e.g. deep water prawn [*Pandalus borealis*] and crab [*Chionoceters opilio*]). However, the broad pattern is that of the fishers in a country or area targeting a succession of species (just as the Clovis hunter did), until the residual species mix ceases to support a fishing (or hunting) economy.

Table 1. Contributions demonstrating the occurence of 'fishing down marine food webs' using local/detailed datasets, following the original presentation of this phenomenon by Pauly *et al.* (1998a), based on the global FAO landings dataset.

Country/area	Years	Decline	Source and remarks
Iceland	1900–1999	1918–1999	Valtysson and Pauly (2003), based on comprehensive catch database of Valtysson (2001).
Celtic Sea	1945–2000	1946–2000	Pinnegar *et al.* (2002), based on trophic levels estimated from stable isotopes of Nitrogen.
India	1950–2000	1970–2000	Bhathal (2005), Bhathal and Pauly (2008).
Gulf of Thailand	1963–1982; 1963–1997	1965–1982; 1965–1997	Christensen (1998); Pauly and Chuenpagdee (2003).
Eastern Canada	1950–1997	1957–1997	Pauly *et al.* (2001), based on data submitted to FAO by Fisheries and Oceans Canada (DFO).
Western Canada	1873–1996	1910–1996	Pauly *et al.* (2001), based on comprehensive dataset assembled by Wallace (1999).
Cuban EEZ	1960–1995	1960–1995	Pauly *et al.* (1998), Baisre (2000).
East Coast, USA	1950–2000	1950–2000	Chuenpagdee *et al.* (2003); emphasis on Chesapeake Bay.
Chinese EEZ	1950–1998	1970–1998	Pang and Pauly (2001).
West Central Atlantic	1950–2000	1950–2000	Pauly and Palomares (2005), based on FAO data (Statistical Area 41, see Ackefors this volume), disaggregated into USA (North) and other countries (South).
World, all fishes	1950–2000	1950–2000	Pauly and Watson (2003), based on spatially disaggregated data.

It is our contention that, given a continuation of effective fishing effort increases driven by the provision of damaging subsidies (Clark and Munro 2002, Clark *et al.* 2005, Sumaila *et al.* 2007) in the face of globally declining catches (Watson and Pauly 2001), and in the absence of a global network of relatively large marine reserves (Russ and Zeller 2003, Wood *et al.* 2008), similar in scope to the national parks that now protect the large mammals of Africa, large marine fishes, both pelagic (some tuna, many sharks and billfishes), and demersal (groupers, large croakers, etc.) may likely be fished into extinction in the next decades. Sadovy and Cheung (2003), and Dulvy *et al.* (2003) provide strong support for this view. The fisheries targeting these species will obviously go bankrupt in the process, though they may continue to last for a while if propped up by sufficient subsidies (Sumaila *et al.* 2007).

Globally, marine fisheries catches, as reported by countries to the United Nations Food and Agriculture Organization (FAO), increased from less than 20 million $t\cdot year^{-1}$ in the early 1950s to a peak around 80 million $t\cdot year^{-1}$ in the mid 1990s (Figure 1, adjusted for over-reporting by China, see Watson and Pauly 2001). Important, however, is that these numbers are only 'reported' landings, and do not include catches taken by fishing gears, but not landed and used (i.e. discards), nor do these figures address Illegal, Unreported and Unregulated fisheries sectors (IUU). Especially unreported and unregulated sectors can be significant, and contribute, particularly in the form of developing countries' small-scale subsistence fisheries, often far more to total catches than the commercial catches these countries officially account for in their national and international (FAO) reporting (e.g Zeller *et al.* 2007, Zeller and Pauly 2007). Considering current best estimates of these components, suggests that total global marine fisheries catches likely peaked around 120 million $t\cdot year^{-1}$ (see Figure 1).

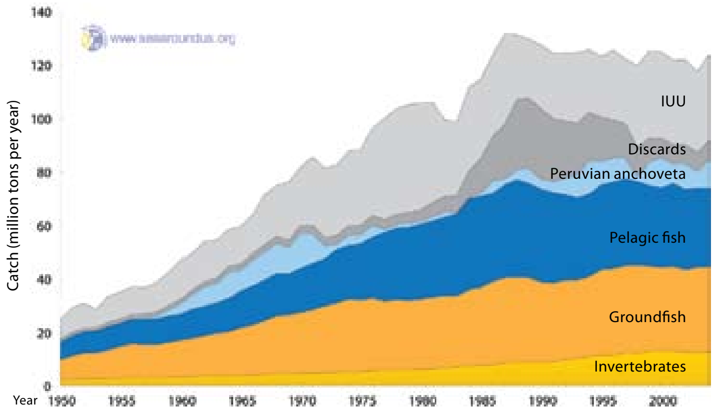


Figure 1. Global fisheries catches by major groupings (invertebrates, groundfish, pelagic fish and Peruvian anchoveta [*Engraulis ringens*]) adjusted for over-reporting by China (Watson and Pauly 2001), and estimates of global discards (based on Zeller and Pauly 2005) and IUU catches (based on Pauly *et al.* 2002).

More reasons for pessimism

The pessimistic outlook for fisheries outlined above has antecedents, notably in Ludwig *et al.* (1993), who pointed at the ease with which, in the absence of a clear experimental context, field data from collapsed fisheries can forever be contested by the fishing industry, a point developed further by Rosenberg (2003), and which, given the capture of management bodies by that same industry (see e.g. Okey 2003), leads to paralysis at best, and to continued erosion of the resource base at worst. This problem, which is very real in developed countries, many of which pride themselves of the way they incorporated science-based advice into policy making, appears largely insurmountable in developing countries, where science is a fragile import. In these countries, the great needs for food and incomes by large human populations, which should lead to more careful use of natural resources, in fact provide decision-makers with a ready excuse for what is, in fact, the wholesale destruction of food production systems.

Indeed, exports have become a major issue in fisheries, with marine products being amongst the most heavily traded commodities (Pauly *et al.* 2002, Alder and Sumaila 2004). The general trend is that the shortfall of products from traditional fishing grounds in the EEZ of developed countries is being compensated for by exploitation (often via distant water fleets)[2] of developing countries (Pauly and Watson 2003). This implies, given the 'debts' that most developing countries have run with respect to international lenders, that marine resources and their underlying ecosystems suffer from increased pressure. Examples are provided by the countries of West Africa, whose dependence on financial support from the European Union forces them to agree to fisheries agreements providing access to European fishing fleets under terms that appear rather unfair to these countries (Kaczynski and Fluharty 2002)[3]. Similar developments appear to be underway off East Africa (Jacquet and Zeller 2007a, 2007b). Another example is Argentina, whose demersal resources, in the early 1980s among the few that were both large and underexploited, have now collapsed under the pressure of both national and international fleets, licensed for their ability to generate foreign exchange (Sánchez 2002).

Also important is the absence of international institutions (i.e. set of rules) capable of action that would reverse, or at least halt, in international waters, trends such as presented above, and impacting on large pelagic fishes (see e.g., Pauly and Maclean 2003 for the case of the North Atlantic, where such institutions and organizations had a long time to develop, but didn't). An exception could possibly be the World Trade Organization (WTO), as it is the only international body with the ability to enforce its rules. As of this writing, WTO members are considering proposals to reduce or eventually even eliminate subsidies for fisheries (Sumaila *et al.* 2007). The current, 'Doha round' of negotiations may fail, but the issue will remain until it is resolved.

Parrish (1995, 1998) developed rather pessimistic scenarios for the future of fisheries, arguing that, given present trends and pressures, and their apparent irreversibility, it is mainly

2, 3. See Battle and Näslund on distant water fisheries in this volume.

small, non-palatable, non-schooling fish species that will be able to survive the present onslaught. Conversely, he argued that the species that fisheries presently target (Table 2) will not survive what he called the "late Holocene", and which many others refer to as the 6th Extinction (see e.g. Eldredge 2001).

Table 2. Marine fish that are unlikely to survive, given continuation of present fisheries trends (adapted from Parrish 1995, 1998, and Pauly 2000).

Major features	Representative groups
Large- to moderate-sized, predaceous, territorial reef fishes and rockfishes with late age at maturity, very low natural mortality rates and low recruitment rates vs. adult stock size.	Snappers, sea basses, emperors, rockfishes, sea breams.
Large- to moderate-sized shelf dwelling, soft bottom predators susceptible to bottom trawling.	Cods, flounders, soles, rockfishes, croakers, skates.
Large- to moderate-sized schooling midwater fishes susceptible to midwater trawling.	Hakes, rockfishes, armorheads, rougheyes.
Large- to moderate-sized shelf dwelling, schooling, pelagic fishes.	Bonitos, sierras, capelin, eulachon, salmon, sharks.
Any species with exceptionally high monetary value.	Bluefin tuna, red snappers, halibuts, medicinal fishes, aquarium fishes, groupers, salmon, red mullets, billfishes.

Whether or not Parrish' scenarios will come to pass, there will be a need to monitor the impact of fisheries on their supporting ecosystems, a task for which appropriate indicators are required. Indicators, beyond the catches themselves, which can be used for this purpose include:

1. The taxonomic resolution of the reported catch over time (which however, has an inherent, if unknown bias, see Figure 2);
2. The Marine Trophic Index (MTI), i.e. mean trophic level of the catch (see Table 1 and text below), and the related Fishing-in-Balance (FiB) index (Pauly *et al.* 2000); and
3. Stock-Catch Status Plots, based on catch time series (Pauly *et al.* 2008).

These indices are relatively easy to apply, as they require only catch time series (e.g. in the form of the global FAO catch dataset; see below) and estimates of trophic levels, available for essentially all fish species in the world (from FishBase; Froese and Pauly 2000) and for all commercially exploited groups (from the database of the *Sea Around Us* Project; see *www.seaaroundus.org*). These indices are here applied to Large Marine Ecosystems (LMEs), of which 64 are now defined (Sherman and Hempel 2008)[4], and which are gradually emerging as convenient entities to report fisheries trends (Pauly *et al.* 2008).

The 'BA-DAP' index – an indicator based on the taxonomic resolution of the reported catch

As mentioned above, fishers, like hunters, tend to concentrate preferably on large organisms. Thus, their catch initially consists of few species, with even fewer individuals contributing the bulk of that catch. As the initial target species become scarce, more species are targeted and contribute to the overall catch, until at the end, the fisheries 'spread' to all catchable and marketable compo-

4. The currently defined 64 LMEs are likely to be re-defined into 66 LMEs through splitting of the previously large and poorly defined Arctic LME, see *www.seaaroundus.org*.

nents of the ecosystem, with none contributing much, the catch having become taxonomically 'even'. Given such trends, an index is needed which captures the elements of this 'spread': i.e. the increasing dominance of catch by species that are large in total number but small in individual biomass (i.e. catch 'evenness').

Moreover, the index must be normalized such that it can be used to compare changes in areas with different species richness (and/or with statistical reporting systems considering different levels of taxonomic aggregation).

Here, we propose a ***B**iomass-**A**bundance-**D**ifference in **A**rea in **P**ercent* (BA-DAP) index to express the changing contribution of catch from the exploited species. Essentially, Warwick (1986) developed the abundance-biomass curve that presents community structure data in the form of *k*-dominance curves, and consists of a logarithmic x-axis with the ranks of species by declining abundance and biomass, and a y-axis along which the cumulative percent abundance and biomass by species are plotted (Figure 2). An 'unstressed' community is generally dominated by species that are large in biomass but small in abundance (i.e. the biomass curve is above the abundance curve). Conversely, in a 'stressed' community, species with small biomass and high abundance become dominant, i.e. the biomass curve is under the abundance curve (Warwick 1986). Similarly, in the context of catch composition, a fishery may initially be dominated by high biomass (large) fish that are relatively low in number. As the fishery develops, catch may be increasingly dominated by species with high abundance but smaller biomass (e.g. small pelagic fishes). The relative position of the abundance and biomass curves can be expressed by a variant of the DAP index originally developed by McManus and Pauly (1990) (here termed the 'Biomass-Abundance-DAP' or 'BA-DAP' index), calculated from the difference in areas between the two curves, or:

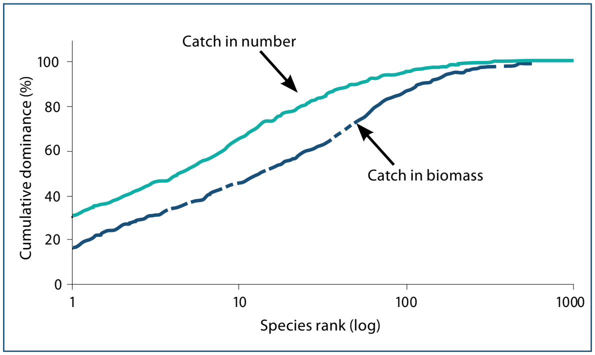


Figure 2. Example of an abundance-biomass curve based on Warwick (1986) presenting community structure data in the form of *k*-dominance curves, here adapted to fisheries catch data for a single year. These curves consist of a logarithmic x-axis with the ranks of species by declining abundance or biomass, and a y-axis with the cumulative percent abundance and biomass by species. The resultant BA-DAP index as presented here (modified from McManus and Pauly 1990) is calculated by comparing the areas underneath the two curves for each year, standardized by the number of taxa reported in that year, as BA-DAP = (Biomass curve area – abundance curve area)/$\log_e$ number of species. It is worth noting, however, that, especially with regards to fisheries catch times series, this approach and the resultant index is sensitive to changes in taxonomic reporting quality, which is a well known historical problem with catch data, and results in currently untested biases.

$$Area = \sum_{i=1}^{s-1} [C_i + (0.5 \cdot Y_{i+1})] \cdot [\ln(i+1) - \ln(i)]$$

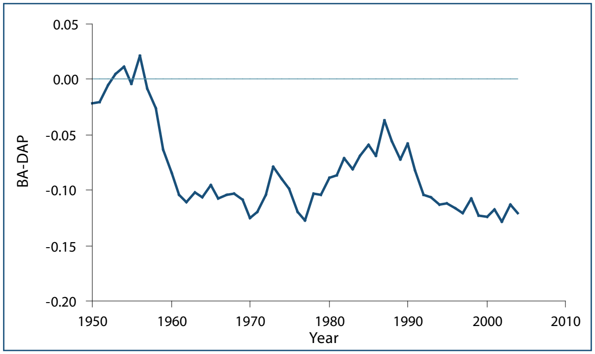
$$BA - DAP = (Area_{Biomass} - Area_{Abundance})/\ln s$$

where *C* and *Y* is the cumulative and individual percentage of abundance or biomass of the species at abundance or biomass rank *i*, respectively; *s* is the number of reported taxonomic groups (species, genus, family or grouping). Thus, the BA-DAP index scales between -1 and +1, with negative values indicating an abundance dominated system.

The BA-DAP index was calculated for each year from 1950 to 2004 for each LME. As the index is normalized by the number of taxa, the index can be readily compared between different LMEs (or other spatial entities) and time. Since catch records by the number of individuals (*C*) is not available for the majority of fisheries, we obtained a conservative estimate of *C* by assuming a power relationship between body length (using maximum size data from the *Sea Around Us* Project and FishBase databases) and weight of each species. This, in practise, amounted to dividing the catch (tonnage) by the maximum length (in centimetres) raised to the third power. To avoid the large number of tiny invertebrates such as *Acetes* shrimp being caught in some LMEs from over-dominating the catch time-series, species with maximum body length of less than 10 centimetres were not included in the analysis.

Figure 3 shows an application by the *Sea Around Us* Project of the BA-DAP index to the catch statistics assembled for 53 of the world's 64 defined LMEs[5], based mainly on data submitted to the FAO by member countries (Watson *et al*. 2004). The BA-DAP declined sharply from the mid-1950s to the early 1960s, indicating that the catch from the 53 LMEs quickly became dominated by small-bodied species. In 1950, Atlantic cod (*Gadus morhua*) contributed the largest biomass of catch, but less than 0.01 percent of individuals. By 1962, the catch (in weight) of

Figure 3. BA-DAP index (Biomass-Abundance-Difference in Area by Percent) based on fisheries catches (species <10 cm maximum length excluded) for 53 of the world's 64 currently defined Large Marine Ecosystems (LME) combined. Eleven LMEs did not have sufficient data to calculate the index and were excluded here. A negative index implies abundance dominance, while a positive value suggests biomass dominance. Index modified from McManus and Pauly (1990).



5. The LMEs not included here are the data poor Arctic and Antarctic LMEs.

Peruvian anchoveta (*Engraulis ringens*) became twice that catch of cod and contributed 11 percent of the catch in individuals. The BA-DAP index increased moderately in the 1980s but reduced again after 1990. The large increase in Alaska Pollack (*Theragra chalcogramma*) increased the dominance of species with larger body weight between 1980 and 1990. However, the decline of Pollack catches contributed to the subsequent fall of the index. Overall, the average decline in the BA-DAP index can be interpreted as an indication of the increasing 'stress' in the reported fisheries catches of the 53 LMEs.

Here, and in the subsequent two sections, we present results for three LMEs as examples, i.e. the Newfoundland-Labrador Shelf LME, the North Sea LME and the Baltic Sea LME.

The Newfoundland-Labrador Shelf LME extends a considerable distance off the eastern coast of Canada, encompassing the areas of the Labrador Current and the Grand Banks. As in some other LMEs, overexploitation is the principal driver of changes within this LME (Sherman and Hempel 2008), although fluctuations in the ocean climate have also been implicated. A description of the changing conditions of the fish and fisheries of this LME is given in Rice (2002). Commercially exploited fish species in this LME include Atlantic cod, haddock (*Melanogrammus aeglefinus*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes* spp.), and more recently, snow crab (*Chionoecetes opilio*) and deep water prawn (*Pandalus borealis*). The BA-DAP index for this LME indicates a virtually continuous decline over the 50+ year time period, with two brief reversals in the second half of the 1960s and early 1980s, driven by temporary increases in Atlantic cod catches (Figure 4). The complete collapse of the cod stocks in the early 1990s precipitated another strong decline in the index. Overall, the index illustrates a clear move from a biomass dominated (positive BA-DAP) to an abundance dominated (negative BA-DAP) fisheries system (Figure 4).

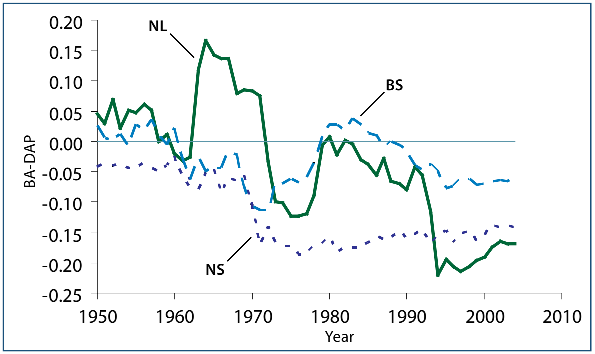


Figure 4. BA-DAP index based on fisheries catches (species <10 cm maximum length excluded) for three example Large Marine Ecosystems (LME): Newfoundland-Labrador Shelf LME (NL), North Sea LME (NS), and Baltic Sea LME (BS). A negative index implies abundance dominance, while a positive value suggests biomass dominance. Index modified from McManus and Pauly (1990).

The North Sea LME is relatively shallow, and is situated on the continental shelf of north-western Europe. The LME includes one of the most diverse coastal regions in the world, with a great variety of habitats (fjords, estuaries, deltas, banks, beaches, sandbanks and mudflats, marshes, rocks and islands). Among its many river systems and estuaries are the Thames, Rhine, Elbe and Ems. A temperate climate and four seasons characterize this LME, with climate being an important driving force (after fishing) of biomass change in the LME (Sherman and Hempel 2008). Fishing is a long-established activity in the North Sea and there is a wealth of fisheries data (Froese and Pauly 2003). The most important species for human consumption represented in the catch are Atlantic cod, saithe (*Pollachius virens*), Atlantic herring (*Clupea harengus*), European sprat (*Sprattus sprattus*) and flatfishes. Landings from the industrial fishmeal reduction fishery consist mainly of sandlances (sandeels *Ammodytes* spp.) Norway pout (*Trisopterus esmarkii*) and sprat. There are several commercially important shellfish species of molluscs and crustaceans. The BA-DAP for the North Sea LME indicates a steady decline in indicator in the early years, followed by a sudden, steep decline in 1970 towards strongly abundance dominated fisheries (Figure 4). The index has remained steady ever since. It is worth noting that throughout the time period considered here (1950–2004), the index was negative, suggesting that the fisheries in this LME have been abundance dominated for the entire time period, as illustrated by the predominance of relatively small, yet abundant species such as, e.g., herring (*Clupea harengus*) and sandlances (*Ammodytes*).

The Baltic Sea is the world's largest brackish water body, and its catchment area is four times larger than its surface area (Sherman and Hempel 2008), nearly 93 percent of which belongs to the nine riparian countries. The non-coastal countries in the catchment area include Belarus, the Czech Republic, Slovakia and Ukraine. Atlantic cod, herring and European sprat dominate the fish community as well as catches in terms of numbers and biomass. The Baltic Sea LME shows an interesting BA-DAP pattern (Figure 4). It initially was marginally positive, suggesting a slight biomass dominance in catches, before declining to an abundance dominated catch pattern until the early 1970s (negative BA-DAP, Figure 4). This was followed by a return to a positive, biomass dominance in the early 1980s, and a subsequent steady decline to an abundance dominance pattern which is maintained today (Figure 4). The decline in index in the 1960s and early 1970s was driven by the increase in catches of herring and sprat, while the 1980 biomass dominance was the result of a brief resurgence of cod catches, with a concomitant substantial decline in sprat catches. The subsequent collapse of the cod stocks and resurgence of sprat catches resulted in the most recent decline in the index (Figure 4). The predominance of three taxa in the Baltic Sea catches, namely herring, European sprat (both abundance dominant) versus cod (biomass dominant), clearly illustrates the response behaviour of this new index.

This illustrates the versatility of this new

BA-DAP index, which integrates the change in contribution of each species in the catches and the 'stress' level of the faunal community (as expressed in reported catches) in a single, standardized manner, and illustrates in yet another way the effects of fishing on marine ecosystems.

The Marine Trophic Index and the FiB index

Pauly *et al.* (1998a) identified a worldwide decline in the trophic level of fish landings by assigning a trophic level to each species in the FAO landings data. This pattern, now known as 'fishing down marine food webs', has been shown to be relatively wide-spread, especially when investigated on a smaller scale (Table 1). The ubiquity of 'fishing down marine food webs' is one of the reasons why the Convention on Biological Diversity (CBD) adopted the mean trophic level of fisheries catch, renamed as ***Marine Trophic Index*** (MTI) as one of eight biodiversity indicators for "immediate testing" (CBD 2004, Pauly and Watson 2005).

However, diagnosing 'fishing down' from the mean trophic level of landings is problematic, as landings only crudely reflect abundances. Furthermore, as fisheries overexploit their local resource bases, e.g. in inshore waters, they will tend to move further offshore to outer shelf waters and beyond (Morato *et al.* 2006). During this spatial expansion, fisheries access previously unexploited stocks, resulting in the MTI calculated for the whole shelf, which may have declined at first, increasing again, especially if the 'new' landings are high. Thus, at the scale of an LME, a trend reversal of the MTI may occur when fisheries expand geographically. This is the reason why the diagnosis as to whether fishing down occurs or not, now performed for many LMEs (Sherman and Hempel in 2008), generally depends on the species composition of the landings, which may indicate whether a geographic expansion of the fishery has taken place.

To facilitate such evaluations, a ***Fishing-in-Balance*** (FiB) index has been developed (Pauly *et al.* 2000). This index is defined such that its value remains the same when a downward trend in mean trophic level is compensated for by an increase in the volume of 'catch'. This is based on the pyramidal nature of ecosystems and an average transfer efficiency of ten percent between trophic levels (Pauly *et al.* 2000). Obviously, the FiB index will decline when both the MTI and landings decline, which is to be the case in many LMEs (Sherman and Hempel 2008). In contrast, the FiB index will increase if landings increases more than compensate for a declining MTI. In such cases (and also when landings increase and the MTI is stable or increases), a geographic expansion of the fishery has likely taken place, i.e. another part of an ecosystem is being exploited (Bhathal and Pauly 2008). This index has been designed such that its absolute value is of no concern, i.e. that the change of the index can be assessed from any baseline. Generally, it is standardized to have a value of zero in 1950.

Figure 5 (based on Pauly *et al.* 2008) presents the MTI and FiB index for 53 LMEs combined, but with two groups of fishes excluded: Peruvian anchoveta (*Engraulis ringens*) and large pelagic fishes (large tunas and billfishes). The very localized South American fishery for Peruvian anchoveta, which is a low trophic level species, is the largest single-species fishery in the world, and it exhibits very large fluctuations in catches (see Figure 1). This extreme variation masks the comparatively more subtle patterns in trophic level changes by the other fisheries of the world. We excluded large tunas and billfishes because much of their catch is taken in pelagic waters outside of the currently defined LMEs. Thus, including these landings from only part of their stock-exploitation ranges would artificially inflate patterns of trophic levels, especially for the recent decade, when tuna fisheries expanded substantially (Pauly and Palomares 2005). The trend in MTI for all LMEs combined (Figure 5, top) indicates a decline from a peak in the 1950s to a low in the mid 1980s. This can be attributed to 'fishing down marine food webs' (Pauly *et al*. 1998a, Pauly and Watson 2005), partly masked by an offshore expansion of the fisheries as indicated by the increasing FiB index (Figure 5, bottom). In the mid 1980s, the continued offshore expansion, combined with declining inshore catches has resulted in a trend reversal in the MTI, i.e. to the fishing down effect being completely occulted. Analyses at smaller scales (e.g., at the level of individual LMEs, see Sherman and Hempel 2008) confirm this.

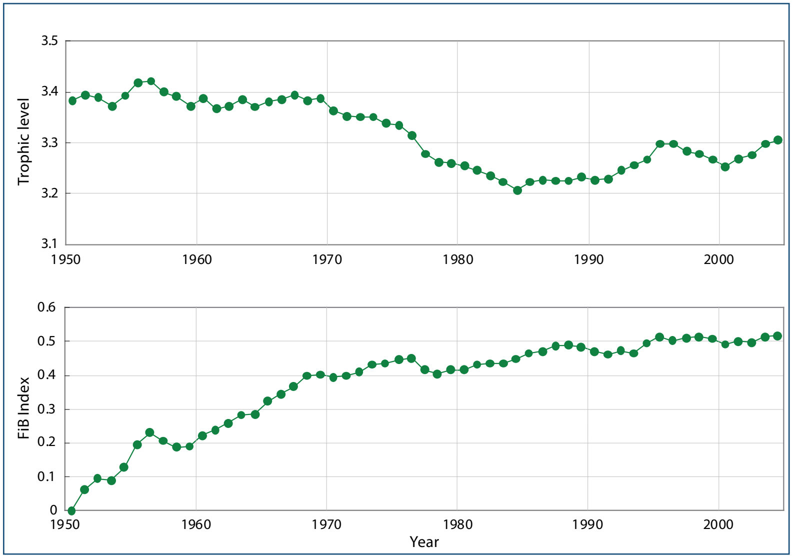


Figure 5. Two indicators based on the trophic levels (TL) of exploited fish, here used to characterize the fisheries in all LMEs of the world combined. Top: Marine Trophic Index (MTI), being the trend of mean TLs; and bottom: corresponding trend of the Fishing-in-Balance (FiB) index, which is defined such that its increase in the face of stagnating or increasing MTI suggests a geographic expansion of the fisheries.

Considering the individual LMEs presented as examples, the Mean Trophic Index of the reported landings for the Newfoundland-Labrador Shelf LME remained high until the 1990s, when the cod stock began to collapse (Figure 6, top), a clear case of rapid 'fishing down' the food web in the LME (Pauly *et al*. 1998a). The FiB index shows a similar trend (Figure 6, bottom), indicating that the reported landings did not compensate for the decline in the MTI over that period. However, these landings do not account for the discarded bycatch from the shrimp fishery, which now accounts for half of the value of the landings (Sherman and Hempel 2008).

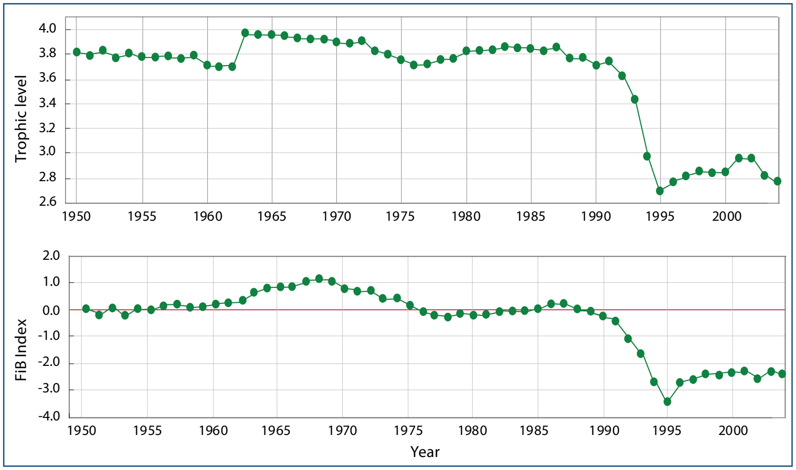


Figure 6. Mean trophic level (i.e. Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Newfoundland-Labrador Shelf LME.

The Mean Trophic Index of the reported landings for the North Sea LME has shown a steady decline since 1970 (Figure 7, top), an indication of a steady 'fishing down' of the food web in the LME (Pauly *et al*. 1998a). The FiB index has been on a similar decline over the past three decades (Figure 7, bottom). Both indices thus correspond with the detailed analysis by Froese and Pauly (2003), which was based on catch data starting in 1903.

The Mean Trophic Index of the reported landings for the Baltic Sea LME shows a distinct decline from the mid 1980s to 2004 (Figure 8, top), driven by the increased sprat landings. However, the simultaneous decline in Atlantic cod landings combines to create a case of 'fishing down' of the local food webs (Pauly *et al*. 1998a). The rapid decline in the FiB index also supports this interpretation (Figure 8, bottom).

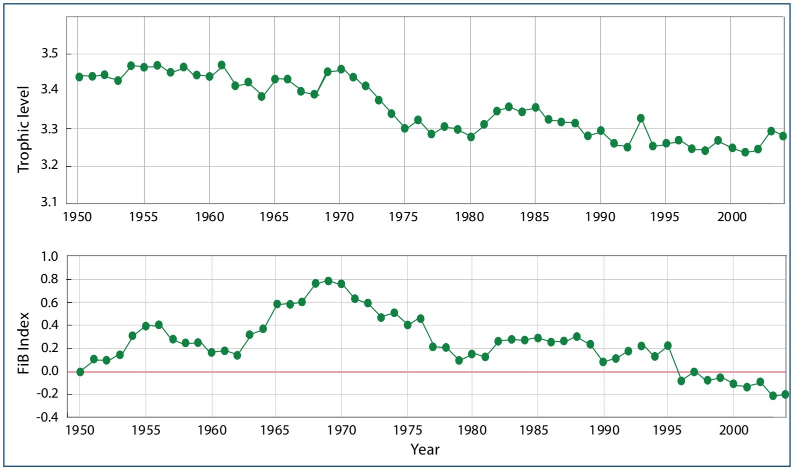


Figure 7. Mean Trophic Index (top) and Fishing-in-Balance Index (bottom) in the North Sea LME.

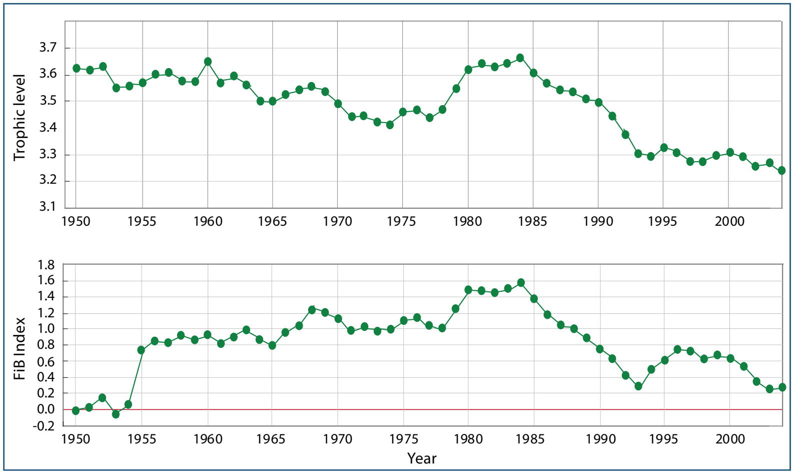


Figure 8. Mean Trophic Index (top) and Fishing-in-Balance Index (bottom) in the Baltic Sea LME.

Stock-Catch Status Plots

This graphical approach has its origin in the work of Grainger and Garcia (1996), who fitted time series of landings of the most important species in the FAO landings database with high-order polynomials, and evaluated from their slopes whether the fisheries were in their 'developing', 'fully utilized' or 'senescent' phases. Froese and Kesner-Reyes (2002) simplified these graphs by defining for any time series (taken as representing 'stocks'[6]), five phases relative to the maximum reported landing in that time series:

1. **Undeveloped**: Year of landing is before the year of maximum landing, and landing is less than 10 percent of maximum landing;
2. **Developing**: Year of landing is before the year of maximum landing, and landing is between 10 and 50 percent of maximum landing;

6. Here, a 'stock' is defined as a time series of one species, genus or family for which the first and last reported landings are at least ten years apart, for which there are at least five years of consecutive catches and for which the catch per spatial entity (e.g. LME) is at least 1,000 tons (Pauly *et al*. 2008).

3. **Fully exploited**: Landing is greater than 50 percent of maximum year's landing;
4. **Overexploited**: Year of landing is after year of maximum landing, and landing is between 10 and 50 percent of maximum landing; and
5. **Collapsed**: Year of landing is after the year of maximum landing, and landing is below 10 percent of maximum landing.

Fisheries in a given area (e.g. LMEs) can therefore be diagnosed by plotting time series of the fraction of 'stocks' in any of these categories (Froese and Kesner-Reyes 2002). Such 'stock number by status plots' were used to document the state of the North Sea LME by Froese and Pauly (2004) and, more recently have been applied to all LMEs of the world (Pauly *et al*. 2008, Sherman and Hempel 2008).

Pauly *et al*. (2008) also proposed a variant of the above 'stock *number* by status plots' in the form of a 'stock *catch* by status plot', defined such that it presents the fraction of the reported landings 'biomass' (i.e. catch) that is derived from stocks in various phases of development (as opposed to the number of such stocks). Such a plot of relative 'catch' by status can present quite a different picture from the stock number by status plots. The combination of these two plots is now termed '*Stock-Catch Status Plots*' (Pauly *et al*. 2008).

Figure 9 illustrates the dual nature of the newly derived *Stock-Catch Status Plots*, for the 53 LMEs combined. Overall, it suggests that 70 percent of global stocks within LMEs can be considered overexploited or collapsed (Figure 9, top). Nevertheless, these overexploited and collapsed stocks still provide 50 percent of the globally reported landings biomass, with the rest contributed by fully exploited stocks (Figure 9, bottom). This confirms the observation (e.g. Worm *et al*. 2006) that fisheries tend to affect biodiversity even more strongly than they affect biomass.

Turning to individual LMEs, the *Stock-Catch Status Plots* for the Newfoundland-Labrador Shelf LME show that over 60 percent of commercially exploited stocks in the LME are deemed collapsed with an additional 20 percent overexploited (Figure 10, top). Over 50 percent of the reported landings biomass is now supplied by fully exploited stocks (Figure 10, bottom).

The *Stock-Catch Status Plots* for the North Sea LME, based on the first analysis of an LME using such plots (Froese and Pauly 2003), indicate that the number of collapsed and overexploited stocks have been increasing, accounting for close to 80 percent of all commercially exploited stocks in the North Sea (Figure 11, top). A majority of the reported landings biomass,

Figures 9–12 show the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. The status of stocks, i.e. species with a time series of landings in an LME, is assessed using the following criteria (all referring to the maximum catch in the species time series): Developing (catches < 50 %); Fully exploited (catches ≥ 50 %); Overexploited (catches between 50 % and 10 %); Collapsed (catches < 10 %).

Top of the figures: Percentage of stocks of a given status, by year, showing a rapid increase of the number of overexploited and collapsed stocks. **Bottom of the figures**: Percentage of catches extracted from stocks of a given status, by year, showing a slower increase of the percentage of catches that originate from overexploited and collapsed stocks.

Note that 'stocks', i.e. individual landings time series, only include taxonomic entities at species, genus or family level, i.e. higher and pooled groups have been excluded (see Pauly *et al*. 2008 for definitions).

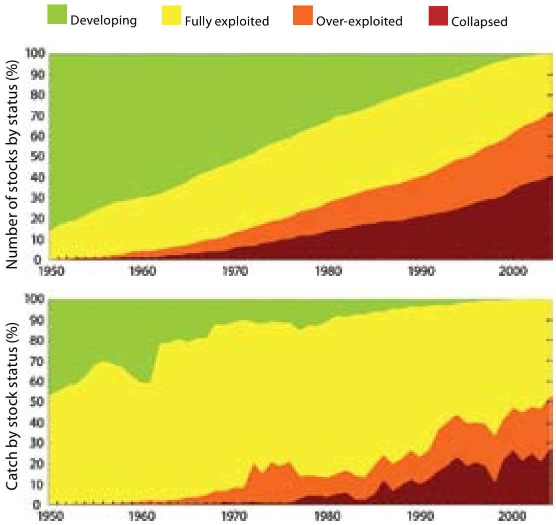


Figure 9. Paired *Stock-Catch-Status Plots* for all LMEs in the world combined.

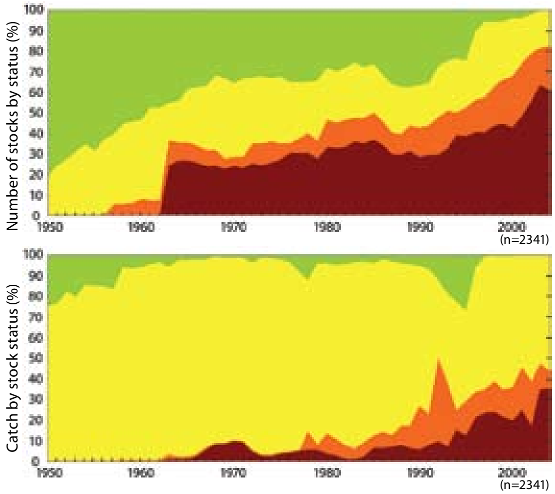


Figure 10. *Stock-Catch Status Plots* for the Newfoundland-Labrador Shelf LME.

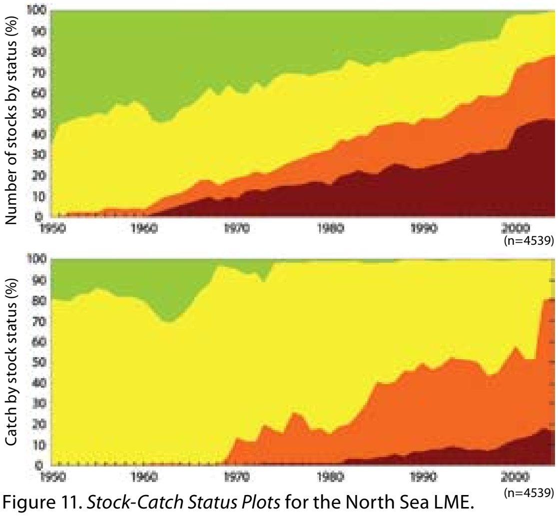


Figure 11. *Stock-Catch Status Plots* for the North Sea LME.

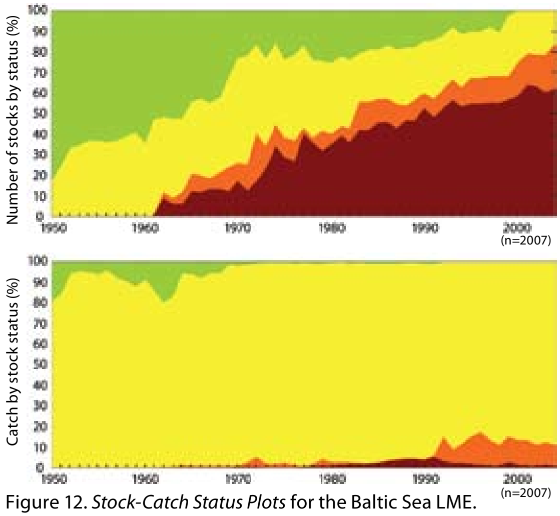


Figure 12. *Stock-Catch Status Plots* for the Baltic Sea LME.

particularly in recent years, is supplied by over-exploited stocks (Figure 11, bottom).

The *Stock-Catch Status Plots* for the Baltic Sea LME indicate that over 60 percent of the fished stocks in the LME have collapsed (Figure 12, top), but that the majority of the catch is supplied by fully exploited stocks (Figure 12, bottom), likely due to the large European sprat catches.

Conclusive remarks

Indices such as those presented here, or others, usually cannot be used to manage fisheries (or fleets) on a year to year (or tactical) basis. They can be used, however, to indicate broad, ecosystem- or indeed planet-wide trends, similar to e.g. atmospheric carbon dioxide concentration used to monitor our success – or lack thereof – in combating global warming. They indicate trends that must be addressed by humanity as a whole if we are to continue extracting benefits from – in this case – marine ecosystems.

The fishing industry is, on its own, incapable of turning around the trends demonstrated above. In fact, many industry representatives and their supporting cast in academia deny or fail to recognize that there is a global problem (see e.g. Bigot 2002, Lomborg 2001). There are other social forces, however, which can and will play an increasing role in the international debates on fisheries, foremost among those the community of non-governmental organizations devoted to maintaining or re-establishing 'healthy' marine ecosystems, and to push toward ecosystem-based fisheries management (Pikitch *et al*. 2004), irrespective of how these terms may end up being implemented in practice. Hence the public debate about fisheries, unheard of two decades ago, and hence the need for conservation biologists to debunk those who deny the need for action. One of these is the above-cited Lomborg, who in his *Sceptical Environmentalist*, inferred from increasing global catch figures reported by the FAO that the underlying ecosystems must be in good shape. However, we now know that the apparent increases of global fisheries catches in the 1990s were due to China massively over-reporting its catches to the FAO, and global catches are in fact declining (Watson and Pauly 2001, Pauly 2002). And we also know that catches can remain high (and in fact usually do) when stocks collapse, as illustrated by the northern cod off Eastern Canada, which yielded good catches until the fishery had to be closed because there were literally no fish left (Myers *et al*. 1997).

Lomborg (2001), here representing a large number of ill-informed commentators, also suggested that 'aquaculture' could help compensate for overfishing. He believes "it appears of minor importance whether the consumer's salmon stems from the Atlantic Ocean or a fish farm". The problem here is that 'aquaculture' covers two fundamentally different kinds of operations; let's call them Aquaculture A and B. Aquaculture A, devoted to the farming of bivalves such as oysters or mussels, or to freshwater fish such as carp or tilapia, relies on plant matter (phytoplankton in the sea or in ponds, sometimes supplemented by agricultural by-products in the case of freshwater fishes), to generate a net addition to the fish food supply available to consumers. Moreover, because Aquaculture A is based predominantly in developing countries (mainly in China, but also in countries such as the Philippines, or Bangladesh), it supplies cheap animal protein right where it is needed (New 2002).

Aquaculture B is the farming of carnivorous fish such as salmon or seabass, and increasingly, the fattening of wild caught bluefin tuna, e.g. in the Mediterranean. In nature, salmon, seabass and bluefin tuna have high trophic levels, ranging from 3.5 to 4.5 (see references in Table 1, and *www.fishbase.org*). When fed only vegetable matter, e.g. soy meal, salmon do not grow well, and end up looking and tasting like tofu. As for tuna, there is no point even trying to feed them with anything but fish. What this implies is that the more aquaculture B is undertaken, the less cheap yet healthy (high omega-3 oils) fish such as sardine, herring, mackerel and anchovies there will be for humans to buy and eat. Aquaculture B does not reduce the pressure on wild fish stocks: it increases it (Naylor *et al*. 2000). It has led to massive imports, by developed countries, where Aquaculture B predominates, of fish-meal from fishes caught and ground up in developing countries, thus exacerbating fishing pressures in these countries. We will not elaborate on the coastal pollution and diseases emanating from the uneaten food and feces of these marine feedlot operations, which responsible practitioners see as a major constraint to the development of the industry (New 2002).

One reason why the practitioners of aquaculture B can get away with all this is that the public at large assumes their operations to be similar to those of Aquaculture A, and that they add to the global fish supply. The continued growth of Aquaculture B will be more difficult once the distinction becomes clear to the public.

There is still time for fisheries, but only if they are reinvented not as the source of an endlessly growing supply of fish for an endlessly growing human population, but as provider of a healthy complement to predominantly grain-based diets. Particularly, fisheries cannot remain a free-for-all for pillaging distant water fleets; they can however, become a regular source of income for communities whose members act in accord with the finite nature of marine resources (Pitcher 2001). Two key elements of such reinvented fisheries will be their considerably smaller size, and their reliance on fish biomass being exported from numerous, large marine reserves, the protected ocean areas that we must establish and enforce if we are to allow marine ecosystems and the species therein to rebuild some of their past abundance, and to share this with us.

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Photo: Ylva Nordin.

CLIMATE CHANGE, SMALL-SCALE FISHERIES AND SMALLHOLDER AQUACULTURE

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Abstract

Fisheries and aquaculture both contribute to meeting the Millennium Development Goals but vulnerability to climate change threatens the contribution that they make to development. Impacts of climate change on small-scale fisheries are of great relevance to poverty reduction. Poverty undermines the resilience of social-ecological systems such as fisheries. The majority of the world's 250 million fisherfolk lives in areas that are highly exposed to climate change. A combination of climate-related stresses and widespread overexploitation of fisheries reduces the scope for adaptation and increases risks of stock collapse. Aquaculture can utilize aquatic resources of marginal economic value and can provide a diversification strategy in the face of environmental change but is also susceptible to external risk factors, including climate change.

The concepts of vulnerability, adaptive capacity, and resilience are central to the discussion on adaptation to climate change. These concepts apply to both ecological and socio-economic systems. Vulnerability to climate change has three key elements; exposure to impacts, sensitivity, and the capacity to adapt. Adaptive capacity encompasses the capacity to modify exposure to risks associated with climate change, absorb and recover from climate impacts, and exploit new opportunities that arise in the process of adaptation.

Complex pathways through which climate change can affect the productivity and distribution of fishery resources and the resilience of fisheries pose a major research challenge. We propose a set of principles upon which to build resilient small-scale fisheries and aquatic resource production systems. Diverse and flexible livelihood strategies will make livelihoods more adaptable to climate change. Flexible, adaptive institutions will increase the capacity of ecosystems and people to accommodate unpredictable change. In aquaculture, technological innovations similar to those in agriculture can be pursued at relatively modest economic and social costs. Policy responses at various levels can help address poverty and resource degradation, and enhance adaptive capacity to climate variability and extreme events.

Uncertainties around estimating future climate change impacts on fisheries and aquaculture are high, but responding to future climate change threats is largely compatible with wider

attempts to reduce rural poverty and vulnerability. Strengthening governance and reducing vulnerability are both mutually reinforcing and synergistic with building capacity to adapt to climate change. We stress the need for integrated and holistic approaches fostering resilient small scale fisheries and smallholder aquaculture, which recognize both the threats to fisheries and aquaculture from climate change and the opportunities that climate change can offer. Whatever progress is made over the coming decades in climate change mitigation, it will be necessary to plan and adapt for impacts of unstoppable change and give prominence to those people whose lives depend so directly on the warming, rising or receding waters, in our response to global climate change.

Vulnerability to climate change threatens the contribution of fisheries and aquaculture to development

The majority of the world's 250 million fisherfolk (fishers and other fishworkers and their dependents) lives in areas that are highly exposed to human-induced climate change, and depend for a major part of their livelihood on resources whose distribution and productivity are known to be influenced by climate variation (Allison *et al*. 2005). While the climate-sensitivity of major industrial fisheries of shelf-sea and oceanic upwelling zones, such as those for the Peruvian anchoveta, are well known (reviewed in Klyashtorin 2001), it is the impacts of climate change on the small-scale fisheries of inland and coastal near-shore waters that are perhaps of greatest concern to poverty reduction.

In coastal tropical areas, coral reefs and associated ecosystems support the majority of small-scale fisheries. The United Nations Environment Program (UNEP) estimates the annual value of coral reefs at USD 100,000–600,000 per km^2. These ecosystems occur predominantly in developing countries and provide important sources of income as well as subsistence nutrition to millions of coastal dwellers (Ahmed *et al*. 2005). Because of their sensitivity to thermal stress (resulting in coral bleaching and mortality) and CO_2-induced ocean acidification (resulting in reduced coral calcification and enhanced reef erosion), reefs were specifically identified as vulnerable in the latest IPCC report (Parry *et al*. 2007).

For inland waters, projected changes in surface water availability are the most obvious threat to fisheries production. There are close relationships between floodplain area, river flow and lake surface area and total fish production (Welcomme 2001). The projected decline in surface water availability in many parts of Africa (de Wit and Stankiewicz 2006), for example, is an obvious threat to fisheries production. Inland waters are of particular importance to the poor due to their accessibility and potential for integration of fish production within farming systems.

A key distinction in the fish-producing sector is between capture fisheries and aquaculture. Although it crucially ignores issues of ownership and the extension of access and exploitation rights, Reay's definition of aquaculture as "man's attempt, through inputs of labour and energy, to improve the yield of useful aquatic organisms by deliberate manipulation of their rates of growth, mortality and reproduction", is particularly apposite here. The farming of aquatic organisms that feed low in the food web, converting plant-based foodstuffs and agricultural by-products into high quality animal protein, is an inherently efficient means of producing increasingly scarce and nutritionally important foodstuffs. Aquaculture can utilize aquatic resources of marginal economic value, e.g. salinized ground waters, and its integration into smallholder agriculture can increase aquatic productivity ('more crop per drop'), thereby reducing pressure on increasingly scarce freshwaters. Farming of fish and shellfish can relieve pressure on overexploited wild stocks, as well as provide a means of livelihoods diversification for poor fishers. Fish are a high value crop, and integrating aquaculture into smallholder farming systems can yield an additional high value cash crop which, in the context of the 2008 World Development Report (World Bank 2008), represents a means of maximizing benefits from agriculture for development. Aquaculture can also help the most vulnerable by promoting gender equality through increased access to, and control over, production resources.

Globally, aquaculture has expanded at an average annual rate of 8.9 percent since 1970, making it the fastest growing food production sector. Today, aquaculture provides around half of the fish for human consumption, and must continue to grow because limited – and in many cases declining – capture fisheries will be unable to meet demands from a growing population (FAO 2007). Based on current per capita consumption targets and population growth trends, there is a growing consensus that aquaculture may be the only means of satisfying the world's growing demand for aquatic food products. Directly and indirectly, aquaculture could contribute to the livelihoods and nutrition of many millions of people, acting as an engine for economic growth and a diversification strategy in the face of environmental change. However, there are also fears that current trends of intensification of production methods and certain types of production technologies may make those adopting aquaculture particularly vulnerable to external risk factors, including climate change.

Climate change threatens the multiple benefits that fisheries contribute to poverty reduction.[1] It decreases production, affects human health, and damages or destroys physical assets. The increases in uncertainty brought about by climate change may reduce incentives for long-term management of resources. The additional risks of investing in aquaculture development may reduce potential investment by the poorer, more risk-averse sectors of rural society, and lending institutions. It is therefore important to understand how climate change might impact the poverty reduction function of fisheries and aquaculture and how this impact might be reduced through appropriate development interventions at policy, programme and project levels. Concerns for climate-induced threats to fisheries in the context of widespread overexploitation of fisheries are compounded

1. See chapter on the importance of fisheries and aquaculture to development (Finegold), this volume.

by consequences of climate change on broader environmental degradation and demographic change.

Defining and measuring vulnerability to climate change

Climate change: vulnerability, adaptive capacity and resilience

Central to discussions of adaptation to climate change are the concepts of vulnerability, adaptive capacity, and resilience. These concepts, which apply to both ecological and socio-economic systems, come from a wide range of intellectual traditions and definitions abound (Janssen and Ostrom 2006). Consensus on the meaning and interrelations among these concepts is of more than academic interest, as they become integrated into international and national law and policy. Lack of consensus will confound and slow progress towards improved fisheries and livelihoods.

We adopt the working definitions of the Intergovernmental Panel on Climate Change (IPCC 2001):

"Vulnerability is the extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity, but also its ability to adapt to new climatic conditions". Vulnerability to climate change is made up of three key components:

1) Exposure is the degree to which an individual or social group will face a change in climate. In a fisheries and aquaculture context, this might be temperature change, sea level rise, change in precipitation patterns or increase in storm frequency.

2) Sensitivity is the degree to which a system will respond to a change in climatic conditions, for example a proportional change in ecosystem productivity (or household income and/or expenditure) as a result of perturbations in temperature or precipitation.

3) Adaptive capacity is the ability of a system to evolve and accommodate climate changes, and offset potential impacts (e.g. Jones 2001). It encompasses the capacity to modify exposure to risks associated with climate change, absorb and recover from losses stemming from climate impacts, and exploit new opportunities that arise in the process of adaptation.

Vulnerability can act as a driver for adaptive resource management, of the kind already seen in many small-scale fisheries subject to climate-driven and other uncertainties (Allison and Ellis 2001, Jul-Larson *et al*. 2003).

'Resilience' is the central concept in the emerging paradigm around the governance of adaptive production and management systems. The definition by Walker *et al*. (2004) is widely used: *"Resilience is the capacity of a complex system to absorb shocks while still maintaining function, and to re-organize following disturbance"*. The term 'complex system' in this context refers to a linked socio-ecological system, which is defined as *"a system that includes societal (human) and ecological (bio-physical) subsystems in mutual interaction"* (Gallopin *et al*. 1989). The mutual dependencies of social and ecological processes make such a 'system' non-decomposable. A social-ecological system may be defined at any scale, from a small reservoir fishery to a large river basin, or from a coral atoll to an archipelago.

Poverty and resilience in small scale fisheries and aquaculture

Acknowledging the importance of societal learning and adaptation, we suggest the following definition of a resilient aquatic resource production system in the developing world. A resilient small-scale fishery in the developing world is one that *"absorbs shocks and reorganizes itself following stresses and disturbance while still delivering benefits for poverty reduction"*. Resilience, as applied to small-scale aquaculture, can be similarly defined.

Fisheries and aquaculture, the farming of aquatic plants and animals, take place in societal and ecological subsystems that are interdependent (Beveridge *et al*. 1994, 1997; Beveridge and Little 2002). Management to maintain resilience should prevent a fishery from failing to deliver benefits by nurturing and preserving ecological and social features that enable it to renew and reorganize itself (Walker *et al*. 2004). This management objective emphasizes elements that differ from conventional (and legally binding) fisheries objectives, which emphasize maximizing long-run 'sustainable' aggregate yields or economic benefits (e.g. FAO Code of Conduct for Responsible Fisheries 1995). Most fishery sector analysts regard the harvest itself as the greatest single threat to the resilience of the fishery system (World Bank 2004, FAO 2007).

Stresses and disturbances are the cumulative and acute drivers of change related to climate that threatens resilience. The growing consensus in the literature on climate change is that the poor are more vulnerable and less able to adapt (e.g. UN 2007). Poverty undermines the resilience of social-ecological systems such as fisheries. Fisherfolks' incomes are often higher than those of other rural dwellers, but fishery sector earnings are highly uncertain, often seasonal, and not evenly distributed within the sector (Allison 2005). Income and capital or physical asset ownership are not, however, the only dimensions of poverty. Fishing livelihoods may be profitable but precarious in conditions where future production is uncertain in the long-term and fluctuates extensively in the short-term, where access rights over resources are insecure, working conditions unsafe and exploitative, and where there is a lack of social and political support for community development and poverty reduction. It is in this 'risk environment' that the added stress of future climate change interferes.

Resource-poor coastal aquaculturists, such as those engaged in seaweed or mussel farming, face similar challenges. However, small-scale farmers although often poor are probably less socially marginalised than fisherfolk. They tend to have better access to health and education, and gender disparities are less apparent. Studies of small-scale, integrated farms in Malawi show that those who have integrated aquaculture into their farming systems are more resilient than those who do not farm fish, maintaining higher on-farm incomes and better nutrition during periods of drought (Dey *et al*. 2007). Since 2003 WorldFish and partners (World Vision) have successfully helped Malawian women- and child-headed families affected by HIV/AIDS achieve a 50 percent increase in farm incomes and a 150 percent increase in fish consumption among adopters, although with only relatively modest increases in fish supplies to local markets (World-Fish Center and World Vision, unpublished data).

Pathways of impact: climate change, fisheries and aquaculture

There are multiple and rather complex pathways through which climate change can affect the productivity and distribution of fishery resources, as well as the resilience of fisheries and their associated livelihood and economic linkages. Even if changes in climate and biophysical variables were predictable, it is not clear what the relative importance of each individual impact pathway would be and how indirect effects and cross-sectoral responses would affect fisheries. Given the uncertainties and multiple potential pathways linking climate change with fish production in biological terms (Table 1), the impact of global warming on the fisheries sector in socio-economic terms is further compounded by the dynamics of human responses. Not only is there great uncertainty regarding the extent and speed of climate change and our knowledge of its biophysical impacts on fish stocks, but there is the added uncertainty of understanding how people and economic systems respond to climate-induced variability and change.

Impacts of climate change are an additional burden to other poverty drivers such as declining fish stocks, HIV/AIDS, conflict and insecurity, lack of savings, insurance and alternative livelihoods. There may also be increased health risks for the poor. For example, cases of cholera outbreaks in Bangladesh coastal communities were found to increase following El Niño-related flooding. Effects on agriculture and water resources will also potentially reduce water and food security. In combination, projected climate, population and market changes could have major negative effects on local fish supply in regions such as the Mekong Basin or West Africa, where fish is an essential component of peoples' diet (Allison *et al*. 2005). For river fisheries, downstream impacts from adaptations in other livelihood sectors are a concern, in particular the effects of reduced flows on floodplains and seasonal spawning.

In aquaculture, production processes are under greater human control. In inland aquaculture, increasing seasonal and annual variability in precipitation and resulting flood and drought extremes are likely to be the most significant drivers of change. Reduced annual and dry season rainfall and changes in the duration of the growing season are likely to create greater potential for conflict with other agricultural, industrial and domestic users in water-scarce areas. These effects are likely to be felt most strongly by the poorest fish farmers, whose typically smaller ponds retain less water, dry up faster, and are therefore more likely to suffer from shortened growing seasons, reduced harvests of inferior fish (falling water levels stimulate early maturation and spawning of some important farmed species, resulting in over-crowding and 'stunting' and poor economic

Table 1. Examples of impact pathways on fisheries.

Type of changes	Climatic variable	Impacts	Potential outcomes for fisheries
Physical environment	Ocean acidification	Effects on calciferous animals, e.g. molluscs, crustaceans, corals, echinoderms and some phytoplankton.	Potential declines in production for calciferous marine resources.
	Warming of ocean upper layers	Warm water species replacing cold water species.	Shifts in distribution of plankton, invertebrates, fishes birds, towards the north or south poles, reduced species diversity in tropical waters.
		Plankton species moving to higher latitudes.	
		Timing of phytoplankton blooms changing. Changing zooplankton composition.	Potential mismatch between prey (plankton) and predator (fish populations) and declines in production and biodiversity.
	Sea level rise	Loss of coastal fish breeding and nursery habitats, e.g. mangroves, coral reefs.	Reduced production of coastal and related fisheries
Fish stocks	HIgher water temperatures Changes in ocean currents	Changes in sex ratios. Altered time of spawning. Altered time of migrations. Altered time of peak abundance.	Possible impacts on timing and levels of productivity across marine and fresh-water systems.
		Increased invasive species, diseases and algal blooms.	Reduced production of target species in marine and fresh water systems.
		Affects fish recruitment success.	Abundance of juvenile fish affected and therefore production in marine and fresh water.
Ecosystems	Reduced water flows and increased droughts	Changes in lake water levels. Changes in dry water flows in rivers.	Reduced river productivity.
	Increased frequency of ENSO events	Changes in timing and latitude of upwelling.	Changes in pelagic fisheries distribution.
		Coral bleaching and die-off.	Reduced coral-reef fisheries productivity.
Coastal infrastructure and fishing operations	Sea level rise	Coastal profile changes, loss of harbours, homes. Increased exposure of coastal areas to storm damage.	Costs of adaptation make fishing less profitable, risk of storm damage increases costs of insurance and/or rebuilding, coastal households' vulnerability increased.
	Increased frequency of storms	More days at sea lost to bad weather, risks of accidents increased.	Increased risks for fishing and coastal fish-farming, making these less viable livelihood options for the poor; reduced profitability of larger-scale enterprises, insurance premiums rise.
		Aquaculture installations (coastal ponds, sea cages) more likely to be damaged or destroyed.	
Inland fishing operations and livelihoods	Changing levels of precipitation	Where rainfall decreases, reduced opportunities for farming, fishing and aquaculture as part of rural livelihood systems.	Reduced diversity of rural livelihoods; greater risks in agriculture; greater reliance on non-farm income.
	More droughts or floods	Damage to productive assets (fish ponds, weirs, rice fields, etc.) and homes.	Increased vulnerability of riparian and floodplain households and communities.
	Less predictable rain/dry seasons	Decreased ability to plan livelihood activities – e.g. farming and fishing. Seasonality.	

Source: FAO SFLP (2007).

returns) and a narrower choice of species for culture (Handisyde *et al.* 2006). Supplies of other essential ecosystem services, such as feed inputs and the abilities to disperse and assimilate aquaculture wastes, can also be expected to be compromised. Higher temperatures are likely to change the prevalence of pathogens, affect stress levels among farmed fish and compromise immunity, leading to increased incidence of disease.

Adapting to climate change

Responses to climate variability and change in fisheries – learning from the past to adapt to the future

Greater understanding of how people cope with and adapt to fisheries with extreme natural variations would assist in developing adaptation strategies to the additional impacts of future climate change. The relative risks of climate change on fisheries sectors also need to be understood in the context of its impact on other natural resource sectors and on other hazards that result in high levels of poverty, including food insecurity, epidemic disease, conflict, political marginalisation, inequity and poor governance. Unfortunately, there are few such examples from aquaculture.

Adapting to future climate change

When considering the complexity and scale-dependence of climate change, adaptations may be viewed as either strategic or tactical. Many projections are sufficiently probable that national and regional policy can be developed. Strategic adaptation refers to changes we can be confident society must make. We can plan for these now, and the research needed to underpin such policy can make specific reference to climate change policy and drivers. In other instances, particularly at local scales, the impact of climate change is much harder to predict and will, in many instances, simply exacerbate vulnerabilities to other stressors. At this scale, it is much more difficult to isolate climate change from other drivers of change. Adaptations at smaller scales must therefore be more tactical or reactive. In the context of small scale fisheries and aquaculture, adaptations must focus on building institutions and rules of management that will increase the capacity of ecosystems and people to accommodate unpredictable change. Flexible and reactive institutions will offer the best chances of minimizing the effects of irreversible change.

We propose a set of principles that combine the strategic and tactical elements of adaptation to provide a coherent basis upon which to build resilient small-scale fisheries and aquatic resource production systems. 'Climate proofing' the world's fishery and aquaculture systems could incorporate the following principles and elements:

• ***Enabling diverse and flexible livelihood strategies.*** Livelihoods that combine activities that vary in their climate-response and sensitivity will be more adaptable to climate change. These can be supported in policy by removing barriers to geographical mobility (such as requirements to be a full-time resident to access a fishery) and disincentives to diversification (such as commodity-based taxes on traded goods).

Diverse and flexible livelihood strategies

Fishing communities have often developed adaptation and coping strategies to deal with fluctuating environmental conditions.

Fishery	Individual and household adaptive strategies and coping responses
Coastal artisanal fisheries for small pelagic species, West Java, Indonesia	On the South Java Coast individuals switch between rice-farming, tree-crop farming and fishing in response to seasonal and inter-annual variations in fish availability. Full-time fishers from the north coast (Java Sea) villages track seasonal and spatial variation in fish stock availability with long-shore and inter-island migrations.
Ansa Chambok, Great Lake (Tonle Sap) area, Cambodia	Livelihoods are sustained by use of both private and common property, including fisheries resources, with intra-household division of labour to optimise complementary livelihood activities. Production activities in one environment are subsidised by inputs supplied by other environments.
Coastal artisanal Fisheries, Galicia, north east Spain	Diverse pattern of fishing activities with respect to the species exploited, location of fishing grounds and gear used. Seasonal fishing supplements incomes of a range of people – e.g. the retired, taxi drivers, shopkeepers, the unemployed.
Lake Victoria, Kenya	"Fishing and farming [and livestock herding] have become inextricably linked over many generations in the overall objective of achieving household nutritional security … In a typical year, oscillations occur between the components of this tri-economy".

Source: Allison and Ellis (2001).

Flexible and adaptable institutions

Co-management approaches to fisheries and to access rights for water can benefit local communities by giving them more control over their resources. However, if new institutions for management are not based on an understanding of livelihoods and of current coping strategies, they can increase communities' vulnerabilities to climate variability. Traditional institutions (rules, customs, taboos) in climate-sensitive environments have tended to be flexible, to accommodate the impact of climate variability.

Fishery	Institutional and regulatory strategies and responses
Reefs and atolls, Palau, Micronesia	Land and sea tenure are integrated. Fishing in inland lagoons is limited to when bad weather prevents fishing in the open sea. Flexible redistribution of fishing rights among neighbouring municipalities, according to needs and surpluses. Access, in times of local scarcity, to neighbouring community-controlled fishing grounds in exchange for part of the catch.
Subsistence fisheries of the Cree, northern Canada	No rigid territorial system, thus allowing greater flexibility in catch distribution and maximizing the yield. Gear limited to small units to maintain mobility.
Peruvian sardine and anchoveta fisheries	Improved El Niño forecasting services, accessible to all. Government fishing bans in periods of resource scarcity, to aid recovery of stocks during favorable climate conditions.

Source: Allison and Ellis (2001), Broad *et al.* (2002).

• *Supporting flexible, adaptive institutions.* Co-management approaches to fisheries can benefit local communities by giving them more control over their resources. New institutions for management should be based on an understanding of livelihoods and of current coping strategies, and explicitly account for the ecology of the natural system. Examples may include the integration of land and water resource tenure, access 'filters' rather than barriers to accommodate access to common property resources by the poor in times of crisis or scarcity, and maintenance of reciprocal resource access arrangements as a social insurance mechanism (Allison and Ellis 2001).

• *Technological innovation.* In aquaculture, technological innovations similar to those in agriculture can be pursued. Many species tolerant of brackish water, such as the tilapias, can be reared using salinized groundwater sources, for example. A shift towards aquaculture based on recirculation systems can help reduce water requirements, and insulate farming operations from the external environment to some degree, although these tend to be intensive (and expensive) systems suited for luxury markets and highly capitalised investors. Genetic improvement programmes may be able to help develop strains of aquatic animals that have different thermal optima, growth characteristics, feed conversion efficiencies and disease tolerances. Stakeholders and geneticists have complementary roles in designing and implementing genetic improvement programmes: smallholders must be involved in identifying breeding objectives while geneticists must temper the aspirations of farmers by communicating clearly what selective breeding can cost-effectively achieve. Fisheries and fisherfolk can also switch fishing gear, species and marketing chains to accommodate different available species and production processes to increase flexibility in the fishery sector. The economic and social costs of technological adaptation to climate change may therefore not be so great.

A further category of technological innovation is multi-sectoral in nature. The rising number of reservoirs being built in response to water resource demands from agriculture, power generation, flood control and domestic water supply are creating opportunities for new fisheries, as well as destroying existing ones. Both technological and institutional innovations are possible in these new water bodies and a variety of fishery strategies such as ranching (stocking the water body with cultured juvenile fish), cage aquaculture and communal ownership arrangements are developing to exploit the productive potential of these water bodies and add value to these water-resource developments.

• *Developing risk reduction initiatives.* Risk reduction initiatives seek to address vulnerabilities through early warning systems, timely seasonal weather forecasts, market information systems, micro-insurance, and disaster recovery programmes. Famine early warning systems (FEWS) are one example. Information and communication technologies are widely utilised in fisheries; appropriate information services will find a ready market and existing means of dissemination. The value of proactive risk reduction initiatives in fisheries is illustrated by Red Cross programmes in Vietnam, where assistance to coastal communities to replant depleted mangrove swamps has improved physical protection from storms. This has reduced the cost of maintaining coastal defences (dykes) and saved lives and property during typhoon seasons. Mangrove restoration has also improved fisheries livelihoods through the harvesting of crabs, shrimps and molluscs (WDR 2001). In inland waters, similar benefits may be achieved through focus on maintaining areas of natural wetland vegetation (e.g. reed swamp) as refuge for fish populations during drought periods. These refuges are threatened by intensification of horticulture and rice-cultivation around wetland areas. GIS and modeling approaches are beginning to be used in decision support systems underpinning aquaculture development. Such information can help identify areas where farmers should increase the height of pond bunds to reduce risks of losing stock during flood periods, for example.

• *Mitigating future impact.* The potential contribution of fisheries and aquaculture to mitigate future climate change through CO_2 emission reduction or carbon sequestration is negligible; the world's marine fishing fleets are estimated to burn 1.2 percent of global annual fuel-oil use (Tyedmers *et al.* 2005). According to Bunting and Pretty (2007) 'aquaculture represents a potential threat to greenhouse gas sinks and reservoirs while aquaculture practices constitute a largely undefined source of greenhouse gas emissions'. Microbial action in fish ponds results in the generation of methane and carbon dioxide which are lost to the atmosphere when pond soils are exposed during harvest, but its impact can be readily reduced through changes in pond management. Moreover, the incorporation of organically enriched pond muds into farm soils can greatly improve soil productivity, helping sequester agriculturally-derived carbon. Integration of pond aquaculture into smallholder agriculture increases the extent of recycling of agricultural wastes, further improving carbon sequestration. Although incorporation of fish culture into rice fields is widely acknowledged as beneficial to both livelihoods of small-scale farmers and to aquatic biodiversity (Halwart and Gupta 2004), it also results in increased methanogenesis (Frei and Becker 2005) which has yet to be fully studied and quantified. At the farm level, further scope for smallholders to mitigate effects of climate change impacts through, for example, increased energy conservation, is limited.

• *Policy responses.* Reducing the vulnerability of fishing and agricultural communities as a whole can help address poverty and resource degradation, and enhance adaptive capacity to a range of shocks, including those resulting from climate variability and extreme events. A range of policy impact strategies and pathways can be identified (modified from FAO SFLP 2007):

Ministries and other national-level and international stakeholders responsible for fisheries management can conduct climate-change risk assessments and allow for the costs of adaptation and the potential changes in economic contributions from the fishery and agricultural sectors under likely climate scenarios in their sectoral planning. They can support initiatives to reduce fishing effort in overexploited fisheries as lightly-fished stocks are likely to be more resilient to climate change impacts than heavily-fished ones. High level policy support can also assist in building institutions that can consider, and respond to, climate change threats along with other pressures such as overfishing, pollution and changing hydrological conditions. Similarly, it is important to link with disaster management and risk reduction planning, especially concerning water resource governance and agricultural (including aquaculture) development. Engagement in adaptation planning, including promotion of fisheries and aquaculture related climate issues in PRSPs and national adaptation programmes of action can help to address longer-term trends or potential large-scale shifts in resources or ecosystems. Finally, providing legal and policy support to existing adaptive livelihood strategies and management institutions can help maintain resilience, as can addressing other issues contributing to increased resilience of fishery dependent communities such as improved access to markets and services, political representation and improved governance.

NGOs and community-based organizations can also help to identify the current and future risks, potential impacts and resilience recovery mechanisms within communities, and engage communities together with governmental and non-governmental agents in preparedness planning. Building resilience of coastal and other fisheries communities can be achieved by supporting community-level institutional development and vulnerability reduction programmes and by supporting risk reduction initiatives within fishing communities, including conservation of wetlands, development of forecasting and early warning systems, preparation measures and recovery processes.

Conclusions

Although the uncertainties around estimating future climate change impacts on fisheries are high, responding to future climate change threats is largely compatible with wider attempts to reduce rural poverty and vulnerability. The additional costs are therefore likely to be modest. There is a growing consensus among fishery sector agencies that strengthening governance and reducing fisherfolk's vulnerability are both mutually reinforcing and synergistic with building capacity to adapt to climate change (e.g. FAO SFLP 2007). Planning at the watershed and coastal zone levels at an appropriate scale is essential to reduce the vulnerability of small-scale fisherfolk, smallholder fish farmers and small-scale coastal aquaculture practitioners to climate change. However, climate change is also likely to affect globally traded environmental services, especially fishmeal, fish oil and grain inputs to aquaculture feeds, with particular consequences for countries such as China, Thailand and Egypt where production methods are rapidly intensifying.

There is also a consensus that many of the threats faced by fisheries are external to the sector, so that a process of engagement with interest-groups in other sectors is required if progress is to be made on reducing poverty in fishing-dependent communities and improving resource governance, so that the sector's contribution to wider poverty reduction is maintained or enhanced (Andrew *et al*. 2007). The fate of the world's fisheries and aquaculture is linked to external processes – water governance, climate change, coastal planning, river and lake basin planning, land use planning, pollution and habitat conversion or destruction. Past attempts to achieve cross-sectoral integration through river basin planning, coastal zone management or watershed and lake basin management, have often foundered through lack of a common conceptual framework, and through identification of sectoral interests as being invariably in conflict, so that the need for 'trade-offs' comes to dominate at the expense of the potential synergies and opportunities for benefit sharing. We therefore stress the need for integrated and holistic approaches fostering resilient small-scale fisheries and smallholder and SME aquaculture, which recognize both the threats to fisheries and aquaculture from climate change and the opportunities that climate change can offer for expanded or indeed novel aquaculture industries. Such potential has been recognized in a number of developed countries such as Norway (Lorentzen and Hannesson 2006). Increased salinization of groundwaters in coastal areas caused by increasing sea level rises may offer scope for coastal dwellers to reduce their vulnerability to climate change by adopting aquaculture. However, such opportunities must be viewed in the context of integrated livelihood diversification strategies and consider risks from other external factors such as market changes. Interventions that secure access to input and output markets will be essential.

Recent analysis of global climate models show that, even if the concentrations of greenhouse gases in the atmosphere had been stabilized in the year 2000, we are already committed to further global warming of about another half degree and additional sea level rise caused by thermal expansion by the end of the 21st century (Wigley 2005, Meehl *et al*. 2005). This means that, whatever progress is made over the coming decades in climate change mitigation, it will be necessary to plan and adapt for impacts of unstoppable change. Under these circumstances, progress in adaptation to climate change almost certainly will require integration of appropriate risk reduction strategies for fisheries and aquaculture with other sectoral policy initiatives in areas such as sustainable development planning, disaster prevention and management, integrated coastal management, and health care planning. It seems appropriate to give prominence in the response to global climate change to those people whose lives depend so directly on the warming, rising or receding waters that the coming century will bring.

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GLOBAL FRESHWATER RESOURCES

Louise Karlberg and Johan Rockström

Abstract

Inland fisheries are part of terrestrial landscapes in which freshwater functions as the bloodstream. Agriculture has a major impact on freshwater ecosystems. Water withdrawal for irrigation and conversion of land to agriculture both affect environmental flows. In order to maintain a high level of resilience in freshwater ecosystems, there is a need for a new approach to Integrated Water Resources Management (IWRM), which considers rainfall as the freshwater resource and which consequently recognises all ecosystem services and functions that this water fulfils on its way through the landscape. In the scope of climate change and the important role of water for sustaining human livelihoods, the need for a rapid development and implementation of such an approach becomes apparent.

Introduction

Water is the bloodstream of the biosphere. From the source, through the landscape, to its final destination in the sea or the atmosphere, water will fulfil many different tasks. It supports industry, households, agriculture and other ecosystem services. Fisheries belong to the latter category. Inland fisheries provide food and income for millions of people. Despite this, fisheries are often not accounted for in water resources planning and management, resulting in today's situation where many inland fisheries are under threat. This chapter takes a holistic perspective on the entire freshwater resource, and describes in particular activities relating to land and water use and management, and the impact on fisheries.

Water – the bloodstream of the biosphere

Inland fisheries are ultimately dependent on freshwater. This resource exists in many forms, and is used in many ways on its journey through the landscape. In some regions, surplus water causes problems to human societies in terms of flooding, whereas in other areas, the lack of water is a main constraint to economic development. Historically, humans have tried to manage water resources to increase the beneficial use of water, both for agricultural and domestic uses. With a global population of around six billion, it is perhaps not surprising that the competition for water in some areas is large. To feed one person on a standard diet requires around 3.5 m^3/day, i.e. 1,300 m^3/year (Rockström *et al*. 2007a). This is why agriculture is the world's largest water consuming economic sector. With such huge water needs for food production, discussions on how to secure freshwater resources for other ecosystem goods and services, such as water for fish habitats, are therefore largely focused on water management in agriculture.

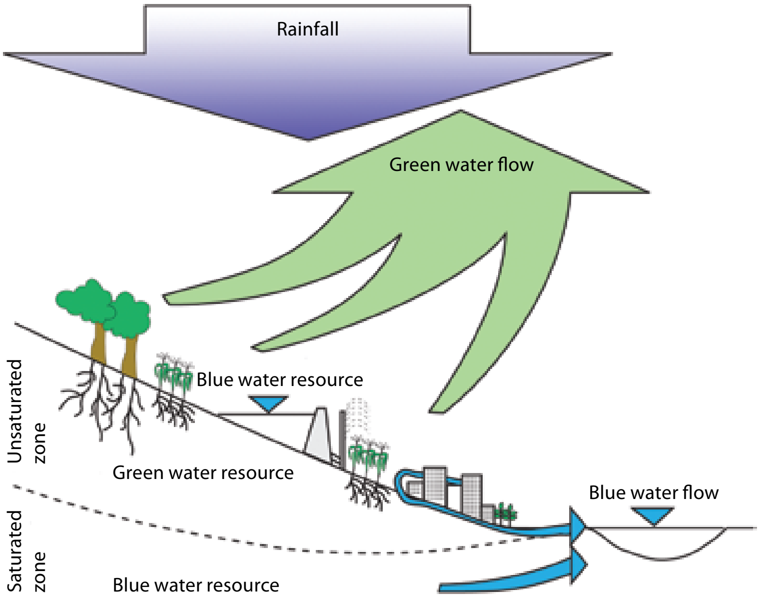

Figure 1. When precipitation reaches the ground it is divided into blue water, i.e. water in rivers, lakes, reservoirs and groundwater, and green water, i.e. soil moisture in the unsaturated zone of the soil. All evaporative (ET) flows of water, such as plant transpiration, soil evaporation and evaporation from water bodies, give rise to green water flows, while the flow of water in rivers is an example of a blue water flow.

Understanding the basic concepts of the hydrological cycle

As rainfall hits the soil surface, it is partitioned into water that infiltrates the soil and water forming surface runoff, from the surplus water accumulating on the surface (if there is more rain than the soil can absorb). Infiltrated water, which forms soil moisture, can be extracted by plant roots and used for transpiration, or continue down through the soil profile until it reaches the groundwater and becomes a subsurface runoff flow. Together with water in lakes, rivers and groundwater, surface and subsurface runoff constitutes the blue water resource (Figure 1) (e.g. FAO 1997), and thus constitutes the environment for inland fisheries. Soil moisture in the unsaturated zone forms the green water resource, which is the water that supports all biomass growth in terrestrial ecosystems (forests, grasslands, agricultural lands).

The amount of water that is available for use is equal to the rainfall within the area of interest, which is often a basin. Globally, precipitation over land surfaces amounts to an average of 113,500 km^3/year (Falkenmark and Rockström 2004). Out of this, the return flow to the atmosphere, or green water flow, is estimated at 72,500 km^3/year, or around 60 percent of the total precipitation. The remaining 40 percent is the blue water flow, i.e. the water flow in lakes, rivers and aquifers.

Regional differences are large. In some tropical regions, such as Kenya, green water flows constitute around 90 percent of the incoming rainfall. This has an impact on the ability to allocate water between different types of water use, since green water is not easily transferable between ecosystems, compared to blue water. Moreover, it might create the perception that the area is very water scarce, since green water is not visible to the eye. Managing water in an area dominated by green water is also different from water management in a predominantly blue water dominated setting. Agriculture for example, is likely to be predominantly rainfed in an area where the access to blue water is limited, which impacts on the water management options available.

What is the water used for?

There is apparently plenty of water available globally; however, all of this water is not readily available for use. An overview of the different components of green and blue water flows, illustrates how water is used by humans and ecosystems today (Figure 2). The figure shows the multitude of ecosystem services that are sustained by water flows. Green water is used for transpiration in all terrestrial ecosystems, and is thus vital for their functioning, while blue water sustains all fresh-

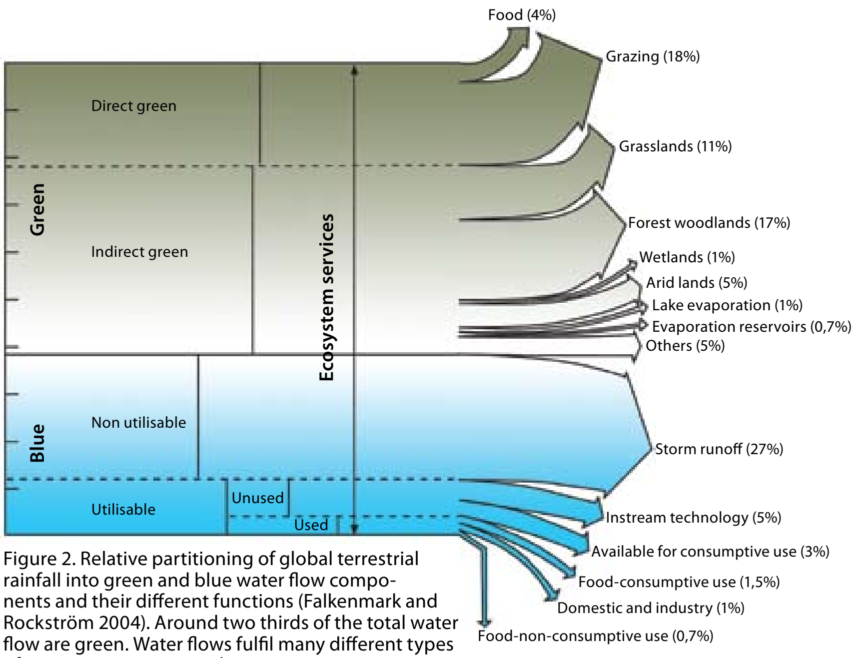

Figure 2. Relative partitioning of global terrestrial rainfall into green and blue water flow components and their different functions (Falkenmark and Rockström 2004). Around two thirds of the total water flow are green. Water flows fulfil many different types of ecosystem services such as transpiration necessary for plant growth or blue water flows to sustain limnic ecosystems.

water ecosystems. Irrigated agriculture is often claimed to be the largest consumer of freshwater, however the amount of blue water used within irrigated agriculture is small (only around two percent) in relation to the total water availability. Another striking feature is the small amount of blue water available for consumptive use, which amounts to around three percent of total global rainfall. The figure also illustrates the large proportion of both green and blue water use for food production within agriculture.

Globally, agriculture relies predominantly on green water flows, so called rainfed agriculture. Approximately 80 percent of the agricultural area is rainfed, generating 62 percent of the world's staple food (FAOStat 2005). Actual yields in tropical rainfed agriculture are estimated to range between two and four times lower than achievable yields, commonly due to poor water management (Rockström *et al*. 2007b). Erratic rainfall and frequent droughts are characteristic of the semiarid and dry subhumid region. Water management options that successfully have been shown to bridge dry spells include water harvesting and supplementary irrigation (Oweis 1997, Fox *et al*. 2005). The impact on poverty alleviation from upgrading rainfed agriculture is potentially large, which more specifically involves investments in water management techniques. Such investments are therefore likely in the future and may have both positive and negative consequences on downstream water users such as fisheries.

Blue water shortage – impacts on environmental flows

Physical blue water scarcity occurs when available blue water resources are insufficient to meet all demands, including environmental flow requirements. Today, some 1.2 billion people live in blue water scarce river basins, and another 500 million people are quickly approaching this level (Molden *et al*. 2007). Physical blue water scarcity is often associated with severe environmental degradation such as river desiccation and pollution, declining groundwater tables, disputes over water allocation, and failure to meet the needs of some groups.

Blue water scarcity is intrinsically linked to the services that freshwater ecosystems provide to humans, such as flood protection, recreation and wildlife, and fisheries. Balancing environmental water flows needed to sustain freshwater ecosystem services, and other uses, involves difficult trade-offs in many blue water scarce river basins (e.g. Vörösmarty *et al*. 2000). The challenge is complicated by the fact that ecological functions in aquatic ecosystems, such as the spawning cycles for river fish, are dependent on both a minimum aggregate volume of freshwater, and a certain frequency and amplitude of flows, such as short periods of surplus floods. Specific water requirements need to be met to maintain the key functions and structure of different ecosystems.

Land use is also a choice about water

Upstream land and water management and land use changes will have an impact on blue water generation, and thus on other freshwater dependent ecosystems. Deforestation and poor land-use in upstream locations of river basins have resulted in upstream land degradation and altered hydrological performance in the whole river basin (Vörösmarty *et al*. 2005). The result is generally an increase in runoff, as a result of reduced water use by forests (Calder 2005). However, this apparent positive (more runoff) is generally a dramatic negative, particularly for aquatic ecosystems such as fisheries, as the shift in land use results in more rapidly flowing and eroding surface runoff, and less stable and slow-flowing groundwater. The result is more storm-flow that generates increased land degradation, with short periods of excess water, followed by long periods of reduced water flow (as base-flow from groundwater recharge is reduced). Reduced water holding capacity upstream has also aggravated recurrent water stress in upstream agricultural communities, and downstream problems related to flooding after storms and increased sedimentation loads of rivers (Bewket and Sterk 2005). The overall impact is negative for fisheries.

So far changes in land use and the implications for downstream water users and ecosystems have not been addressed by policy instruments in most countries. One exception is the South African legislation, in which a permit is required for stream flow reduction activities, such as afforestation projects (South Africa National Water Act 1998).

Fishing – an ecosystem service under threat

Inland fisheries consume very little water. Instead they require water of certain amounts, quality, timing and variability, in rivers, lakes, wetlands and estuaries (Welcomme and Petr 2004). This can lead to trade-offs with other water users. Water development for agriculture, for example, has direct and mostly negative consequences for fisheries (e.g. Dugan *et al*. 2007). Inland fisheries and aquaculture contributes about 25 percent of the world's production of fish, and because it is often small-scale, it has a large importance for local food security. Presently, it is often fisheries and the people that depend upon them that loose out to more powerful water users (Dugan *et al*. 2007). A contributing problem is that inland fisheries are greatly undervalued in policy making and water management.

Inland fisheries as part of the terrestrial landscape

Fishing from freshwater bodies is one of the most resilient forms of harvesting of natural resources (Welcomme and Petr 2004). Despite this, many inland fisheries, particularly in the developing world, are heavily exploited, and suffer from large environmental pressures in the form of deteriorating water quality and habitat. These pressures are predominantly caused by agricultural activities, but also by other activities in the landscape (Dugan *et al*. 2007). Therefore, management and conservation of inland fisheries must be addressed at the landscape scale.

Rivers and wetlands

Maintaining environmental flows is vital for the functioning of rivers and wetlands. In general, environmental flow requirements range from 20 to 50 percent of the mean annual river flow in a basin (Smakhtin *et al*. 2004); however, one threat to inland fisheries is that this environmental flow requirement is often unknown. Reduced flows may lead to substantial habitat loss of wetlands, floodplains and lakes.

The construction of large scale dams for irrigation and hydropower disrupts longitudinal conductivity, thus preventing instream migration, which has been shown to be detrimental for inland fisheries (World Commission on Dams 2000). Dams might also stop seasonal flooding of the floodplains and change water discharge patterns and sedimentation, causing similar negative impacts (Bunn and Arthington 2002).

Water removal from rivers for irrigation can be substantial, and accounts for around 70 percent of all water removed from rivers (Dugan *et al*. 2007). Although a large part of this water might return to the river further down-stream, the water quality may have been substantially altered. Agricultural drainage water is commonly rich in nutrients and pesticides, which might cause eutrofication and pollution of the river ecosystem. As salts are leached from the soil by excessive irrigation, the salinity patterns of the receiving water body might be changed, also affecting the biome. Both the construction of dams and water management in agriculture might affect the sedimentation load in rivers, which might affect species in different ways.

Lakes and reservoirs

Lakes depend on the flow from rivers to sustain their ecological functioning. If the quality and quantity of river discharge is altered, this will have a direct impact on the lake habitat. River depletion for agricultural purposes has had drastic effects on freshwater ecosystems. In the Aral Sea, water abstraction for irrigation has resulted in the loss of about 50,000 tons of food fish per year (Petr 2004). Likewise, lakes are dependent on land use surrounding the lake, such as agriculture, and the location of industries and urban areas, as well as the availability and efficiency of wastewater treatment plants.

In a few cases, the impact of agriculture on fisheries might in fact be positive, such as in the case of rice paddies. These flooded fields become fish habitats, together with reservoirs and canals. However, reservoirs are subject to abrupt changes in water levels, and the fish species planted in the reservoirs therefore have to be adapted to these changes, which is a severe constraint to many species.

Coastal marine zones and estuaries

Similar to lakes, coastal marine zones are vulnerable to changes in freshwater input from rivers (Dugan *et al*. 2007). Estuaries are dependent on a certain quantity of freshwater from the rivers to maintain a salinity level of the water that the systems are adapted to. Poor water quality can also impact on coastal marine zones and estuaries. For example, the coral reefs in the Caribbean have been largely destroyed due to poor water quality of the water discharged from the major rivers surrounding the corals (Burke and Maidens 2004). Moreover, in the eastern Mediterranean the fisheries noticed a drop in harvests following the construction of the Aswan High Dam and the concurrent regulation of the Nile River (Nixon 2004).

An integrated approach to water management

To ensure an efficient and sustainable use of freshwater resources, an integrated approach to water management including both blue and green water flows is required. Water quality and seasonality in water flows are aspects that are of particular importance for inland fisheries. Moreover, the connectivity of different habitats is crucial for many fish species and hence requires attention. Since land-based activities such as agriculture, forestry, urban activities and industries all affect the water processes governing the freshwater ecosystems, water management needs to encompass all these areas. Water transfer between basins and trans-national river basins are complicating factors.

A systems approach is also needed in order to understand the risk for non-linear shifts in the productivity of inland fisheries as a result of multiple social and ecological pressures. Ecosystems, such as an inland lake system, are complex adaptive systems, characterised by non-linear dynamics, alternate stable states, and internal thresholds, which under multiple stressors may tip the system from a desirable to a non-desirable state. This is a key resilience character of the system – the ability to withstand disturbance (such as nitrogen loads and overfishing) without changing structure and function. Research on lake systems shows that under multiple stresses (from land use upstream, increasing nutrient loads and reducing blue water recharge, and from unsustainable fisheries), the system may during long periods show very limited signs of disturbance. Then suddenly, as a result of a trigger event (such as a drought), the system flips to a new stable state (Walker 2007). A classic example is the collapse of cod fisheries off the coast of Newfoundland in the 1970s, which despite efforts of restoration, has locked itself in a non-productive stable state after having been pushed across a threshold due

A system-wide green-blue perspective on water for ecosystem services remains a largely unexplored area in water resource planning and management. There is an urgent need to analyse green water needs upstream to sustain terrestrial ecosystem services (such as biodiversity, food, fibre and fuel) and the trade-offs in relation to blue water availability downstream, for fisheries, and other social and ecosystem uses.

to overfishing. The Aral Sea is another massive scale inland sea collapse, where the diversion of blue water flows for large-scale irrigation of cotton upstream, triggered positive feedbacks that accelerated desiccation by increasing air temperatures (raising evaporative flows). To decrease vulnerability and maintain a high level of resilience of the freshwater ecosystems, the key functioning and structure of the systems has to be known. One aspect of this is the determination of environmental flow requirements, but as shown above there are many other variables that have to be monitored and managed in order to avoid unwanted regime shifts. Some examples of the latter are water temperature, salinity level, nutrient and sediment load and flooding patterns. The complex dynamics of aquatic ecosystems, their dependence on water impact of land use upstream, and particularly the existence of non-linear dynamics and thresholds, indicate the need for new ways of thinking on water management, away from traditional efficiency and optimisation strategies, to a system-wide resilience framework.

Looking into the future

Feeding the future human population will require large amounts of additional water for agriculture (CA 2007). These large amounts of water may partly be offset by improvements in water productivity on the field, as well as saving of losses of food from field to fork. Nevertheless, pressure on fisheries for food production is likely to increase, both directly from a higher demand on fish for food and feed, and indirectly from larger water demand from the agricultural sector.

Climate change poses an immense challenge on freshwater management for all ecosystem uses. Already at present, changes in precipitation and runoff flows are observed, where evidence clearly points at climate change as the trigger. Over the past 40 years, reduced runoff flows are observed in almost all semi-arid and dry sub-humid tropical regions (sub-Saharan Africa, India, South Asia, southern Europe, Eastern Latin America, Northern China) (Dai 2006). Despite all uncertainties, climate models converge around a set of critical hot-spot regions in the world, where freshwater availability is projected to decline significantly over the coming 50 years due to climate change. These include Western USA, North-East Latin America, Southern Europe, North Africa, west coast regions of West Africa, Southern Africa, and Southern Australia. Water availability is one of the foremost and most immediate social impacts of climate change world-wide. For freshwater dependent fisheries, climate change has to be considered already at present, both in terms of the immediate effects on changes in water availability, and in terms of the growing pressures it will trigger on other water demands. For example, the IPCC 4th assessment projects that food production could decline with up to 50 percent over the coming 30 years, if greenhouse gas emissions continue unabated (IPCC 2007). Such a dramatic future, related primarily to projections of increased water related vulnerabilities, may pose tremendous pressure on finite and scarce water resources.

Increases in gross domestic product (GDP) have also been shown to affect the amount of water used for food production. Considering also the likely change in diets with increasing GDP, which normally involves a shift from more cereal based products, to more water consuming foods such as meat and vegetables, the pressure on the water resource is likely to be even larger. Consequently, intensification of the agricultural sector is to be expected, with reduced environmental flows and deteriorating water quality posing additional strain of the freshwater habitats. Feeding the future human population will also directly increase demand on fisheries, which increases the risk for unsustainable harvesting of the fish populations.

Conclusions

Inland fisheries provide an important part of the human diet, and are a crucial source of income for many poor communities. Agriculture often poses a threat to inland fisheries, by altering blue water availability and quality. On the other hand, agricultural activities can have positive effects on fisheries, for example by generating new habitats in farm reservoirs, irrigation canals and on flooded fields. To manage inland fisheries, an integrated and holistic approach is required, in which the total rainfall in the basin constitutes the water resource and accounts for both blue and green water flows. In addition, all activities affecting water flows and quality in the landscape have to be accounted for. Feeding the human population in the future is likely to increase pressure on inland fisheries. Sustainable management of this important resource will therefore require nothing less than a paradigm shift away from traditional optimisation strategies, towards an approach that will focus on maintaining a high level of resilience in freshwater ecosystems.

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WATER AND FISHERIES

Patrick Dugan, Bastien Bandi and Christophe Béné

Introduction

This paper highlights the importance of fisheries and aquaculture in management of the world's water resources. It underlines the value of these resources and the critical importance of managing water quantity and quality for fisheries and aquaculture as well as for other human uses. This will require more holistic approaches to water management and the effective governance systems these require.

The World's water

Water covers 70 percent of our planet's surface, and our water resources total some 1.3 billion cubic kilometres. However of this amount only 2.5 percent is freshwater, and only a small portion of our freshwater is directly available to support human lives. More than two thirds of the 35 million cubic kilometres of freshwater are in the form of ice and permanent snow concentrated around the two poles or at high altitude and almost a third (eight million km^3) is found underground, whether in groundwater basins or as soil moisture. Lakes and rivers, including associated wetlands, contain a mere 0.3–0.4 percent of the world's freshwater (105,000 km^3) (Shiklomanov and Rodda 2003).

The inherent scarcity of the world's freshwater is further exacerbated by its unequal distribution, variable demand, and the history of land and water management in different regions and countries of the world. As a result of this combination of factors, the past decade has witnessed growing concern at the water crisis being faced in many parts of the world. An increasing number of countries are suffering from severe water stress (UN 2003, Falkenmark 2001) and this has led to growing calls for more efficient use of water in all sectors. Agriculture is the main user of water worldwide and the growing call for water efficiency has led to calls for a Blue Revolution.

As calls for water efficiency have increased, so has awareness of the need to embrace a wider understanding of the value of freshwater and in particular of the role of freshwater in sustaining natural ecosystems and the values they provide for people (Dugan 2005, Postel and Richter 2003). It is in this context that there has been growing attention focused on the value of fisheries and aquaculture as components of water management strategies that improve water productivity. In the following sections we set out this value and the implications for land and water management.

Freshwater and the value of fisheries

Nearly all freshwater ecosystems support fisheries in one form or another and these resources contribute significantly to total water productivity (Dugan *et al*. 2007). These include fisheries in lakes and rivers, together with those in their many associated wetlands. They also include the fisheries in coastal systems that are dependent on the freshwater and nutrients provided through river outflows to coastal lagoons, deltas, and inshore waters.

The latest official estimates of freshwater fisheries production give a value of 9.2 million tonnes per year (FAO 2006). While this is much smaller than the catch from marine systems, inland fisheries have sustained a growing trend of about two percent per annum worldwide (FAO 2002) and the potential for further increase in production is high in some systems (Kolding and van Zwieten 2006).

The economic value of these freshwater fisheries is high. Europe's inland recreational fishery has been valued at USD 25 billion a year (Cowx 2002), and wild fisheries represent seven percent of Cambodia's GDP and four percent of Bangladesh's. With a farm-gate value of USD 28 billion in 2003, the contribution of freshwater aquaculture has increased rapidly in recent decades and is now the major contributor to total inland water production (Figure 1).

In some regions the potential of inland fisheries is underexploited. For example, in West and Central Africa Neiland and Bene (2006) have shown (Table 1) that fisheries provide livelihoods

Figure 1: Production trend of marine and inland capture and marine and inland aquaculture. *Source*: FAO 2004, in Dugan *et al*. 2007.

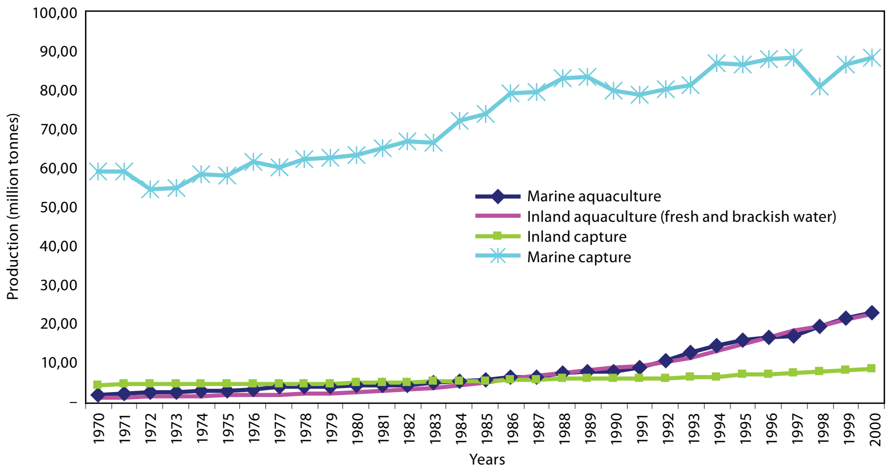


Table 1: Contribution of the fisheries of the major river basins and lakes in West and Central Africa to employment and income.

River basins and lakes	Employment (fishers)	Actual production		Potential production	
		Volume (metric tons per year)	Value (millions of USD per year)	Volume (metric tons per year)	Value (milllions of USD per year)
River basins					
Senegal-Gambia	25,500	30,500	16.78	112,000	61.60
Volta (rivers)	7,000	13,700	7.12	16,000	8.32
Niger-Benue	64,700	236,500	94.60	205,610	82.24
Logone-Chari	6,800	32,200	17.71	130,250	71.64
Congo-Zaire	62,000	119,500	47.80	520,000	208.00
Atlantic coastal	6,000	30,700	46.66	118,000	179.30
Lakes					
Volta	20,000	40,000	28.40	62,000	44.02
Chad	15,000	60,000	33.00	165,000	90.75
Kainji	20,000	6,000	3.30	6,000	3.30
Total	**227,000**	**569,100**	**295.17**	**1,334,860**	**749.17**

Note: Table excludes the numerous men and women who engage in part-time (seasonal or occasional) fishing. *Source*: Neiland and Béné 2006.

to more than 227,000 full-time fishers and yield and annual catch of about 570,000 tons, valued at USD 295 million (first sale value). They estimate however that the total annual fisheries production for this region (about 1.34 million tons with an estimated annual value of USD 750 million) is more than twice the estimated production.

As the analysis by Neiland and Béné (2006) indicates, inland fisheries are not only important for the value of the catch, but also because they provide an important source of income for 50–100 million people. For example, research in the Zambezi floodplain has revealed that inland fisheries generate more cash for households than cattle-rearing and in some cases more than crop production (Table 2). In Sri Lanka, recent economic valuations have shown the value of fisheries is about 18 percent of the total economic returns to water in irrigated paddy production (Renwick 2001). In addition, because fishers and, to a lesser extent, fish-farmers, can access cash year-round by selling fish, fisheries provide a 'bank in the water' for rural populations who lack access to formal financial systems. This contrasts with agriculture where farmers have to invest in, and wait for, harvest before earning cash returns.

Fisheries also serve as a major source of protein for more than one billion people, particularly in Asia and Africa. For example, people in Cambodia obtain about 60–80 percent of their total animal protein from the fishery of the Tonle Sap Lake and in Malawi, 70–75 percent of the total animal protein for both urban and rural low-income families comes from inland fisheries. This "rich food for poor people" provides a global average of 16 percent of the animal protein intake and also contains many vital vitamins, minerals, fatty acids and other micro-nutrients crucial to a healthy diet.

The water regime and inland fisheries

In view of the importance of fisheries and the potential of aquaculture, there is growing international recognition of the importance of ensuring that water is managed to secure these fishery benefits. Among the many challenges to achieving this, the most important is to sustain the quantity, quality, timing, and variability of the water flow they require (Welcomme and Petr 2004). Changes to water flow can occur naturally due to climatic variability, as seen in Sahelian rivers (Dansoko *et al*. 1976, Lae *et al*. 2004), but more commonly they result from human modifications to the flow regime, notably through the construction of dams and other water management structures, as a result of water off-take for agriculture, domestic and industrial use, and through land management changes in catchments.

These alterations in water flow generally lead to significant ecological changes in the rivers downstream, especially in those rivers that have significant floodplains and associated wetlands. These play an especially important role in fish feeding and breeding and reduced flooding reduces fish production (see also Box 1).

Reservoirs and most lakes also depend on flow from rivers or streams for their existence and productivity. Year-to-year fluctuations in the productivity of Lake Kariba and Lake Turkana illustrate the dependence of even large water bodies on river inflows – as these provide both variation in area and inflow of nutrients (Karenge and Kolding 1995, Kolding 1992). Other lakes, such as Lake Chilwa and Lake Chad, depend on inflow for their existence and in both, a reduction or failure in flooding from inflowing rivers results in diminished area and failure of their fisheries, although these are restored when more normal flow conditions reappear (van Zwieten and Njaya 2003). In the case of the Aral Sea water abstractions in support of irrigated agriculture for non-food crops led to the loss of about 50,000 tons of food fish per year (Petr 2004).

Coastal fisheries are also vulnerable to changes in freshwater inputs. For example, the pelagic fisheries of the eastern Mediterranean experienced a marked downturn following the regulation of the River Nile's flow by the Aswan High Dam (Nixon 2004). There is also evidence that coral reefs and their fish populations can be affected when freshwater discharge patterns are modified and in particular where land use results in excessive sedimentation. In fresh–salt water transitional zones in estuaries, changes to flow can affect the intrusion of salt water into the freshwater system and associated soils. This affects the distribution, reproduction, larval development and growth of many freshwater, brackish water and marine fish, crustacea and molluscs. Mangrove forests are particularly at risk in areas where coastal transition zones suffer changes in salinity by reductions in freshwater inputs or are degraded by declining sediment deposition.

Many forms of aquaculture are only viable if flow conditions are suitable. Successful rearing of fish generally depends on reliable supplies of clean water, although many rain-fed still-water ponds and more advanced recirculation systems may be extremely economical in their water use. Intensive running water culture systems need constant inputs of high quality water to ensure that there is sufficient oxygen for the fish and that wastes are removed; sufficient flow is needed in the river into which farm effluents are discharged to dilute wastes and nutrients without damaging the ecosystem (Brown and King 1996). In many parts of the world granting of licenses for fish farms is dependent

Table 2. Impact of other users of river and lake basins on fisheries (from Welcomme 2001).

Use	Mechanism	Effect
Power generation	Dams	Interrupt longitudinal connectivity
		Stops water flooding the floodplain (loss of habitat)
		Change water discharge patterns
		Sedimentation changes
		Entrainment of juvenile fish
		Entrainment of fish
	Uptake of cooling water	Changes to thermal regime
	Discharge of cooling water	
Flood control	Dams	As above
	Levees	Interruptions to lateral connectivity
Navigation	Dams	As above
	Channel straightening and deepening	Loss of habitat
		Changes in basin morphology
		Changes in the structure and functioning of the channel
		Wave creation and turbidity
Domestic use	Dams	As for dams
	Water transfers	As for water transfers
	Domestic sewage	Eutrophication or pollution
Agriculture	Dams	As for water transfers
	Water extraction	Altered flow regimes
	Diffuse fertilizers and animal wastes discharges	Eutrophication
	Pesticides discharges	Pollution
Forestry	Removal of vegetation cover	Altered runoff, increased sedimentation
		Acidification
	Monoculture of pines	
	Inappropriate use of alien species with high water requirements	Unsustainable use of groundwater
Industry	Waste discharge	Pollution
Mining	Discharge of waste and tailings	Pollution and increased sedimentation
Water transfers	Movement of water from one river to another	Changes in hydrology in donor and recipient basins
		Risk of transfer of organisms
Wildlife conservation	Protected areas	Usually positive reinforcing fisheries needs if incorporating sustainable use

on certain flow criteria being met and alterations to flow can place some of these in jeopardy.

This short review of the water management needs of fisheries and aquaculture illustrates how managing water for inland fisheries requires an ecosystem approach to the management of watersheds. This approach should consider not only water quantity and quality but also connectivity of the system because many highly mobile fish species need to be able to move between spawning, nursery and feeding areas within a basin. This management approach needs to consider land use practices, such as agriculture and forestry, as well as the needs of industry, urban areas and water borne transport that impact on basin processes and in turn on the quality, quantity and timing of flows (Table 2). The approach is further complicated by the fact that many river basins are transboundary and may be located across several countries. In these cases appropriate and effective international mechanisms to regulate and manage river flow are needed.

Environmental Flows

If fisheries and freshwater are to be sustained in river systems, water flows need to be maintained. These flows are called Environmental Flows (EFs) and, for fisheries purposes, are defined as that portion of the original flow of a river that is needed to maintain specific, valued features of its ecosystem or the quantity of water that must be maintained in a river system at all times to protect the species of interest for fisheries or for conservation and the environments on which they depend (Arthington *et al*. 2007). In addition to water quantity, EFs also need to consider factors of timing and rates of change (Box 1). Clearly a regulated river system cannot reproduce all aspects of natural flow, while at the same time providing for competing uses (Dyson *et al*. 2003). EFs are not intended to mimic a pristine river but rather to support the ecological functioning of the river to sustain its desired services to people and nature.

The type of environmental flow regulation needed to maintain fisheries depends on the primary cause of flow modification and the desired nature of the fishery in question. Restrictive management is required where water is abstracted directly from a donor waterbody. Some 70 percent of all water removed from rivers is for agriculture (FAO: AQUASTAT). Although this may be returned in part to the donor river, the discharged water may be of lower quality and quantity and the timing may also be inappropriate. The net impact of these high levels of removal on fisheries has rarely been investigated, although it is assumed from knowledge of the dynamics of fish populations in rivers that such effects are generally deleterious. However in some irrigated landscapes such as rice-farming systems, aggregated impacts of irrigation on fisheries production and on the livelihoods of fishing communities are not always negative at catchment level, as demonstrated in Laos and Sri Lanka by Nguyen-Khoa *et al*. 2005a.

Active management is required where releases from dams are involved. Damming has proved particularly detrimental to downstream fisheries (Jackson and Marmulla, 2000) by suppressing flood peaks and preventing the periodic inundation of floodplains downstream, altering their timing and preventing instream migration (Bunn and Arthington 2002) with negative consequences on the fishing communities. To combat these impacts artificial flow regimes are needed that allow for peak flows that are so timed as to act as triggers for breeding and should be of sufficient depth and duration as to flood riparian wetlands for sufficient time for young fish to grow. They should also allow fish to migrate, access riparian floodplains and otherwise complete their normal life cycles. The success of such approaches is illustrated by flood releases from the Pongolo Dam in South Africa that were sufficient to flood the Pongolo Flats downstream and rehabilitate the fisheries of the floodplain (Weldrick 1996). Active management can also be applied to poldered systems where the floodplain is enclosed to control flow for rice and other crops. Here correct management of the sluices controlling flow can favour fish as well as rice (Halls 2005).

While discussion of EFs has tended to focus first on water volume, we also need to consider quality. Good quality water is essential for breeding and growth of many fish species and the aquatic fauna and flora upon which they rely. Pollution by noxious chemicals, usually as a result of agriculture or industry, is always bad and, coupled with de-oxygenation caused by excess eutrophication, was responsible for the fishless nature of many European waterways in the 18th, 19th and early 20th centuries. The reversal of these trends, with the restoration of many fish species over most of the continent, emphasises just how significant rehabilitation and protection measures can be. Eutrophication is a problem mainly in lakes and reservoirs and has been the major cause of deterioration in such waters, to the extent that many initiatives to rehabilitate closed or semi-closed waters are based on control of nutrient inputs. In rivers, a certain amount of eutrophication appears to be a natural part of the downstream evolution of water quality but even this needs to be controlled to avoid total anoxia in the system and the elimination of species sensitive to low dissolved oxygen.

Intensive agriculture on riparian lands, coupled with inappropriate chemical use and land management is increasing chemical loading in the associated waterways. At the same time, changes in flow regime in rivers and discharge patterns to lakes can influence the dilution factors of pollutants and eutrophicating nutrients to a point where the waterbodies no longer provide adequate assimilation and aquatic organisms decline. Major demographic trends and increasing amounts of contaminated waters discharged by growing urban communities suggest that future trends will be for a lowering of water quality in many parts of the world. This trend is intensified by the designation by some countries of agriculture as the priority water use, because agriculture is itself the major source of diffuse water pollution and eutrophication.

RESPONSES OF FISH TO DIFFERENT FLOW CONDITIONS

After Welcomme and Halls 2004.

Most rivers have pronounced seasonality of flow throughout the year with one or more high water episodes (floods) alternating with periods of low flow. The relationships of fish to flow are complex and depend on various aspects of the hydrograph such as, timing, continuity, smoothness, amplitude, duration and rapidity of change of the floods (Figure 2). These are influenced by the extent to which the channels of the river are connected to the lateral floodplains and other seasonal wetlands. In rivers with less prominent floodplains the abundance of fish is conditioned more by the amount of water remaining in the river during low flow events.

Changes in flow affect different reaches of the same river in different ways. In upland reaches, alterations to natural flow regimes may affect the alternation of pools and rapids essential to the survival of fish. Deep water pools in rivers are particularly important as refuges and spawning grounds. In lowland reaches, the floodplain is essential to the reproduction, breeding and growth of many species. Flow manipulations alter the extent, duration and depth of wetland flooding and in some cases may suppress it entirely. The importance of the floodplain in maintaining fish catches is shown by the close correlation between flooding and catch in subsequent years.

Timing: The timing of the flood is important to many river fish species because of the synchronisation between physiological readiness, or stimulus, to migrate and spawn and the flood phase.

Continuity: Discontinuities in flow may be particularly damaging to breeding success and survival of young fish.

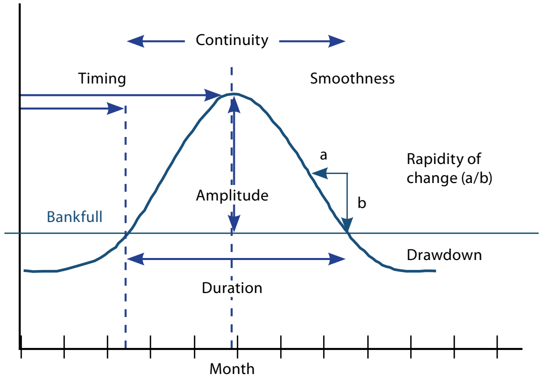
Smoothness: The smoothness of the flood is critical for certain types of spawning behaviour such as nest building and fish that spawn in marginal vegetation and shallow areas.

Amplitude: The amplitude of the flood is important for regulation of food production and spawning success. The greater the area of floodplain flooded the better the catch in the same or subsequent years.

Duration: The duration of flooding influences the time available for fish to grow and for them to shelter from predators.

Draw down: The dry season is a period of great stress to the majority of river fish species. At this time most species are confined to the main channels of the river although some specialists can survive in permanent floodplain waterbodies. Adequate water must remain in the system to ensure survival.

Box 1. Responses of fish to different flow conditions.



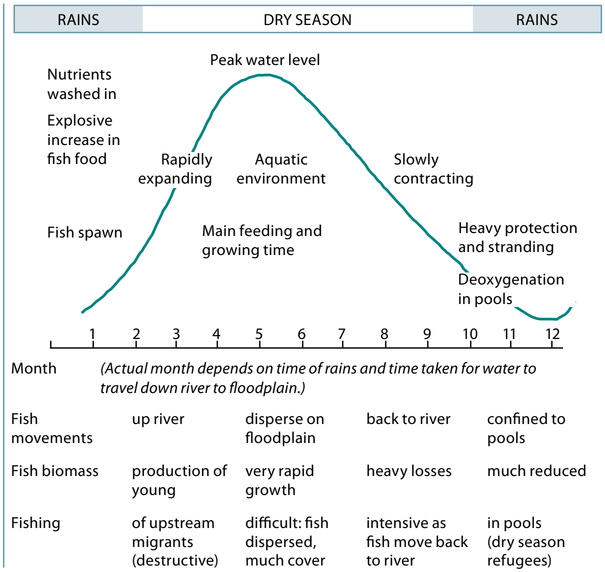


Figure 2. Left: various parameters of a flood curve having biological significance (from Welcomme and Halls 2001). Right: the seasonal cycles of events in a floodplain river (from Lowe-McConnell 1987).

Fisheries, agriculture, and water productivity

"Water productivity" is a tool to consider how to optimise the provision of services from water. The traditional use of the approach must however be considerably broadened to take fully on board the wider and more complex values that should be assigned to the benefits of fisheries and aquaculture. The value and future role of fisheries is substantial. The important but complex linkages between fisheries and poverty must be understood if desired poverty reduction outcomes through water use are to be achieved. It is not simply a choice between fisheries and other benefits from water. Well planned and managed systems can optimise all services. Fisheries and aquaculture considerations can be incorporated into agricultural systems resulting in net positive gains to water productivity. Agricultural practices can be modified so as to benefit fisheries, and where this incurs costs to agriculture these can be offset through increased net overall benefits. Tools are available to help achieve this outcome, although some need further refinement. The major constraints today are not technical but relate to the need for effective governance and institutional arrangements that enable the development of policies for water use that achieve clearly defined poverty reduction outcomes through fair, realistic and transparent trade-off decisions. Essential to this process is the effective and meaningful participation of stakeholders in the policy arena, and their involvement in management, particularly at the local level. Improved governance systems should be promoted based on the principles of subsidiarity and downward accountability, leading to a better integration of the needs and aspirations of the fishery-dependent communities into the wider multi-sector water management decision-making process. To support improved governance systems and improve poverty reduction outcomes major investment is required in the development of better valuation methods which demonstrate the full contribution of living aquatic resources, and in particular fisheries, to livelihoods.

Fish and other aquatic species can be integrated into other agricultural activities. For example, fish can be raized in rice fields or reservoirs. Integrated Agriculture – Aquaculture (IAA) optimizes the agricultural use of water and also presents numerous advantages such as the increased value of production, the reduction of risk and minimal labour required. Typically, "natural" rice paddies produce 120–300 kg/ha/year of diverse mixed fish and other animals which contribute directly to household diets and in some cases to profit margins. More intensively managed fish stocking and harvest has been shown to increase rice yields (due to weed control and the aeration of soils) by some 10 percent while producing up to 1,500 kg/ha of fish and reducing both the necessity for and costs of pesticides (de la Cruz 1994, Halwart and Gupta 2004). The community based management of fisheries, aquaculture and rice farming practiced in Bangladesh or Sri Lanka is a good example of achieving maximum synergy through appropriate technical and management interventions (Dey and Prein 2003). Fish production on these floodplains has increased from the traditional 50–70 kg/ha to 650–1700 kg/ha, while maintaining the rice production at 6–7 t/ha. Away from the paddy fields, livestock may be integrated with fish and crops where every constituent in the system helps to increase production and income. Livestock manures, household waste and cereal brans added to ponds feed aquatic plants and animals that in turn feed the fish; and finally, the mud that accumulates as sediment can be used to fertilize the land for fruit and vegetable crops. An additional benefit of the IAA system is that the water stored in farm ponds can be used to extend crop production into dry seasons, thereby increasing total production and attracting premium prices for out-of-season produce. This alone is a major asset and can greatly improve rural livelihoods in rainfed areas, such as in Africa.

Developing inter-sectoral policy framework adapted to inland fisheries

The consensus amongst practitioners and scholars is clearly that new evaluation techniques, investment approaches, and governance reforms can support and improve the contribution of fisheries and aquaculture to water productivity. The implementation of these approaches, however, still represents an enormous challenge for a large number of institutions in developing countries. Adaptive policy support mechanisms are required to ensure that reforms realise the potential benefits on offer in terms of local economic development and improved food security. In many countries the wider integrated natural resource management framework into which inland fisheries can fit is lacking. Effective policies for the conservation and sustainable use of freshwater biodiversity are also generally absent despite the increased recognition of its role.

Many countries have yet to develop national policy and legal frameworks tailored specifically for inland fisheries. More usually, inland fisheries continue to be placed under policy frameworks that evolved to address different coastal and marine fisheries issues. There is an urgent need for all countries to develop and implement frameworks specific to inland fisheries. These should in particular have explicit links to integrated approaches to sustaining aquatic environments.

An essential attribute of an effective inland fishery policy framework is the adoption of an ecosystem approach to fisheries (EAF). This is still a major challenge in the low-capacity and data deficient environment in less developed countries. However EAF offers a much better adapted framework for fishery management than the sector based approach still prevalent in the vast majority of those countries. This would involve fisheries considerations, and related environmental concerns, being included into integrated planning, particularly for water use. One mechanism to promote such integrated multi-sectoral approaches is through participatory scenario-based negotiations where the needs of stakeholder groups within fisheries can be better integrated with those of other interests, and take account of gender perspectives. These processes should in particular facilitate the establishment of inter-sectoral consensus mechanisms through the collective negotiation of land and water issues and their relationship to aquaculture and fisheries.

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INLAND FISH AND FISHERIES

Erik Petersson

Abstract

About a millennium ago, there was a major shift in the fishing habits in Europe; from freshwater to sea fishing. However, the inland fishery has certainly not stopped, it is actually more important than the inland water area could make us think. Since 1950, the catches from inland waters have increased from circa two to nine million metric tons, and now make up about 12 percent of the total fish catches. Not surprisingly, most inland fisheries are reported from Asia, and China alone account for about one-quarter of the world's inland catches. The inland fisheries struggle with about the same problems as the marine fisheries, especially decreasing catches. Catches are only increasing for one out of 123 species analysed, and that species (silver barb) has been introduced to many new areas in Oceania and Asia. Even if overfishing occurs in many lakes, this is not the only threat to inland fish populations. Most likely species introductions, impoundments and water quality problems are more important. Until now, fishery science and management has focused on one species at a time. There is a need for a shift to ecosystem-based management that takes into account the whole ecosystem in lakes and rivers.

Introduction

A Swedish archaeological finding from the Stone Age is a plaited wire cage made of birch and willow (dated to 5000–4000 BC). It is likely it was used for fishing in inland waters, because until about one millennium ago most fishing was done in coastal and inland waters. Thereafter a major shift from freshwater to sea fishing took place in Europe, caused by a combination of climate, population growth and religion. Based on an extensive survey of the evidence, Barrett *et al*. (2004) argued that this change occurred relatively rapidly in England, within a few decades around year 1000, and was a response perhaps to the depletion of freshwater fish stocks and the great demand for fish from growing urban populations. However, this shift from inland to marine fishery did not take place simultaneously in the world. It is difficult to find information about areas outside Europe, but in Southeast Asia, the catches from inland areas were about equal to the marine catches (Sugiyama *et al*. 2004). Most of the marine fishery was subsistence fishing by coastal villages. The region's marine fish stocks were almost certainly lightly exploited and, although no detailed surveys were carried out until after

1945, several contemporary 19th century records comment on both the quality and the abundance of fish in many areas and on the simple fishing methods used in marine fisheries.

In the 20th century, the modern fishing industry has established with engine-powered ships, larger trawlers, hydro-acoustic equipment, satellite navigation and so on, and the intensity of marine fishery increased. Consequently, the relative importance freshwater fishery has decreased. However, the importance of inland waters is not proportional to its share of all surface water, but much larger. Small-scale commercial and subsistence fishing often provide the employment of last resort when other labour opportunities cannot be found (Kura *et al*. 2004). This is particularly true for inland fisheries. In many countries, fishing communities are an important group of landless people, with incomes corresponding to absolute poverty level. With the increasing population, the person/land ratio is increasing, compelling people to seek sources of income outside of agriculture, for example in fisheries, where fishermen sell their labour to earn their income. However, Béné (2003) argued that poverty in fisheries could not easily be explained through a linear relationship between the low incomes of fishermen and the overexploited resources.

There are no global estimates of the number of people engaged in inland fisheries, but in China alone, more than 80 percent of the 12 million reported fishers are engaged in inland capture fishing and aquaculture (Kura *et al*. 2004).

Inland fishery in salty water!

Inland fishery is often equated to freshwater fishery, but that is clearly to oversimplify. Inland waters are those that are surrounded by land. Marine waters, oceans, on the other hand, are waters that surround land. The largest lake in the world, the Caspian Sea, is not freshwater; its salinity is 1–2 percent, almost the same as the southern Baltic Sea. The Baltic Sea is an "ocean bay", just like the Mediterranean and the Black Sea. Actually inland waters may be more saline than oceans; the most salty water in the world, the Dead Sea in Israel, is a lake. Nevertheless, inland salty waters are included in inland fishery statistics. It is the geographic property of the water body (surrounding or surrounded by land), not the salinity that makes the difference. The bewildering consequence is that some marine fisheries occur in waters that have the same salinity as some inland waters.

The unique features of inland water ecosystems probably contribute strongly to the fact that 0.9 percent of the world's water contains about 40 percent of all fish species (10,000 out of 25,000 known species). Nevertheless, just as for marine ecosystems, all fish species are not commercially important. Commercial fishing means that the work is done in order to exchange or sell the caught fish on a large scale, and a commercial fish species should be suitable for such business. Cultural differences or different tastes between countries, to some extent direct the fishing pressure towards certain species. Here are three slightly generalized examples:

1) In Bangladesh there seems to be a strong consumer preference for freshwater fish, 75 percent of the total fish consumption in a year comes from freshwater sources, despite that Bangladesh has access to marine fish (Toufique 1998).
2) The most important inland species in Finland is the vendace (*Coregonus albula*) (Lundqvist 1999), which is consumed the normal way. Swedes on the other hand are more particular and prefer to eat just the vendace roe.
3) Small perch fillets (15 g; *Perca fluviatilis*) are preferred in the French-speaking area, whereas medium sized (40 g) are eaten in the German speaking area.

However, times are changing: Today's rubbish fish can become tomorrow's tidbit. Swedish fishermen hope to reintroduce the burbot (*Lota lota*) on the market, as a compensation for the drop in eel catches (NWT 2007).

Data on inland fisheries

The FAO is the only organisation with a worldwide remit to engage in the systematic data collection and compilation on fisheries and aquaculture information. The data are provided by FAO members and verified from other sources wherever possible (FAO 2008). The reliability of the analysis based on the data, and the quality of the advice to which it gives rise, depends on the reliability and quality of the data themseselves. In order to improve the quality the FAO seeks to continue supporting and strengthening national capacity in the collecting, analysis and use of accurate, reliable and timely data. National reports are the main but not the only source of data used by FAO to maintain its fishery statistics database. In cases where data are missing or are considered unreliable, FAO includes estimates based on the best available information from any source, such as regional fishery organizations, project documents, industry periodicals, or statistical interpolations.

Obviously, it is hard to gather data that completely mirror the amount of fish that is caught in different waters. In commercial fisheries in developed countries might it be relatively easy, as fishermen must have licences and may be obligated to report landings. However, illegal fishing is nearly impossible to estimate. In many regions, licence and reporting systems are not in place for inland fisheries.

Fisheries landings from inland waters have increased more than fourfold, roughly three percent annually, since data were first compiled in 1950 (Allan *et al*. 2005). China accounts for about one-quarter of the world's inland catch (Figure 1). In almost all developing or transitional economies the inland fish harvests have increased rapidly over the last 10 to 15 years. In developed regions many inland commercial fisheries have been abandoned and replaced by recreational fisheries, which may add substantially to the total fisheries harvest but are not always reported (Cooke and Cowx 2004). In some countries, the catches in the recreational fishery are higher than the commercial fishery; Germany reported 10,896 metric tons 1994 from commercial fishing and 18,871 metric tons from recreational fishing (Nilge

1998). The global recreational harvest is poorly documented, but may be approximately two million metric tons (FAO 1999).

Management programmes that include releases, i.e. anglers practice catch-and-release angling, are sometimes viewed as a successful way to preserve a population (Wingate and Younk 2007). However, not all fish survive, and those that do often experience sub-lethal consequences including injury and stress. Recreational fishing can result in substantial post-release mortality (Muoneke and Childress 1994) and reduced growth and fitness (Cooke *et al*. 2002). The extent of decline due to recreational fishing is often unappreciated, even in well-managed regions, because of inadequate records, and a lack of historical population estimates. Pine *et al*. (2008) showed in a simulation study that post-release mortality can have major population level effects at higher exploitation rates and may limit the effectiveness of existing conservation measures for population recovery, such a length limits. The post-release survival is also affected by fishing method used (e.g. Alós *et al*. 2008). In addition, for a number of obvious reasons, marine fishers usually tend to under-report their catches, and consequently, most countries can be presumed to under-report the catches to FAO.

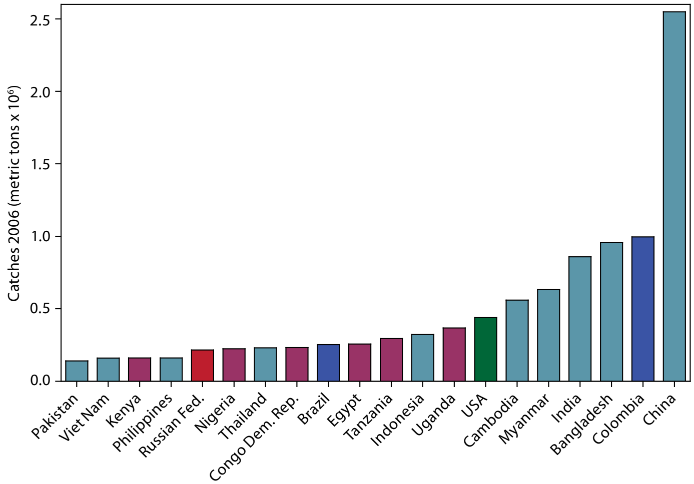

Figure 1. Inland fishery in the 20 countries with the largest reported catches.

Another limitation of the database is that not all catches are identified at species level, or not even at group level (genus, family, suborder or order). If just the weight of the catches is of interest, this might be sufficient, but in a longer perspective bad taxonomy prevent analyses, forecasting and proper management. The misinterpretation of environmental conditions caused by taxonomic errors occurs more often than we think. For example, many misinterpretations of the bio-indicators of environmental pollution are currently due to taxonomic failures involving sibling species. If sibling species (or species just usually caught at the same time and not separated in reporting) are common in an environment, then failure or omission to recognise them affects the evolutionary and ecological understanding of the fish populations and the environmental factors affecting them. Sibling species might have different growth rates, toxic resistance and/or oxygen isotopic ratios, etc. If this is not known or ignored and the species as a group are used as an indicator of environmental degradation and global climate variation, the presumed environmental signal is confounded (Bortolus 2008).

One interesting example is the Black and Caspian Sea sprat. According to FishBase (2008) and FAO Fact sheet (2008) this species is of important commercial value in the Caspian Sea, and one of the most landed inland species in the world. However, according to CEP (Caspian Sea Environmental Programme 2008), Black and Caspian Sea sprat is of low commercial value in the Caspian Sea, where instead the species *Clupeonella engrauliformis*, anchovy sprat, makes up about 70 percent of the total catches. (This has been confirmed by Dr. Vladimir Salnikov, National Institute of Deserts, Flora and Fauna, Turkmenistan; pers. comm.).

In addition, non-fish taxa are included in the database. This is not a problem; it is positive that harvests are declared at all. However, reports of crocodiles and invertebrates illustrate another issue. Crocodiles were not reported before 1973; does this mean that they were not "fished" until then, were not reported before that year or that the decision was made to include them from 1973 and onwards? Despite the limitations of the FAO database, it is the only global database available. Moreover, the question is what is best; to struggle obstinately for an almost perfect database and after several decades find that the most important fish stocks have been depleted, or use what we have for an educated guesswork – and call for action now.

Inland fisheries – trends, distribution

Inland fishery makes up an unexpected high proportion of the world's total fishery; during the past five to six decades, it has varied between 7 and 12 percent. In fact, the estimate from 2006 indicates an "all-time-high" since 1950 (Figure 2). Inland fisheries have steadily increased during the period, whereas the marine fisheries have levelled off since the late 1980's. In addition to this, inland areas have aquaculture of various degrees of intensity, making the inland fish production even higher. (This important aspect is covered by Subasinghe in this volume).

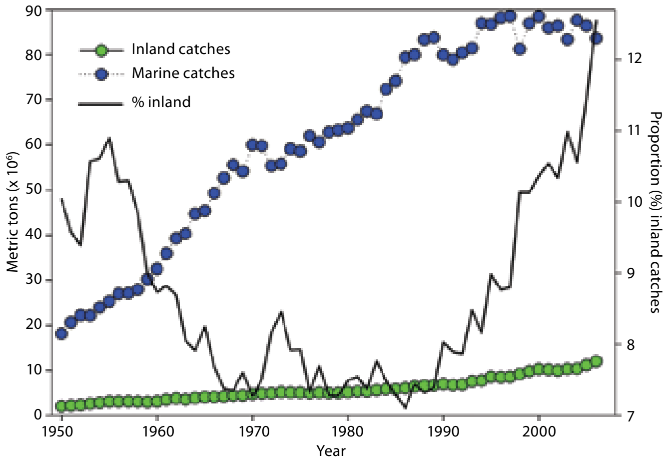

Figure 2. Catches in marine and inland areas since 1950, and proportion of inland catches to all catches.

The fish catches in inland fisheries depend on the size of the water area, the productivity of the water bodies and the fishing effort. Consequently, similar lake areas in temperate and tropic areas allow very different harvests. Most often, there is a correlation between land area and lake area, but most areas that were covered by ice during the last glaciation have an unusually high proportion of lakes. Nevertheless, it is not surprising that more than half of the world's inland catches are reported from Asia (Figure 3). Fish landings from inland waters have experienced a more than fourfold increase, roughly three percent annually, since data were first compiled in 1950 (Allan *et al*. 2005). In almost all developing or transitional economies, the inland fish harvests have rapidly increased over the past 10 to 15 years. Developed regions of the world have seen the opposite trend. North America, Europe, and the countries of the former Soviet Union all have declining trends in inland fisheries.

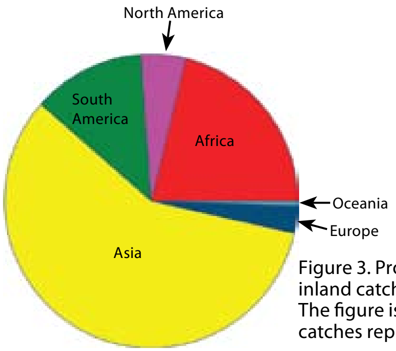

Figure 3. Proportion of inland catches in the world. The figure is based on catches reported in 2006.

Sustainable fishing, just fishing and overfishing

During the period 1950–2006, the landings have changed, in both amount (Figure 2) and composition (Figures 4 and 5). As can be seen in Figure 4, the diversity dropped around 1970, probably when the catches of anchovy sprat reached their maximum. The largest changes in global composition of catches occurred between 1950 and 1970. Some species were not fished (or not reported) in earlier years, like the hilsa shad. The catches that have decreased tend to be the European species, like anchovy sprat and freshwater bream. Species where the catches have been increasing are the Asian and African ones (dagaas, Nile tilapia, Nile perch, silver barb), supporting the observation by Allan *et al.* (2005). There are several reasons for the rapid change from 1950 to 1970: **1)** Increased fish catch by introduction of mechanized boats (especially in the Third World), **2)** introduction (and later improvement) of new vessels and gear materials, and **3)** intensification of exploratory fishery surveys. Most of these changes started in marine fisheries, but spread to inland fisheries. These improvements increased the fishing pressure on preferred species, which in many cases are the top links in the aquatic food chains (e.g. northern pike, pike-perch and brown trout). The result will be that the fishery goes for species further down the food web, a situation that has been called 'fishing down the food web' (Pauly *et al*. 2000).

Such changes in "catch diversity" can only happen if a few species are harvested more than other species. The reasons might be cultural or

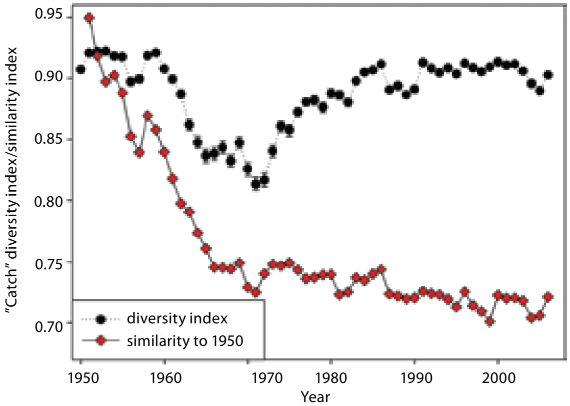

Figure 4. "Catch diversity" for each year and similarity of the global catch composition of fishes each year, compared with the catch composition in 1950. A low value of catch diversity means that the catches are dominated by a few species; a high value indicates that the catches are more evenly distributed among species. The similarity index shows how the composition of catches has changed over time; a value=1.0 means that the species composition is identical with the catches in 1950. The lower the value of the similarity index, the more different the species composition in the catches is compared to 1950. The diversity index is Hurlberts PIE, and the similarity index Czewanoswsi. For PIE the software Ecosim was used. Both indices are based on weight of reported catches in the FAO database.

due to the catchability of the species. Lake Malawi (Africa) has at least 500 species of fish, the great majority belonging to the cichlid family, many endemic to the lake. Five species are particularly important to fishermen: *Chambo* (tilapia) is the most abundant fish in the shallow southern waters, easily caught, easily cured and excellent food. On rocky shores where the bottom slopes away steeply, *utaka* (*Haplochromis*) are caught in substantial numbers, while the salmon-like *mpasa* (*Barilius microlepis*) congregates at the mouths of rivers. The tiny *usipa* (*Engraulicyprius sardella*), similar to whitebait, is highly valued both as food and bait, and there is a market for the catfish, *kampango* (*Bargus meridionalis*) (McCracken 1987).

Humans have interacted with the biophysical environment since the beginning of human history, but the scope

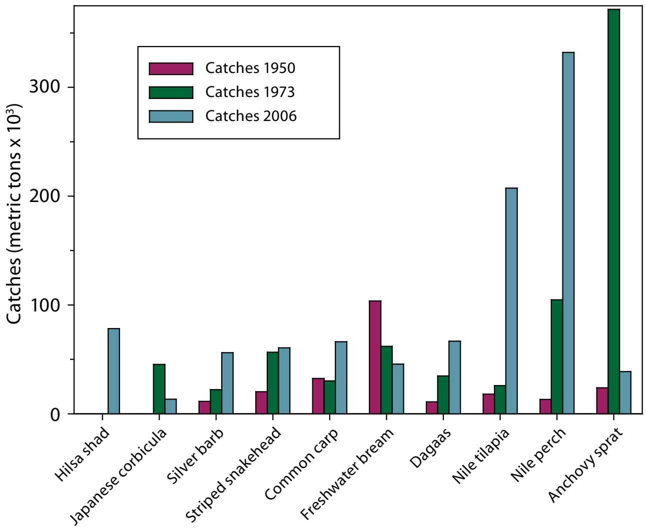

Figure 5. Catches in 1950, 1973 and 2006 according to the FAO database. These ten species are those that over the entire period (1950–2006) have been the most landed in weight.

and intensity of these interactions have increased dramatically since the Industrial Revolution. Historically, most human-nature interaction took place at the local scale, although there were some large-scale human migrations and other broad activities, such as trade and wars. Today, interaction between human and natural systems at the regional, continental, and global scales has emerged as a special concern, because human activities are globally connected. Inland fisheries are still at the local or regional scale, because the fishing in a particular lake or river falls within the jurisdiction of one or a few countries. Most likely, not all countries utilize their inland waters to the same extent. In a perfect world, you could get production values (e.g. primary production) for all lakes that you were interested in and you would be able to measure whether the harvest of different taxa in the lake were sustainable or not. For example, the primary production in tropical lakes might be more then 100 times higher than in high-latitude lakes, ranging from less than 10 g Carbon m^{-2} $year^{-1}$ at high latitudes to nearly 1,900 g Carbon m^{-2} $year^{-1}$ in the tropics (Alin and Johnson 2007). However, locally there can be large differences between nearby lakes. For example, in southern Sweden Lake Vättern (189,300 ha) has a total phosphor content of about 5 µg/l, but in Lake Roxen (9,700 ha; less than 40 km east of Lake Vättern) the total phosphor content is of about 30 µg/l. Consequently, the commercial catches per area unit are much higher in Lake Roxen – 3.48 kg/ha compared to 0.29 kg/ha in Lake Vättern (values from year 2000). As a comparison, in Lake Victoria, the most productive freshwater fishery in Africa, about 112,000 metric tons are harvested each year, corresponding to 16.7 kg/ha, and the total phosphor content is about 52 µg/l in the open lake.

All fish populations can be overfished, i.e. harvested in such amounts that the natural recruitment could not keep up with the human-induced mortality. From a fish population's point of view, fishing is a mortality factor that mostly strikes the population in an unnatural way. Deaths in fish populations are generally split into fishing mortality and natural mortality, but it is a tricky task to separate them. Catch-mark-recapture experiments are the common way to investigate the topic, but these always miss the early mortality experienced by small individuals (from newly hatched juveniles up to "taggable" size). Estimates of fishing mortality are relatively scarce for inland species. For kilka fishes (*Clupeonella* spp.), particularly anchovy sprat (*C. engrauliformis*), in Iranian waters of the Caspian Sea natural, fishing and total mortality coefficient was estimated at 0.69, 0.31 and 1.00 per year respectively (Bourani *et al.* 2008). For Prussian carp (*Carassius gibelio*) in Buldan Dam Lake (Turkey) the total mortality, natural mortality and fishing mortality were calculated as 0.63, 0.46 and 0.18 per year (Sari *et al.* 2008). Crawford and Allen (2006) studied bluegill sunfish (*Lepomis macrochirus*) and redear sunfish (*L. microlophus*) in Lake Panasoffkee, Florida, USA, and concluded that natural mortality had a greater influence than fishing mortality on those two species in the studied lake. Hence, in these three cases fishing mortality were lower than natural mortality. Exploitation rate differs between lakes, making the applicability of general estimates for inland fish species variable. In Lake Oyan (South-Western Nigeria) the fishing mortality has about the same degree as the natural mortality, but in the nearby Lake Asejire, the fishing mortality is about four times higher (Adedolapo 2007).

Fishing mortality is often assumed age-independent, but Jiang *et al*. (2007) showed that both fishing mortality and natural mortality rates are age-dependent, and that it is possible to estimate these age-dependent rates, from tagging experiments carried out over several years. The fishing mortality might have complex appearances: in an excellent analysis of pike (*Esox lucius*) in Lake Windermere, UK, Haugen *et al*. (2007) showed that:

1) The mortality rates differed in northern and southern part of the lake.
2) For large pikes, the fishing mortality was generally lower than natural mortality.
3) For smaller females (30–75 cm), both natural and fishing mortality increased with size, fishing mortality always being higher.
4) For smaller males (30–75 cm), fishing mortality was almost non-existent, whereas natural mortality was high.

With increasing size fishing mortality increased and natural mortality decreased, from male size about 50 cm fishing mortality were higher than natural mortality. Obviously, the population structure should be different in the lake if fishing did not occur.

From FAO data, a running five-year proportional change in catches was calculated for all inland fishes and crayfishes, by species and for some groups of a few species. The first point in the new dataset consisted of the sum of catches from 1955 to 1959, divided with the sum of catches from 1950 to 1954. The second point was the sum of 1956–1960 divided by the sum of 1951–1955, and so on. The new dataset was analysed for each species, with linear regression, and it was tested if the slope was significant and if the intercept at year 1950 differed from 1.0. From these analyses and the raw data, eight categories of changes in catches were identified. Actually there is one more possible category, positive slope and negative intercept ("first-down-and-then-up"), which means that the species first decreased in catches and thereafter increased, but that pattern was not identified for any of the species investigated.

Category 1 – "First-up-and-then-down". In this category, the catches of a species first increase and then decrease, i.e. there is a peak in catches and no sign of a substantial recovery after declining catches. Both the negative slope and the positive intercept are significant. Most likely the species are overexploited, the fishing pressures have more or less depleted the population, and time and regulations (fishing-free areas, reduction of number of fishing days, increased mesh size, etc.) are needed to regain a viable fishery. Of cause there are alternative explanations to the pattern; the catches may have decreased due to political causes (war or other conflicts) or because the species have been pushed off the market by imported fish, or similar reasons. One example is Anchovy sprat from the Caspian Sea (Figure 6).

Category 2 – reports in late years, decreasing catches. These species have only been reported in latter years, thus data points are fewer and the analyses less informative. Most likely, the species were fished before reporting to FAO started, and in many cases it is hard to find information on abundance and landings from earlier years. All species in this category are decreasing, which for some species may mean that the reporting started after a peak in catches. An example is red swamp crawfish that probably, for which reporting began after the export to Europe initiated in 1970s. Sweden (as an example) imports crayfishes from different areas in order to meet demand. The national crayfish resources in many European countries have declined due to the crayfish plague.

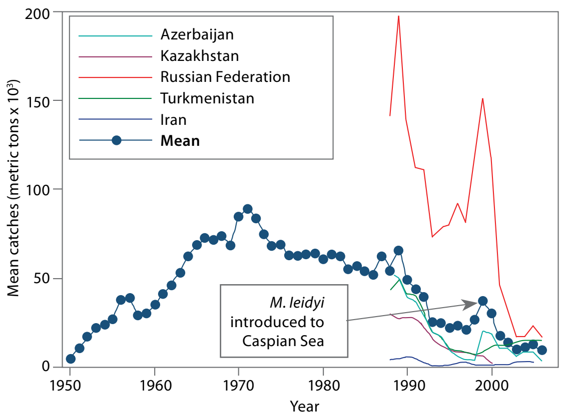

Figure 6. Inland catches of Anchovy sprat. Until 1989, all reports came from the USSR; the mean value from that period has been estimated by dividing the total catch by five. From 1989 onwards, sprat catches are from the five countries that report catches of the species in the Caspian Sea. Total catches peaked in 1971 at 443.5 metric tons. In addition to this, Iran has probably caught about 34,060 (min 2,400; max 95,000) metric tons per year since 1986, but has reported them as "not exactly identified". The ctenophore, *Mnemiopsis leidyi*, (American comb jelly) is a major carnivorous predator of edible zooplankton (including meroplankton), pelagic fish eggs and larvae, which is associated with fishery crashes. The comb jelly is indigenous to temperate to subtropical estuaries along the Atlantic coast of North and South America. In the early 1980s, it was accidentally introduced via the ballast water of ships to the Black Sea where it had a catastrophic effect on the entire ecosystem.

Category 3 – reports in late years, increasing catches. As in the previous category, the species have only been reported in latter years, and it is sometimes hard to get information on earlier years. A good example is beluga. According to FAO data, there has been a slight increase in catches, but this does not mean that the populations have recovered from overfishing. There are three sturgeon species of interest in the Caspian Sea: the beluga (*Huso huso*), the Russian sturgeon (*Acipenser gueldenstaedti*), and the stellate sturgeon (*Acipenser stellatus*), which are important in that they are the primary source of caviar from the Volga-Caspian region. The sturgeons of the Caspian Sea face numerous problems at present (cf. Khodorevskaya *et al.* 2002). Overfishing, poaching, and pollution threaten the stocks. After the division of the Soviet Union, regulation of the legal commercial fishery and the illegal fishery (poaching) has been difficult. Instead of only two, newly created states, such as Azerbaijan, Turkmenistan and Kazakhstan, now regulate their own fisheries along with Russia and Iran. These new states have internal problems more important than poaching, and the black market trade in sturgeon caviar flourishes. Pollution, along with overharvest, has contributed to decimating the beluga population to a point where present day levels are estimated at ten percent of stocks ten years ago. Beluga sturgeon has lost 90 percent of its Volga River spawning grounds (Secor *et al*. 2000). The number of beluga sturgeon entering the Volga to spawn dropped from 26,000 annually in 1961–1965 to 7,000 in 1991–1995 (Khodorevskaya *et al*. 2002) One source indicates that during 1998–2002, an average of only 2,800 individuals were observed (Armstrong *et al*. 2003). In the Ural River, which is unhindered by dams, the number of beluga sturgeon entering the river system declined from 3,900 individuals in 1994 to 2,500 individuals in 2002 (Armstrong *et al*. 2003). Illegal catches have been estimated at 6 to 10 and 11 times greater than legal catches in the Caspian and Azov Seas, respectively (Vaisman and Raymakers 2001) Illegal fishing is one of the main factors causing the continued decline in beluga. Similar discouraging histories might be valid for the other species in this category as well.

Category 4 – increase, and then level off. For these species, with an increase in catches increased to start with, and then levelled off in the last decade or so. This might mean that the catches have reached a maximum, and that future increases in effort might cause the populations and catches to decline. One example is dagaas and Nile perch. Another plausible explanation might be that the market price for the species has decreased and that fewer fishermen are keeping the catches at a steady level with increased efforts.

Category 5 – decrease, and then level off. In this category, the catches of species were high to start with, but subsequently levelled off at a lower level. This might be due to expectations for high yields being exaggerated, or that the decline started after an increase in catches before 1950. An example is common dace. A parallel is the Arctic char in Lake Vättern (Sweden). In this lake, catch data exist from the 1910s and char catches have declined since the 1950s. The start of decline coincided with the introduction of nylon gill nets, which are more efficient than the earlier cotton nets.

Category 6 – sudden high catches reported in late years. Catches of some species have been low, but lately unusually high catches have been reported. Largemouth black bass have been introduced by fishermen, conservation groups, and governmental wildlife departments across the world for recreational fishing. Apart from North America, Japan and South Africa have active programmes. Therefore, the sudden increase is the result of stocking programmes. For the other two species, one explanation might be that they have become profitable after the decline of other species. The asp (*Aspius aspius*) is caught in Iran for food, but makes up only a small portion of the catch. Nevraev (1929) reports catches of 267 to 2,429 fish for the period 1914–1915 to 1917–1918 in the Anzali region. Holčík and Oláh (1992) record the catch in the Anzali region for 1969–1970 and 1970–1971 at 45.2 and 36.1 tons respectively, which was 84 and 69 percent of the total Iranian catch of asp. In 1921–1930, the annual catch in the lower Kura River averaged at 249,000 fish, and in 1936 the Azerbaijani catch was 810 tonnes and 300,000 fish. Since 1950, the species have not been reported from Iran, but might be included in unidentified freshwater species. The landings between 2000 and 2006 varied from one to five tonnes per year. The problem with this category is that few data exist from before 1970s, making it hard to draw any conclusions on the status of these populations.

Category 7 – increasing throughout the period. Species in this category show no indications of levelling off or decreasing. Notable is that this was the case for only one species, silver barb (also called Java barb). It is native to Asia (Sokheng *et al.* 1999), and has been introduced in Oceania.

Category 8 – no change in catches. This category is a hotchpotch of several different species with different histories. It can be divided into subcategories, if the status of the different species is analysed more carefully. One such subcategory is exemplified by Mozambique tilapia, where the catches vary, probably with the natural increases and decreases of the populations. If the catches of this species keep this pattern in the future (*nota bene:* without increased fishing pressure!) this fishery most likely is sustainable (in general, not necessarily locally).

Another subcategory is species, where catches already in 1950 (or before reporting started) had decreased to a low level, and have remained there. One such species might be river lamprey (*Lampetra fluviatilis*). The reporting of this species started in 1987, but the catches probably were much higher in the past. Only four countries have reported high catches, Latvia having the highest catches that peaked in 1997 at 140 metric tons. Former USSR and the Russian federation have also reported high catches of miscellaneous lampreys, but some of them might be *Lampetra tridentate*, the Pacific lamprey, or other species. USA has also reported high catches of miscellaneous lampreys, but not which of the 23 native lampreys that are harvested. Pollution, river engineering works and changes in land use have affected this species. Sweden has observed a decline in numbers of river lampreys migrating upstream for spawning since the 1960s. The catches nowadays are small, but it has been estimated that 1–15 metric tons are caught each year along the northern part of the Gulf of Bothnia.

Yet another subcategory is species where the wild population has been manipulated in one way or another. Atlantic salmon (*Salmo salar*) are commonly stocked, in order to compensate for reproduction losses due to dam constructions, like most of the salmonid species in this category. European eel (*Anguilla Anguilla*, Figure 7) have been transplanted in order to keep up catches. However, all available information on the status of the stock and fisheries supports the view that the population as a whole has declined in most of the distribution area, that it is outside safe biological limits and that current fisheries are not sustainable. Recruitment is at a historical minimum and most recent observations do not indicate a recovery. The level observed since 1990 is below 20 percent of the level observed not more than three generations ago.

A fourth subcategory is species that have minor commercial value (but might be appreciated game species). The catches remain on a stable level, despite fluctuation in population sizes. Such

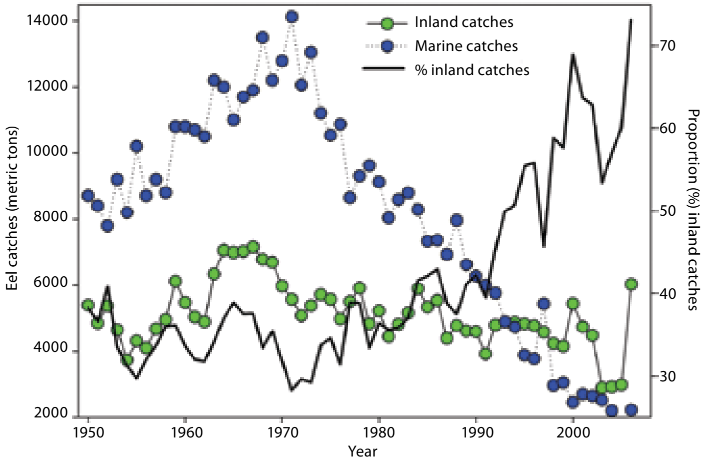

Figure 7. Catches of European eel (*Anguilla anguilla*) in inland and marine areas.

species are ruffe, orfe and the American gizzard shad. The gizzard shad is not valued for human consumption because of its soft, rather tasteless flesh, and numerous fine bones and strong odour. In addition, the species pollution-tolerant, and as such as has increased in numbers in some areas. Thus, the species proliferates in impoundments or eutrophicated water. Another such species is the mud carp.

Fishing to extinction?

According to the IUCN Red List, 81 freshwater fish species have become extinct. For 67 of these, the reason for extinction is unknown (or at least plausible reasons are not mentioned). Extinction may have multiple causes, but alien species are one of the reasons for 12 of the extinct species, habitat destruction for six, fishing for five, and pollution for two. Notable is that of the extinct freshwater species, 31 belonged to the genus *Haplochromis* (African cichlids). However, the assessment for most species needs to be updated; recently updated species are listed in Table 1.

Conventional wisdom among marine fisheries managers is that while overfishing can lead to the collapse of a fishery, it cannot alone bring about the extinction of a species (Karpov 1998), and the same might be true for inland fishes. In the literature, the most referred single threat is water abstraction. In addition, large dams built for irrigation, flood control and power generation have a major impact on species in large rivers, and have led to local extinction of numerous migratory species. Inappropriate fisheries management has led to overfishing and the introduction of alien species (and their diseases). Thus overfishing is not the only – and not the most important – factor in the majority of cases of extinction of inland fish species. The most cited and known example of overfishing and extinction concerns the blue pike (*Stizostedion vitreum glaucum*, a close relative to the walleye; there is a debate about taxonomic status, as it was first recognized as an individual species as late as 1926). Before the 1960s, commercial fishermen caught about 500,000 metric tons each year of blue pike, endemic to the USA and Canada. For

Table 1. Extinct freshwater fishes in the world. The table is based on information from the IUCN Red List (ISSG 2008). Only recently assessed species are included. Thus, there is a bias towards European species; almost all Asian, American and African species need updating.

Family	Species	Water (country/region)	Last recorded
Cichlidae	Ptychochromoides itasy	Lac Itasy (Madagascar)	>40 years ago
	Tristramella intermedia	Hula Lake (Israel)	>30 years ago
	Tristramella magdelainae	(Syrian Arab Republic)	>50 years ago
Cyprinidae	Acanthobrama hulensis	Hula Lake (Israel)	1975
	Alburnus akili	Lake Beysehir (Turkey)	1998
	Barbus microbarbi	Lake Luhondo (Rwanda)	> 50 years ago
	Chondrostoma scodrense	Lake Skadar (SE Europe)	> 20 years ago
	Romanogobio antipai	Lower Danube (SE Europe)	> 40 years ago
	Telestes ukliva	Cetina River (Croatia)	1988
Gasterosteidae	Gasterosteus crenobiontus	Lake Techirghiol (Romania)	> 40 years ago
Poeciliidae	Pantanodon madagascariensis	Rivers (eastern Madagascar)	?
Salmonidae	Coregonus bezola	Lake Bourget (France)	> 40 years ago
	Coregonus fera	Lake Geneva (W. Europe)	1920
	Coregonus gutturosus	Lake Constance (W. Europe)	> 30 years ago
	Coregonus hiemalis	Lake Geneva (W. Europe)	> 100 years ago
	Coregonus restrictus	Lake Morat (Switzerland)	1890
	Salmo pallaryi	Lake Sidi Ali (Morocco)	> 70 years ago
	Salvelinus neocomensis	Lake Neuchâtel (Switzerland)	1904
	Salvelinus profundus	Lake Constance (W. Europe)	> 30 years ago

almost four decades however, nets and lines have come up empty as the blue pike disappeared from its Lake Erie habitat. As the number of blue pike declined through overfishing and the loss of habitats due to pollution by toxins such as mercury, it may have interbred with yellow walleye. The blue pike was declared extinct in 1975. Another species where overfishing has been important to its present very low population numbers is the Chinese paddlefish (*Psephurus gladius*). It is one of the world's largest freshwater species; it can grow to more than four metres and weigh over 150 kg. Since 2003, no adult paddlefish has been caught in the Yangtze River. Even more worrisome, no young paddlefish has been seen since 1995. The species was appreciated for its rich, plentiful meat, and it is said that the giant fish were commonly offered as gifts to the Chinese emperors during imperial times.

Of the 123 species included in the analyses above, only one seems to be increasing in catches, namely silver barb, which has been introduced in several areas in Asia. Some species appear to be stable (no change over time), but most likely this stability is false; the species were already overexploited in 1950 and occur in numbers much lower than they did before overexploitation started. Yet other species have declined, and show a pattern that clearly indicates overexploitation. One category of species seems to have stabilized at a level that might be sustainable. Most of the species listed above need a management plan in order to recover.

Another issue is the collecting of live fish for aquariums. For some popular species, the removal of breeding adults coupled with loss of habitat may significantly have impacted local populations. Such over-harvesting has been documented among characins and the arowana (family Osteoglossidae). However, the impact of aquarists on fish species has two sides. The aquarists obviously can have a role in conservation of some species, if they can be bred in captivity. Aquarists are helping to maintain species that are essentially extinct in the wild. By keeping these species and populations viable, the fish-keeping community is protecting against extinction. When and if reintroduction to natural habitats becomes possible, it will be in part thanks to aquarists.

Fisheries management

Historically, fisheries management and conservation biology were considered different disciplines; the former focused on harvestable species and the latter was concerned with preserving biodiversity, especially non-game taxa (Soulé 1985). The differences between these fields have narrowed and fisheries managers have to consider ways to maximize the sustainable yield of biomass and human enjoyment from fisheries, as well as how to maintain the integrity of aquatic ecosystems and preserve the diversity of aquatic biotas (Rahel 2008). The threats to freshwater fish species are to a high extent also threats to freshwater fisheries. So preserving fish is to preserve fishery, and fishery management is an important part in fish conservation.

Consequently, the first step in a management strategy is to identify the threats and try to find countermeasures. Declines in fish stocks often have many causes, but they are rarely equally important. An analysis revealed that the main threats are species introduction, impoundments (dams and weirs) and water quality problems (Cowx 2002). Habitat degradation, overfishing, flow regulation and over-abstraction of water were also prevalent, but of less importance. A listing of human activities and their effects on trout and salmon can be found in Crisp (1993, 2000). However, ranking and listing gives a general view; for an individual lake or stream, the ranking of threats might be different. In addition, it is hard to sort out and understand the combined effects of different threats. For instance, overfishing with accompanying pollution and habitat destruction in coastal waters has simplified ecosystems and made them respond to external influences in unpredictable ways, as the buffering mechanisms and resilience in the earlier systems have been degraded (Jackson *et al*. 2001).

Even if the threats are identified, the costs can be too high and possibilities low to fire back effectively. Introduced species can be almost impossible to remove, thus the best management strategy is to prevent future introductions. Dams and weirs are usually constructed for irrigation or energy production, making the removal of these constructions politically impossible, even if it is practically possible. Each fishery management issue has to face the attributed importance of other human activities. Moreover, even within the fisheries sector there are conflicting interests. Either the basis for the management is to conserve species, a lake or a stream – the "conservation approach", or the measures are taken in order to maximize the catches of certain species – the "desired harvest approach". In many temperate inland streams (and coastal streams), the management intention has been to make the recreational fishing more attractive. Therefore, the stream management has given high priority to salmonid migration and spawning grounds (Table 2, cf. Bain and Meixler 2008).

Obviously, there are many opportunities for conflicts over the management of an aquatic resource. Although there are many well-founded management manuals for practical measures (reconstructions of spawning beds, removal of weirs, restore canalized streams, etc), there are still the conflicts over if fishing, conservation or something else should be the focus of the measures taken. Thus, there is not only a resource to manage, but also a conflict. It is clear that despite the best efforts of managers and policymakers, diminishing species and declining fish stocks are clear signs that humans are not using natural resources sustainably. This brings into question the efficacy of conventional top-down strategies that dominated this far. Consequently, alternative approaches that devolve decision-making and management responsibilities to local resource users are of interest. In the current natural resources management era, grass-root stewardship is paramount to enforce compliance of hierarchical rules.

Community-based management (CBM) is a term commonly applied to decentralized, grass-root approaches to natural resources management. However, Zanetell and Knuth (2002)

Table 2. Examples of measures taken depending on the basis for the inland fishery management.

	Conservation approach	Desired harvest approach
Practical measures	Reconstruction of habitat to pristine conditions. Removal of introduced species. Stocking in order to re-establish natural species.	Modifying habitat in order to make it optimal for desired species. Removal of all fish (e.g. rotenone) before stocking the preferred species. Removal of individuals in order to get fewer but larger specimens. Stocking in order to increase catches.
Other measures	Fishing strictly regulated or banned. Monitoring for control and adjustment of actions. Action plans for conservation. Eco-tourism encouraged.	Fishing licences. Fishing tourism encouraged. Monitoring for assessment. Investment in infrastructure.

concluded in a study of the Portuguesa river fishery (Venezuela) that the characteristics of the government and institutions might be significant barriers for CBM to work. In particular, a top-down regulatory hierarchy is not conducive to local participation and systematic corruption precludes sustainable resource management. Adaptive management (AM) is another type of management strategy. AM focuses on learning and adapting, through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable ecosystems. Feldman (2008) noted that efforts to agree on a resource allocation formula failed because preconditions needed for adaptively managing in a Florida watershed were impeded by lack of a shared vision and conflicting demands, and separation of water quality and quantity regulations. Most likely, these problems exist in other water disputes as well and highlight limitations in implementing adaptive management practices. Conflicts vary in terms of their legal, political and institutional framework, economic constraints and pressures, social structure, stakeholder interests, ecological situation and history behind the conflict. Perceptions are as critical as 'facts' in identifying and managing conflicts (Jones *et al*. 2005). I think this is partly overlooked by or unfamiliar to many scientists.

A quick look in the crystal ball

A good way to forecast the future is trying to interpret the past. Researchers, administrators and others have warned many times of increased fishing efforts. More than 300 years ago, a Swedish author wrote about Lake Mälaren (Fisherström 1785):

> *There is a general complaint that the catches of fish have been declining seriously. However, as more people fish today than before, as tributaries and streams are more and more cut off, as the disturbance of the spawning activities is increasing, as the forests are incautiously cut down along islets, spits, and inlets, where the fish thrive, and when too large and fine-meshed seine nets are used, removing the sexually immature fish and fish fry, the cause of these changes are easily identified.*

And little more than 60 years ago, this was written about introduction of alien species (Norman 1947):

> *However much such introductions of foreign species may benefit the sportsman, they are to be wholly deprecated by the biologist, who wishes to study the indigenous fauna of a country under normal conditions, and it has been found necessary to enter a strong protest against these interferences with natural conditions. … In the Great Lake of Tasmania lives a most interesting crustacean of an archaic type, which is found nowhere else in the whole world: the introduction of Trout into the lake has played a considerable part in the decimation of this creature.*

(Until now, no species has become extinct. For more information about Tasmania Great Lake, see Threatened Species Section 2006.)

Therefore, there have been warnings and facts for a long time, but has overfishing stopped, has introduction of new species stopped? No. Both the marine and the inland ecosystems have their limits, the yield cannot be higher than the production the ecosystem offers. All harvest above the production will inevitably lead to a decrease in the fish population and thus a decrease of the catches. There are management methods that will improve the catches marginally, such as fishing free periods during spawning migration, size limits, selective fishing gears, etc. In the future three threats are obvious for inland fish and fisheries:

1. **Alien species:** The introductions of new species also threaten the ecosystem in the receiving waters. It is worrisome that the three species in Figure 5 with increased catches during the period 1950–2006 all have been introduced in different areas. If this will be seen as the best way to restore the fishery in waters where the desired species have been more of less depleted, more fish species will become extinct in the future. Each introduction is a threat, not only to native fish species but also to other taxa. Not all threats will be realised, and the uncomfortable truth is that we are not able to do clear-cut risk assessments.
2. **Environmental changes:** As the human population grows, the pressure on water resources for irrigation and drinking water will increase. Water from irrigated agricultural areas may go back to the lake or river, but then most likely transporting mud, nutrients and pesticides. The need for wood for cooking or building will open up land, which in turn will increase run-off; the water becomes more turbid, more sedimentation occurs and land areas become eroded. Grazing might have the same effect. In Switzerland, the brown trout has declined by about 50 percent in 15 years (Burkhardt-Holm *et al*. 2002). A large project was launched to investigate the decline. One conclusion was that suboptimal habitat conditions are the most important and ubiquitous stress factor and have effects of sufficient magnitude to explain the reduced fish populations observed (Borsuk *et al*. 2006).
3. **Overfishing:** To catch more than a lake produces, threatens both the biodiversity of waters and the ecosystem goods and services on which people rely. At the same time, fishing pressure interacts with other factors, like pollution and habitat destruction. Managing fisheries today is not limited just to satisfying the commercial fishing industry, but must accommodate the wide array of economic and social benefits that people derive from freshwater ecosystems, including food security and economic growth (Allan *et al*. 2005). Overfishing is caused by overcapacity and excess effort. This is in turn due to the generally open access regimes of many inland fisheries and to the effective use of fisheries as an occupation of last resort in developing economies. High fishing pressure will doubtlessly result in population decline, and if the fishing effort then increases, the situation will deteriorate. For instance, large increases in numbers of fishers and fishing effort have been noted

in Zambia and Zimbabwe (Marshall 1992), the former experiencing an eightfold increase in fishing effort on the sardine fishery, the latter a fivefold increase in the ten years to 1989. The Ugandan sector of Lake Victoria (Kudhongania *et al*. 1992) experienced an increase in the number of fishing canoes from about 3,300 in 1971 to 8,000 in 1990. The Tanzanian sector of Lake Victoria has experienced an even more dramatic increase in the numbers of fishers (Mwamoto and Hoza 1992).

Previously, fisheries science and management mostly has focused on one species at a time. This is still the case in most management advice. There is clearly a need for a shift from single species to ecosystem-based fisheries management (Pikitch *et al*. 2004). However, this will be a new and difficult task; it is not only important to assess the effects of fishing on community-wide interactions among fish populations, it is necessary to extend the assessment beyond fish populations (e.g. to benthos or producers). Harvest reserves and no-take zones, strategies with similar potential for achieving benefits beyond the fishery itself, have attracted impressive attention from the marine conservation and management communities (Hilborn *et al*. 2004) and also merit greater attention in inland waters (Hoggarth *et al*. 1999).

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INLAND FISHERIES IN THE LOWER MEKONG BASIN – IMPORTANCE, CHALLENGES AND MECHANISMS TO MEET THOSE CHALLENGES

Chris Barlow

The fisheries in the Mekong river are immense, even by world standards. Recent studies have shown that the yield from the fisheries and aquaculture (including aquatic animals other than fish) is between two and three million tonnes per annum. To put some perspective on that figure, the capture fishery yield from the Mekong is approximately two percent of the total world marine and freshwater capture fishery.

Extrapolation from average prices for capture and aquaculture product gives a first sale value for the fishery of at least USD 2,000 million. This figure is very conservative and probably an underestimate, due to increasing price of fish and the rapid expansion of aquaculture in the Mekong delta in Vietnam in the last few years. The multiplier effect of trade in fisheries products would increase the value of the fishery markedly.

There are about 850 species of fish in the Mekong freshwater system, with many more marine vagrants occasionally entering freshwaters. In terms of fish biodiversity, the Amazon River contains the most fish species of any river in the world, but the Mekong probably ranks second along with the Zaire river. The Mekong has more families of fishes than any other river system. Up to 100 fish species are regularly traded.

The fisheries are nutritionally important for the approximately 60 million people living in the Lower Mekong Basin (LMB). Fish are the primary source of animal protein, and a major supplier of several micro-nutrients, notably calcium and vitamin A. Consumption of fishery products is about 46 kg/person/year as fresh-fish-equivalent, or 34 kg/person/year as actual consumption. There are no readily available foods to substitute for fish in the diets of people in the LMB. Hence, fisheries are extremely important for food security.

The major threats to the fisheries of the Mekong are loss of habitat, reduction in the extent or changes to the timing of the annual flood, barriers blocking migration of fish, and over-fishing. The first three of these arise from activities outside the fisheries sector, such as alienating wetlands for agricultural or industrial development, flood control schemes, and dams for irrigation and hydropower development. Building of dams for hydropower production is a high priority activity for governments in the region. These include dams on the mainstream of the Mekong, which will be very deleterious for the fisheries based on highly migratory species (the “white fishes”). Management agencies face difficult decisions in balancing the needs for development (for instance hydropower dams,

	Cambodia	Lao PDR	Thailand	Vietnam	Total
Estimated consumption (kg/capita/year as actual consumption) of inland fish and other aquatic animals in the LMB					
Inland fish	32.3	24.5	24.9	34.5	29.3
Other aquatic animals (OAAs)	4.5	4.1	4.2	4.5	4.3
Total inland fish and OAAs	36.8	28.6	29.0	39.0	33.7
Estimated consumption (tonnes/year as fresh whole animal equivalents) of inland fish and other aquatic animals					
Inland fish	481,537	167,922	720,501	692,118	2,062,077
Other aquatic animals (OAAs)	105,467	40,581	190,984	160,705	497,737
Total inland fish and OAAs	587,004	208,503	911,485	852,823	2,559,815

Table 1. Fish consumption in the Mekong river areas of Cambodia, Lao People's Democratic Republic, Thailand and Vietnam, based on populations in the year 2000.

The total tonnage of fish consumed in the Lower Mekong Basin (LMB) is a surrogate measure of yield in the LMB. However, the consumption figures for each country are not indicative of the yields within the countries, as they do not account for the trade of fisheries products between countries.

Details can be found in Hortle, K.G. 2007. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin, *MRC Technical Paper* no. 16. Mekong River Commission, Vientiane.

with their focused income streams and easily recognized benefits) with maintenance of fisheries (which are a form of traditional, communal wealth with generalized benefits which are not readily appreciated).

Mechanisms for managing the fisheries include traditional effort and gear restrictions as well as protected areas; but the most widely developed management approach is co-management, or communities and governments working together under various arrangements to manage the fisheries jointly. It is paramount to communicate effectively to governments the importance and value of fisheries in comparison with other water development activities, if the resource is to maintain its current level of productivity. Within the Mekong, the governmental fisheries agencies and the Mekong River Commission (MRC) have also developed a regional fisheries management body (known as the Technical Advisory Body for Fisheries Management, or TAB). The TAB has brought the regional element of fisheries management into the realm of national agencies. However, it and other fisheries bodies still face considerable obstacles in communicating the importance of fisheries across all levels of government and into private commercial development initiatives.

RECREATIONAL FISHERIES – SOCIAL, ECONOMIC AND MANAGEMENT ASPECTS

Phil Hickley

Abstract

The importance of commercial capture fishing is decreasing and recreation is becoming the more important beneficiary of fish stocks. In most developed countries recreational fishing is now the principal form of exploitation of most inland and many coastal waters. Approximately a tenth of the population across all countries engages regularly in recreational fishing, providing much social, economic and ecological benefit to society. Recreational fishing is a major economic driver; overall economic impact of angling in the United States of America being USD 125 billion, and in Europe the annual expenditure by anglers is an estimated EUR 25 billion (EUR 1,000 angler^{-1}). In addition there are benefits to the social fabric of both rural and urban areas. The regulation and management of recreational fisheries must address overall fishery performance, that is the total package of conservation or improvement of fish stocks and fish habitats, fishing satisfaction as measured by catches, and the fishers' environment such as scenic beauty, access to the water, and congestion management. An ecosystem approach to recreational fisheries management should be adopted wherever feasible and it is essential that the sector recognizes its responsibilities. Issues for the recreational fisheries sector in the future include such challenges as multi-user demand on its resources, non-native species introductions, fish welfare, over-exploitation and changing attitudes of fishers and the public. Given that recreational fishing is a pleasure activity, management philosophy should rely less on fish ecology and increasingly on social science with stakeholders promoting recreational fishing whilst recognizing that this has to be alongside conservation and protection of the sector's resource.

Introduction

The fisheries sector comprises commercial, subsistence and recreational fisheries but commercial activity has predominated in marine and inland capture fisheries. In response to societal change, the importance of commercial capture fishing is decreasing and recreation is becoming the more important beneficiary of fish stocks. In most developed countries recreational fishing is now the principal form of exploitation of most inland and many coastal waters. Approximately a tenth of the population across all countries engages regularly in recreational fishing, providing much social, economic and ecological benefit to society and harvesting millions of fish on a global scale. Unfortunately, in the context of international policy on the management and conservation of resources and ecosystems, recreational fisheries have been largely overlooked, probably in the belief that they are less valuable than commercial fisheries, but recent research has clearly challenged this perspective (Cooke and Cowx 2006) and the situation is being addressed.

Recreational fishing has been described as the ritual pursuit of pleasure associated with the experience and such experience is one of the most prized conditions of being human (Kellert 1984). There are two principal components to be considered; a fishing factor which includes the number and size of fish caught, and a recreational factor which includes non-catch components such as personal satisfaction. Aspects contributing to satisfaction are senses of freedom, excitement, relaxation, enjoyment of the natural setting and, less important than might be expected, catching a fish. Beyond this, in many places, recreational fishing is now big business and can be important both in contributing to rural economy and in providing social benefits in urban areas. It is also increasingly recognized that recreational fishing fulfils a valuable role in raising environmental awareness of wildlife and the environment.

History

Egyptians invented various methods for fishing and these are clearly illustrated in tomb scenes and papyrus documents; the oldest known illustration of an angler using a rod or staff being dated about 2000 BC. It was in 1496, however, that the first real guidance on the use of a fishing rod was published in English. Usually attributed to Dame Juliana Berners from an abbey near St Alban's, the book is entitled *A Treatyse of Fysshynge wyth an Angle*. In the opening text the author asks "whiche ben the meanes and the causes that enduce a man in to a mery spyryte", goes on to name the "foure good disportes and honest gamys… of huntynge: hawkynge: fysshynge: and foulynge", and proclaims that "The beste to my symple dyscrecon whyche is fysshynge: callyd Anglynge wyth a rodde: and a lyne and an hoke.". This implication that angling can seemingly induce a person into a merry spirit certainly embraces the principle of recreation as it is understood today.

A later and equally definitive work followed in 1653 when English angler Izaak Walton published *The Compleat Angler, or the Contemplative Man's Recreation*; perhaps the single most influential book ever published about recreational fishing. Since this mid 17th century commendation of angling as a recreational pursuit, a whole variety of different angling practices have developed, both freshwater and marine.

Definitions

To require a correct and robust definition of 'Recreational Fisheries' might appear relatively unimportant but, in fact, there is a need for absolute clarity if best practice, policies and legislation are to be developed and applied in an appropriate way. The FAO (1997) defined recreational fisheries as those in which *fishing is conducted by individuals primarily for sport but with a possible secondary objective of capturing fish for domestic consumption but not for onward sale*. This statement, based as it is on motivation, could be considered as not generic enough. A suitable redefinition could be: Recreational fisheries are those where *fishing is conducted during times subjectively defined by the individual as being leisure and for aquatic animals that do not constitute the individual's primary resource to meet nutritional (physiological) needs*. With this definition, if fish did constitute a primary resource to meet nutritional needs, the fishery would be commercial (if products are sold or traded) or purely subsistence but not recreational.

The recreational fisheries sector is best described as being the entire network of stakeholders involved in recreational fisheries from ministries, non-governmental organisations and managers through to associated business operators, the specialist media and, of course, the recreational fishers themselves. Also, some non-fisheries stakeholders could be considered part of the sector if their activities impinge on the exploitation of recreational fishing opportunities.

In theory, given that it is concept of catching fish as a leisure activity that makes recreational fishing what it is, any form of fishing gear can be used. In practice, however, certain fishing methods predominate, especially hook and line, gill nets, spears and various types of trap. Also, fishing with a specialized bow and arrow is increasing in popularity. Globally, however, angling with a rod and line is by far the most common recreational fishing technique, which is why recreational fishing is often assumed to be synonymous with angling.

Status

Recreational fishing is one of the largest participatory pastimes. Across Europe, the number of anglers is approximately 25 million, representing 6.5 percent of the EU population, although such participation varies noticeably across countries, with Eastern Europe generally showing lower rates (e.g. Poland 1.6 percent, Slovakia 2.3 percent, Czech Republic 2.6 percent) and Nordic countries higher ones (e.g. Sweden 22.7 percent, Finland 26.7 percent, Norway 32.2 percent).

In the United States of America, almost 30 million adults went angling during 2006. Ignoring overlap, 25 million people fished in freshwater, 8.5 million fished in saltwater and 1.5 million in the Great Lakes. Activity was assessed at nearly half a billion fishing days. Similarly, fishing is an important leisure activity in Australia with 3.5 million (19.5 percent of the population) fishing at least once a year. Inland waters are much less frequented than in Europe or the USA with sea fishing at 45 percent of fishing effort (coastal 41 percent), estuarine at 35 percent and freshwater at 19 percent.

Note, however, that accurate participation figures are notoriously difficult to quantify. Assessment methods that use fishing licence sales tend to produce lower estimates than those obtained when specialist surveys are carried out.

This is because the number of people that can legitimately be counted as being anglers do not all fish during any one year, so the churn rate ought to be taken into account. For example, during a recent survey in England and Wales (Simpson and Mawle 2005), six percent of the population over 12 years of age said that they had been freshwater angling in the previous two year period but only 2.9 percent of the population held a fishing licence during the year of the survey. Notwithstanding such inaccuracies and errors, however, the popularity of recreational fishing cannot be disputed.

Target species

A fisher's preference for type of fishing and target species, angling or otherwise, is most likely influenced by upbringing, local practice, availability and fashion. The range of opportunity is immense; big game fishing in the Indian ocean, tournament fishing for bass in the United States, stealthy fly fishing for brown trout in an English stream, to name but a few.

European recreational fisheries are based mostly on coarse fish (cyprinids and other non-salmonids) whether or not the catch is generally retained (mainland Europe) or released (e.g. United Kingdom). Other species such as trout (*Salmo trutta*), salmon (*Salmo salar*), sea-trout (*Salmo trutta*) and pike (*Esox lucius*) are important to specialist fishers, especially in Nordic countries, but the generalization is fair as demonstrated by the following examples. In England and Wales, a typical angling catch from the middle reaches of the river Severn comprises chub (*Leuciscus cephalus*), roach (*Rutilus rutilus*), dace (*Leuciscus leuciscus*), and gudgeon (*Gobio gobio*) as principal species (North and Hickley 1989). Records for France (CSP 2004) show bream (*Abramis brama*), zander (*Sander lucioperca*), barbel (*Barbus barbus*) and catfish (*Siluris glanis*) as important. In Poland (Wolos *et al.* 1998), carp (*Cyprinus carpio*), bream (*Abramis brama*) and roach (*Rutilus rutilus*) predominate.

In the United States (USF and WS 2006), black bass (*Micropterus salmoides, M. dolomieu*), catfish (*Ameirus* spp., *Ictalurus* spp.) and trout (Salmonidae) sustain the bulk of recreational fishing in freshwater other than in the Great Lakes where walleye (*Sander vitreus*) take the lead. In the less popular sea fisheries, flatfish and red drum (*Sciaenops ocellatus*) are most frequently landed.

Principal finfish species harvested from saltwater by Australian recreational fishers are whiting (Sillaginidae), flathead (Platycephalidae), Australian herring (*Arripis georgianus*), bream (Sparidae), mullet (Mugilidae), and garfish (Hemiramphidae) (Henry and Lyle 2003). Also taken in large numbers are prawns (Penaeidae) and yabbies (*Callianassa australiensis*). In freshwater, carp (*Cyprinus carpio*) and golden perch (*Macquaria ambigua*) are the main catch from rivers, and perch (*Perca fluviatilis*) and trout (Salmonidae) from lakes.

Angler preferences can be seen to change with time. For example, in England and Wales the preferred target species amongst coarse (non-salmonid) anglers during 1969–1970 was roach

(*Rutilus rutilus* 39 percent) followed by pike (*Esox lucius*, 29 percent). In 1994, although one quarter of anglers did not mind which species they caught, of those with a preference, 36 percent expressed a preference for carp (*Cyprinus carpio*), 28 percent for roach (*Rutilus rutilus*) and 21 percent for bream (*Abramis brama*). Using reports in the angling press as a barometer of angler preference, not only is the popularity of carp fishing continuing to increase but the number of specialist anglers wanting to catch the exotic, novelty species is also increasing. Also, there is an increasing preference for stillwaters which has led to the creation and intensive stocking of purpose-built fisheries and an ongoing reduction of fishing on rivers.

Economic value

Sportfishing is truly a major economic driver and America's conservation powerhouse. This is the view held by the American Sportfishing Association. Moreover, there is evidence available to support such a view. In the United States of America, anglers generated USD 45 billion (USD 900/angler^{-1}) in retail sales. This level of spend stimulates the ripple effect of providing income which generates yet more spend. Economic multipliers can be remarkably effective; the overall economic impact of angling in the USA was USD 125 billion and this supported over one million jobs nationwide. Similarly, in Europe the annual expenditure by anglers is an estimated EUR 25 billion (EUR 1,000/angler^{-1}). The importance of this spend is put into perspective when compared with total EU fishery imports of EUR 24 billion and exports of EUR 13 billion. In Australia, estimated expenditure on services and items attributed to recreational fishing was AUD 1.8 billion over a 12-month survey period, AUD 552/fisher^{-1} yr^{-1}.

It is because environmental economics is such an important tool for the strategic management of the aquatic environment that in recent years attempts have been made to quantify the value of recreational fisheries, as in the following example from the United Kingdom. In England and Wales, recreational angling is an important business with the most recent study (Radford *et al.* 2007) having shown total angler effort on freshwater angling by licensed anglers to be 30.25 million angler days. The gross expenditure related to this level of activity is GBP 1.181 billion (USD 2.3 billion) with coarse (non-salmonid) angling responsible for GBP 971 million (USD 1.9 billion) of this. This equates to an average spend per angler of almost GBP 1,000 (USD 1,950) per year. In addition, these expenditures generated household income of GBP 980 million (USD 1,900 million) yr^{-1} and supported 37,386 jobs across England and Wales. If angling were to cease, although expenditure would be diverted to other activities, it is estimated that over GBP 130 million (USD 250 million) in household income and 5,000 jobs would be lost.

Fisheries where there is a non-use public interest can also be described in terms of existence value, the value that is derived by an individual from knowing the resource exists regardless of whether or not it is exploited. Financial figures have been attributed to existence values but it could be argued that it is their political rather than actual monetary value that is of greater importance.

Fishing as tourism is a particularly important component of the recreational fisheries economy in some countries. Of course, fishing days gained by one region or country are lost by the home location but there will be overall economic benefit to the sector from additional expenditure on travel and accommodation. In the United States, the top three destination states for fishing by non-residents were Minnesota, Florida and Wisconsin. The top three states for resident fishing days exported to other states were Illinois, Texas and Pennsylvania (Ditton *et al*. 2002). Some fishery development specifically targets tourist interest as the outcome e.g. the Funen sea trout (*Salmo trutta*) project in Denmark (Møller and Petersen 1998). It can be a specific species, rather than fishing in a particular region or country, that provides anglers with the motivation for fishing away from home. Freshwater angling tourists visit Ireland seeking high quality roach (*Rutilus rutilus*) and bream (*Abramis brama*), France for specimen carp (*Cyprinus carpio*) and Spain for the famous, giant wels catfish (*Silurus glanis*) of the river Ebro. The main attraction for sea angling tourists is often big game fish, especially billfish, and often in exotic locations such as Africa or the Caribbean. It is important, however, that infrastructure is such that an appropriate share of the tourist spend makes its way into the supporting country's economy. In Kenya, for example, where recreational sea fishing is almost entirely based on foreign tourism and daily fees run into many hundreds of dollars, in some cases, only a small proportion of the income goes beyond the operating company.

It is clear, therefore, that angling in industrialised societies constitutes an important and highly valued leisure activity. Always associated with direct angling expenditure are indirect and induced financial flows in local, regional and national economies, including effects on employment and transfer of expenditure via tourism. Overall, recreational fishing provides a myriad of economic, social and ecological benefits to society, albeit the exact dimensions are often poorly known or very difficult to quantify.

Social welfare

Peirson *et al*. (2001) demonstrated benefits of recreational angling to the social fabric of both rural and urban areas. The mixed Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*) fishery of the river Teifi in rural Wales has not only injected money into the local economy but has also contributed to social benefits of generating employment. In Leeds, a large city (population circa 725,000) in the north of England, an important reason for people going fishing is that of being with friends. Many of the angling clubs in England and Wales are based at social clubs and places of work which highlights how fishing plays an important social, communication and relaxation role in the lives of the participants. In the inner city, recreational fishing can be particularly important in raising social and environmental awareness amongst young people, who are increasingly disconnected from the natural world.

That angling can become an alternative to crime and drugs is exemplified by the 'Get hooked on fishing' campaign in the United Kingdom (Brown 2007) whereby the police, Environment Agency and others support fisheries projects that provide angling opportunities for young people, thus providing positive distraction from involvement in youth crime.

Management

The basic fisheries resource needs to be managed so as to optimise the social and economic benefits from its sustainable exploitation. It is important to recognize that the resource comprises not just fish stocks but includes their habitat and all the economic and social features of the fisheries which the stocks actually or potentially support. Also, an understanding of the fishers' environment is essential. There are two important components which recognize the human and non-human dimensions of recreational fisheries systems, namely improving the quality of life and enhancing wildlife. Thus, the regulation and management of recreational fisheries must address overall fishery performance, that is the total package of conservation or improvement of fish stocks and fish habitats, fishing satisfaction as measured by catches, and the fishers' environment such as scenic beauty, access to the water, congestion management and so forth. In many instances, however, success is as much about management of perception as it is about reality.

One of the main challenges is to manage recreational fisheries with respect to changing user habits and attitudes. Fishing pressure is often highest at key locations where anglers know they will get a good return for their effort. In particular, many lake fisheries are overstocked in conventional terms in order to meet popular demand for a guaranteed high catch rate. Modern management strategies not only have to balance the protection of stocks with fishery performance but also have to account for business needs. Such strategies must have a sound base and so fisheries science should have a role in supporting the interface between facts and perceptions when managing overall fishery performance.

An ecosystem approach to recreational fisheries management should be adopted wherever feasible. The ecosystem approach strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems, and their interactions, and applying an integrated approach to fisheries within ecologically meaningful boundaries. The ecological services thus derived from the aquatic ecosystems and fish stocks comprise services that are supporting (e.g. nutrient cycling), regulating (e.g. water quality), provisioning (e.g. fish yield, recreational fishing experience) and cultural (e.g. existence value, spiritual and educational dimension). In any event, management measures should attempt to ensure that recreational fishing effort is commensurate with the productive capacity of the fishery resource. In many recreational fisheries, it may be necessary to adopt a regional perspective such that management measures introduced for one fishery do not induce undesirable consequences for another; for example, if fishers move to exploit a different fish stock in response to a new control measure.

A key tool in the management process is regulation. The law is capable of directing people away from certain ways of catching fish and towards others, the objective being to confine recreational fish capture to fair and sustainable methods. However, regulations should be used in as sensitive a manner as possible and be as sparing in their imposition as is compatible with preserving the ethic of stock conservation and the wise and acceptable use of the fishery. Transferable from the commercial sector are the traditional approaches to the protection of fish stocks and the maintenance of sustainable yield. Techniques include the imposition of closed sanctuary areas and closed seasons, limitations on the size or amount of catch, control over the amount of fishing, restrictions on types of gear used and the definition of permissible conduct. Note that input control measures (i.e. effort controls, closed areas, closed seasons) are more likely to be successful than output control measures (i.e. size-based harvest limits, bag limits, gear restrictions, mandatory catch-and-release) as the latter measures do not constrain total recreational fishing effort and mortality. Whatever regulatory mechanisms are employed, the implementation thereof is highly dependent upon education and liaison, whether this be the education of decision makers, user groups and general public or the improved understanding and communication between fisheries managers and the fishers.

For the effective management of recreational fisheries in the long term, it is essential that the sector recognizes its responsibilities. Accordingly, the sector should:

- promote high quality recreational fishing experiences within the limits set by ecology, economics and society;
- adopt measures for the long term conservation and sustainable use of recreational fisheries resources;
- adopt the ecosystem approach as the guiding philosophy and exercise the precautionary principle;
- identify all relevant parties having a legitimate interest in the recreational fisheries resource and engage them in the management process;
- base recreational fisheries management action on pre-defined management objectives, formulated as a recreational fisheries management plan;
- consider all environmental, economic and social values and impacts in the appraisal of management measures.

A multitude of factors can contribute to good quality recreational fishing, e.g. scenic beauty, amenities, availability of fish species and the type of fish caught. Ultimately, the assessment of recreational fishing quality depends upon a subjective evaluation by the fisher as to the perceived fulfilment of the needs that the fishing experience was supposed to provide. So, irrespective of how good management strategies might appear to those responsible for implementation, account must be taken of such subjectivity so that the important element of fishery performance is not compromised. In this context, fishing trip satisfaction has been defined as the fulfilment of various psychological outcomes (Holland and Ditton 1992). These include not only the catching of fish but also a sense of freedom, excitement, relaxation and enjoyment of nature. Unfortunately, with an increasing degree of industrialisation and urbanisation of societies, fishers are at risk of losing the ability to link aquatic ecosystem status to fish stock health and fishing quality.

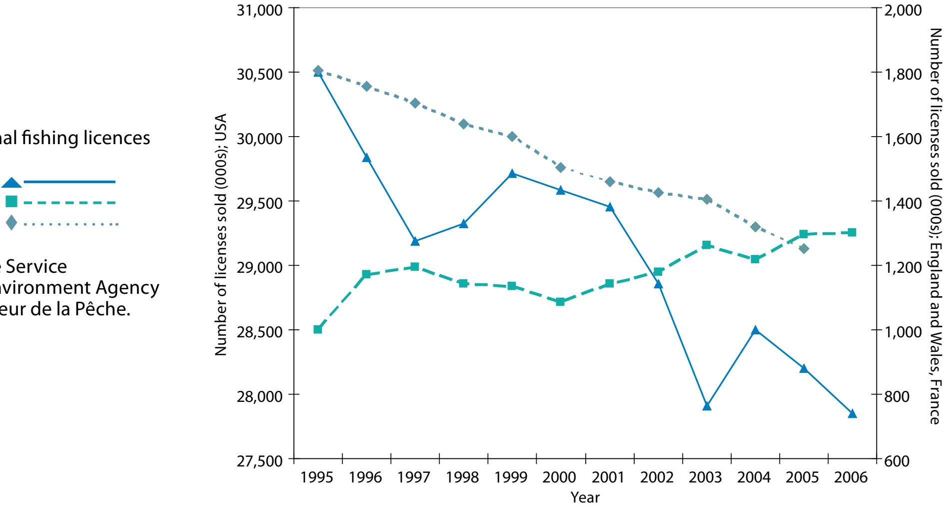
Issues for the future

The main issues to be addressed now and in the future are not so much related to conventional fisheries problems but centre more around pressures induced by user groups and their activities and attitudes. Whilst there are universal, environmental concerns such as water resource management, land use practices, diffuse point pollution and climate change, the recreational fisheries sector has to face such challenges as multi-user demand on its resources, non-native species introductions, fish welfare, over-exploitation and changing attitudes of fishers and the public.

Participation

Notwithstanding the demonstrable value of recreational fishing, some downward changes in participation rates could be problematic. Figure 1 shows three examples of fishing licence sales during a ten year period. Contemporary press reports quote the American Sportfishing Association as "being concerned about the numbers" and for France the headline is that the

Figure 1.
Numbers of recreational fishing licences sold in:
The USA
England and Wales
France
Data sources:
USA: US Fish & Wildlife Service
England and Wales: Environment Agency
France: Conseil Supérieur de la Pêche.



"number of fishers continues downward slide". (The steady increase shown for England and Wales is the result of a specific action plan, outlined later in this section.)

To properly address participation issues it is necessary to understand types of anglers, reasons for fishing and, just as important, reasons for not wanting to fish. Clearly, being interested in the variety of aspects associated with a recreational activity is generally considered a pre-requisite for engaging in that activity. Some people do not fish because it is not something that they are interested in pursuing, while some may try fishing only to find out that they do not enjoy it. Others might have an interest but are constrained by factors that inhibit them from actively participating. Constraints on fishing and people's behavioural response to different management actions were investigated by Aas (1995). In terms of the general, non-participatory public, there was a perception that fishing is boring. Interested non-participants cited constraints such as lack of time, child care responsibilities and old age. Not having someone to go fishing with is also a key factor. It is vital that stakeholders are able to recognize the nature of any constraints if marketing and management is to be cost-effective. As summarized by Fedler and Ditton (2000): *Intrapersonal constraints* are constraints that involve a person's psychological state and affect preferences for recreational activities; *Interpersonal constraints* are constraints that are the result of personal interactions with others that can influence activity preferences as well as participation frequency; *Structural constraints* are items that generally come between the desire to participate and the ability to do so. It is probably within the structural constraints category that most can be done to recruit participants. For example, whilst authorities can do little to address the lack of time constraint, they do have the facility to improve fishing access and opportunity.

Equally important as the assessment of actual participation is an assessment of churn rate. In Texas, of persons classed as recreational fishers, 17 percent were inactive, six percent were recent drop-outs, 27 percent had re-started fishing and only 50 percent were continually active anglers (Fedler and Ditton 2001). It was shown that in any particular year, nearly a quarter would quit fishing within one or two years. In terms of substitution activity, anglers were asked if there were other outdoor recreation activities that would provide them with the same satisfaction and enjoyment they received from fishing, 51 percent answering that there were (Ditton and Sutton 2004). The most frequently identified substitutes were hunting and golf for males, and camping and swimming for females. Knowing the relative proportion of residents and tourists who are likely to be interested or not interested in fishing within active, inactive, and non-fisher groups is essential if future trends in recreational fishing are to be predicted and managed.

To counter slippage in numbers of fishers, the benefits of recreational fishing needs to be better publicised to potential participants. A potential fisher is one who has not been fishing in the last few years but who is interested in doing so in the future and the category includes both lapsed participants and possible new recruits. Promotional activity is extremely worthwhile, if the England and Wales experience is representative. Sales of angling licences have increased steadily in recent years (Figure 1) and this is considered to be the direct result of targeted marketing, developed specifically to increase participation (Environment Agency 2006). This promotional activity is expensive but an investment of two percent of licence income is preventing the decline in angling seen elsewhere and is delivering average sales income increases of six percent. In parallel, working in partnership with other stakeholders saw associated activities such as the creation of the Get Hooked on Fishing Charitable Trust, through which many thousands of young people have been coached successfully in angling and have then continued with the sport (Brown 2007). Also, National Fishing Week, whereby fishery owners organise about 500 events, gives people of all ages the opportunity to try angling for the first time. Note, however, that not all progress can be by enticement and some enforcement is a necessary part of the process, with unlicensed anglers being prosecuted and fined.

Conflicts between users

Much scope exists for conflict between user groups when human activity impacts upon the aquatic environment. Recreational users are likely to protest at the negative impacts of pollution, pesticides and eutrophication on water quality, and that of abstraction, hydropower and impoundment on water resources. Less comprehensible is the often shown reluctance to sharing a recreational facility across the user groups where a favourable interaction between fishers with others would be more constructive in maximising the benefits to society. Angling is known to conflict with groups such as bird watchers and boaters; the concept of behavioural interference. Apart from direct competition for use of the resource, there are concerns such as the damage done to wildlife by discarded fishing tackle. The conflict matrix can be complex but most areas of contention can be categorised as horizontal conflicts between potential users or vertical conflicts between management authority and user desires.

Consultation is always proposed as the panacea for conflict resolution. To a large extent this is true. Consultation with interest groups is essential, alongside a quantification of the scale of potential problems, and the establishment of decision making regimes. Increasingly, managing people, rather than managing the fish directly, appears to be a more constructive approach. Given that interactions and conflicts between stakeholders are the rule rather than the exception in many recreational fisheries, the sector and individual participants in recreational fisheries should ensure that decision making processes are transparent and differing views are handled in a democratic way. The participation of interested parties before policy actions are taken enhances the likelihood of a sustainable outcome in terms of recreational fisheries management in particular and aquatic ecosystem development in general. During any consultation process, however, it will be necessary to strive to avoid negative interactions both within the sector (e.g. between angler groups) and across the sectors (e.g. between fishers, dog walkers, bird watchers, canoeists), and to reach compromise solutions based on mutual understanding and hard facts.

Stocking

The relative merit of creating and maintaining fisheries by stocking as against the protection of self-sustaining wild populations generates extensive debate. Meeting the needs of both the environment and fishers can place conflicting demands on fisheries management. Carp (*Cyprinus carpio*) fisheries in particular can be shaped by stocking as, for example, in Poland and the United Kingdom, and it is well known that carp can be damaging to the environment. Applied with caution, however, stocking can be a useful and sustainable rehabilitation strategy often supported by urban anglers, particularly in artificial water bodies where certain recruitment bottlenecks are very difficult to circumvent. Unfortunately, management of fisheries entirely by maintenance stocking can lead people to believe that good fishing results from simply putting fish in the water and reduces the effectiveness of aquatic education programmes and the efforts to make anglers part of the management process. Therefore, there is a need to publicise the risks associated with management by stocking and that abnormally high fish densities and opulent catch opportunities cannot be expected in every fishery.

The recreational fisheries sector must accept that many enhancement or maintenance practices, particularly stocking of farmed fish species, can conflict with the conservation of aquatic biodiversity through such consequences as introgression of non-native genes, spread of disease, altered predator-prey dynamics and habitat changes. Ideally, stocking should not take place if natural recruitment is satisfactory and ought only to be an option if none other exists to maintain the fishery. Decisions should only be made after first assessing the potential ecological and economic advantages and disadvantages, following an appraisal protocol such as outlined by Cowx (1998).

Non-native species

There has long been a fascination with introducing non-native species. In the late 19th century, for example, non-native wels catfish (*Silurus glanis*) and zander (*Sander lucioperca*) were introduced into England. Unfortunately, the desire for the exotic has not waned and angling for novel species continues to be popular, leading to a proliferation of waters being stocked with alien species. Articles in the UK angling press relating to fishing for large, non-native fish such as wels catfish and sturgeon (*Acipenser* spp.) have fuelled a demand from the angling community for more opportunities to fish for exotic species. This has put financial and competitive pressures upon fishery owners, managers, fish farmers and fish dealers to provide fisheries with these highly sought after non-native specimens.

When a novel factor is added to an ecosystem in balance, the ecosystem will alter to accommodate it. It is the shift in balance that is unknown, in terms of severity and magnitude of impact on both threatened species and habitat.

The detrimental effects that could result from the stocking of non-native fish into recreational fisheries include direct predation, competition with indigenous fish, hybridisation with resident fish, the introduction of new diseases or parasites, and the alteration or degradation of the aquatic environment. Introductions of non-native fish should not in any circumstances be allowed to jeopardise the well being of natural ecosystems. This has happened world wide with introductions of carp (*Cyprinus carpio*), particularly in the United States, India, the Netherlands, and the Murray-Darling basin in Australia. Similarly, largemouth bass (*Micropterus salmoides*) has been introduced outside its native range specifically for recreational angling and has had a serious impact upon populations of endemic fish, such as in parts of the Iberian Peninsula (Godinho and Ferreira 1998). Of course, fisher demands for new experiences need be taken into account but non-native introductions should only be allowed where there are demonstrable social and economic components to any recreational benefit. It is essential to influence anglers, fishery owners and managers to stock non-native fish only where it is ecologically sound to do so and the precautionary approach (FAO 1996) should be adopted always when taking account of potential impacts.

Fishery collapse and sustainability

Recreational fisheries are typically, but incorrectly, viewed as being different from commercial ones in that they are often perceived to be self-sustaining and not controlled by the economic forces of the open market in a way that commercial fisheries are. In many cases, however, the maintenance of the recreational sector is equally dependent upon the ability of aquatic ecosystems to provide fishery harvest. Commercial fisheries have been blamed repeatedly for the worldwide declines in fish populations and many commercial marine fisheries are in a state of collapse from over-exploitation. However, Cooke and Cowx (2004) contend that the recreational fishing sector also has the potential to negatively affect fish and fisheries and argue that the sector warrants consideration as a contributor to over-exploitation of fish in marine and inland waters. Unfortunately, the paucity of global statistics on recreational fishing participation, harvest, and catch-and-release has compromised the ability to understand fully the magnitude of any impact. Moreover, failure to recognize the potential contribution of recreational fishing to fishery decline will put important ecological and economic resources at risk, whereas identifying global conservation concern could facilitate development of strategies to increase the sustainability of recreational fishing. The sheer numbers of participants means recreational fishing cannot be seen as benign and needs to be better managed.

In Australia, recreational fishing is open access and, in many inshore regions, the catch does indeed exceed the commercial harvest. The environmental impacts from angling have been recognized as being ecologically significant and broad in scope; including the removal of biomass of many species, problems with introduced species, impacts on habitat through bait harvesting, damage to sea-birds and marine mammals, and angler generated pollution. (McPhee *et al*. 2002) Such impacts of recreational fishing are cumulative but, where they are not actually ignored by those in authority, there is still a tendency to consider each impact in isolation. The concern is that unless the management approach changes to take account of the entire suite of ecological impacts, recreational fishing in Australia might not be ecologically sustainable in the long term. Similarly, in Canada, four high profile fisheries showed dramatic declines over the last several decades (Post *et al*. 2002). Contributory factors ranged from the predatory behaviour of anglers, which reduced angling quality, through to the ecological responses of disrupted food webs. Such evidence suggests that to prevent collapse of harvest-based recreational fisheries it is necessary for scientists and managers to ensure that models of sustainability adequately incorporate the angler-driven processes.

In addition to fish communities in general, individual species can become threatened by recreational fishing. Analysis of catch records in the United States of America shows that sport fishing is taking a heavier toll on some threatened marine species than is commercial fishing, landing 64 percent of the over-fished species along the Gulf of Mexico and 59 percent along the Pacific Coast. For individual stocks, the situation can be worse. In 2002, for example, sport fishing accounted for 93 percent of the catch of red drum (*Sciaenops ocellatus*) from North Carolina to Florida and 87 percent of the bocaccio (*Sebastes paucispinis*) catch in the Pacific (Hecht and Vince 2004). In the coastal fisheries of Kenya, Mauritius, South Africa and the Seychelles, similar challenges exist with several game fish listed as threatened species (WIOMSA 2006). Measures such as tag and release of sailfish (*Istiophorus platypterus*) are, however, helping to promote conservation and improve management strategies. Also, Marine Protected Areas have a part to play, enabling a combination of prohibition and zone separation for control of angling, shellfish collection and spearfishing.

A robust approach to legislation and change in angler behaviour is sometimes necessary if fishery collapse it to be prevented, as exemplified by the case of the Atlantic salmon (*Salmo salar*) in the United Kingdom. The numbers of Atlantic salmon returning to UK waters had declined significantly during the 1980s. In response, new restrictive national legislation was introduced in 1999 to meet international demands for action. Byelaws were introduced which required salmon caught early in the fishing season to be returned immediately to the water with the least possible injury. Although the situation for Atlantic salmon was showing some improvement as a consequence of such action, 2009 saw the introduction of additional byelaws to ban the sale of any salmon caught by rod and line. In similar fashion, it is expected that new Eel River Basin Management Plans (for *Anguilla anguilla*), mandated for Europe, will impinge on recreational fisheries as well as commercial ones.

Urban fisheries

With recreational fisheries management being as much about people as about fish stocks and ecosystems, and with a background of increasing urbanisation, urban fisheries are necessarily becoming more important. Urban ecosystems generate important ecological services for society and, in general, enhance recreational and cultural values. As well as providing opportunities for activities such as bird-watching, boating and swimming, they can form a valuable fishery resource of benefit to many people and angling is often the single largest recreational activity in urban water bodies. Urban fishery restoration can make a major contribution to sustainable development by enhancing the social value of angling as a widely available and healthy form of recreation. Expert fisheries staff working in partnership with local councils and angling clubs can facilitate programmes to improve the availability and quality of fishing in urban areas. An additional benefit of increasing angling participation by urban populations is that this not only affects the metropolitan centres themselves but also, as the avidity of these new recruits increases, many might move into more rural fisheries outside towns and cities.

Urban fisheries are particularly important in terms of accessibility and their environmental and social benefits (Peirson *et al*. 2001). Thus, a key task within urban fishery development and rehabilitation is enabling good and environmentally sympathetic access to the fisheries. Accordingly, alongside the physical habitat improvement for fish, plans should include the creation of angling places and platforms, access paths, parking places, connection to public transportation and specialist facilities for the disabled. Properly managed in this way, urban fisheries provide a fishing opportunity for those unable to travel or with limited time availability, e.g. the young, the disabled and the elderly. It has been shown that significantly more young people, single people, and less educated people fish in urban than in rural waters (Arlinghaus and Mehner 2004a). Urban fisheries, however, not only serve the constituencies of the less mobile groups but also highly committed anglers and are especially important to people for whom angling is of great importance to their life style. Highly committed anglers are particularly important angling stakeholders because they are typically more successful and engaged as compared with less committed anglers and tend to benefit more from their angling (Arlinghaus and Mehner 2004b). Motivations of urban anglers, when compared with other angler groups, tend to be more catch orientated. In Germany, urban anglers placed greater importance on the achievement and quantity aspects of the angling experience (Arlinghaus and Mehner 2004a) and in North America (Manfredo *et al*. 1984) they had expectations of catching trophy fish and/or many fish with less emphasis on finding a challenging and unique fishery. Such attitudes have consequences for fishery management regimes because the non-catch motives – the so called play, rest and relaxation components – are probably easier to satisfy than catch-based ones.

Fish welfare

Fish welfare is an important aspect of contemporary recreational fisheries participation and management. The topic is being raised as a matter of concern more frequently by a number of segments of society. Public influence is having various but generally increasing impacts in different countries. In Germany, for example, a good reason is required for fishing in the context of leisure as against fishing for food. National attitudes are always going to vary but attempts must be made to keep economic, environmental and sporting motives in balance.

Public acceptance of recreational fishing is important. In many instances it is the public sector, on behalf of the fishers, that is involved in setting up and maintaining the institutional infrastructure by which the fisheries are managed, whether it be local council provision of facilities or international agreements on migratory fish stocks. A survey on public attitudes to angling was conducted in England and Wales (Simpson and Mawle 2005). This clearly showed that most people viewed angling positively with 71 percent agreeing with the statement that "Angling is an acceptable pastime" and only eight percent disagreeing. There was less certainty, however, about whether "Angling is a cruel pastime"; 24 percent agreed, whilst 47 percent disagreed and 26 percent neither agreed nor disagreed. Nonetheless, when the United Kingdom published its new Animal Welfare Bill in 2005 it was specifically stated that nothing in it applies in relation to anything which occurs in the normal course of fishing.

Practical things can be done to show recreational fishing in a good light. Good welfare means that an individual fish is in good health, with its biological system functioning properly and not being forced to respond beyond its capacity (Arlinghaus *et al*. 2007). Therefore, fishers should make efforts to minimize or avoid fish welfare impairments by accepting that the nature of their activity may cause harm to individual fish and adopt behaviours that minimize or avoid detrimental impacts. Careful handling of fish, state of the art designs for keep nets and the use of barbless hooks are examples of how anglers are able to contribute directly to fish welfare. Improved fish handling will help to close the perceived cultural divide between the fishing and animal welfare factions. Unfortunately, in some instances there is evidence of an increasing pattern of greed, with more anglers competing for trophies or money and some fishery owners promoting angling as the basis for business with little regard for the welfare of either the population or individual fish. This does little good to the reputation of recreational fishing as a legitimate activity and should be countered by a combination of enforcement and education.

Catch and release

Catch-and-release angling has a long history and has received increasing attention recently. It refers to the process of capturing a fish, usually by angling, and releasing it alive. Catch-and-release involves a continuum from mandatory release of protected sizes and species to voluntary catch-and-release of unprotected fish (Arlinghaus *et al*. 2007). World wide, many millions fish are released after capture by recreational anglers each year, the release rate being about 60 percent (Cooke and Cowx 2004). In the United States of America in 2000, an estimated 11 million anglers participated in 78 million marine fishing trips and caught 445 million fish, of which 57 percent were released. However, diversity of culture, institutional environments and target species means difficulty in obtaining reliable estimates that apply in general. Angling for coarse fish (non-salmonid) species in the United Kingdom exemplifies an extreme situation where almost all fish are released. The same is true for some specialist fisheries around the world, such as big game angling in the USA, e.g. for Atlantic white marlin (*Tetrapturus albidus*) and bonefish (*Albula vulpes*), and for carp (*Cyprinus carpio*) in much of Europe. Release rates are much lower in many recreational fisheries in parts of Eastern and Northern Europe where much of the catch is still taken for human consumption.

Release of fish in compliance with regulations is unlikely to be contentious because such release is seen to enable the implementation of necessary control measures. That angling can impact fish stocks is receiving more attention because in many temperate freshwater systems, and some coastal ones, recreational fishing has largely replaced commercial fishing as the principal exploiter of fish stocks. Using estimates from Canadian recreational fisheries, Cooke and Cowx (2004) suggested that on a global scale, angling catch could be as high as 47.1 billion fish annually, of which about 17 billion are retained. So, from a fisheries management and conservation point of view, common sense would suggest that further application of catch and release encourages the biological, economic, and social sustainability of recreational fishing. In contrast to mandatory release of specific categories of fish, voluntary catch and release can induce controversy. This form of catch and release could be seen as the perfect expression of the fact that recreational fishing is not about the necessity to obtain food. In such situations, there is no desire to kill and eat the fish and the release itself becomes very important. It is against such activity that ethical arguments are mounted because of the disconnect with need. For example, for some stakeholders, releasing fish is a reprehensible practice because the act of catching can then be perceived as playing with fish for no good reason. Such an attitude has created social and legal conflicts in Germany with some anglers receiving monetary fines for releasing trophy fish and it being deemed cruelty to animals (Arlinghaus *et al*. 2007). Catch and release is, therefore, somewhat complex to manage because the history, laws, culture and economic environment differ from one country to another. Undoubtedly, however, the relevance of its application will increase in the future.

Education

Education and liaison between the authorities, fishers, fishery owners and the general public is crucial if interested parties are to closely identify with the management of the recreational fishery resource. Education should aim at a meeting of minds between scientists, managers and participants. Recreational fishing organisations can be limited in their vision, often focussed on a single species group, whereas they would have much to share and much to gain by exchange of information. The tendency to fail to recognize the importance of healthy ecosystems and to understand the complexity of fisheries management could be addressed by improved communication. The sector must improve its education and awareness role if the benefits of recreational fishing are to be protected in the long term. Techniques range from the straightforward issue of informative literature through stakeholder meetings to the formal training and examination currently found in Germany. Whatever, there is a need to promote responsible recreational fisheries through education of recreational fishers, interested people, managers, politicians and other stakeholders. Publicity should be given to conservation and management measures to ensure that regulations governing their implementation are effectively disseminated, with the bases and purposes of such measures being explained. Fishing communities and individuals should be engaged in the formulation of policy and management plans, establishing co-management where appropriate. In essence, awareness and education programmes should be aimed at improving knowledge, attitudes and behaviour of all those engaged in the recreational fisheries sector. Public outreach is important. Communication of the economic and social value of recreational fisheries practices will help strengthen the sector and enable further development for the benefits of fish, the environment and those that enjoy recreational fishing.

Codes of practice

Voluntary codes of practice already exist in some countries and organisations therein. For example, in the United Kingdom, the National Angling Alliance has produced a Code of Conduct for Coarse Anglers covering such aspects as care of the environment, general behaviour, tackle and fish handling. Although many other countries have a similar inclusion of behavioural, conservation and fish welfare recommendations in leaflets and guidebooks, produced either by the authorities or angling associations, there has been little in the way of high profile, nationally agreed, promotional documentation. In Australia, however, a national code of practice has been published as a joint initiative between the authorities and the fourteen national and state fishing associations (Recfish Australia 1996). Also, the Nordic Angler Association, which covers Denmark, Sweden, Finland, Norway and Iceland, has established a code for recreational angling. Nonetheless, there is still a perceived need for more international agreement on good practice. Accordingly, facilitated by the European Inland Fisheries Advisory Commission (EIFAC), a new international Code of Practice for Recreational Fisheries has been developed to assist this process (FAO 2008).

In its Code of Conduct for Responsible Fisheries, the FAO (1995) states that users of living and aquatic resources should conserve aquatic ecosystems and that the right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources. Accordingly, the objective of the EIFAC Code of Practice for Recreational Fisheries is to establish best practice principles among nations for responsible management and fishing practices, taking into account all relevant biological, technological, economic, social, cultural and environmental aspects. The Code has to fit alongside national legislation and regional best practice guidelines and is designed to prescribe the minimum standards for environmentally friendly, ethically appropriate and socially acceptable recreational fishing. It works from the general assumption that recreational fisheries provide a vital source of recreation, employment, food and social and economic well-being for people throughout the world, both for present and future generations. It acknowledges that recreational fishing and its associated social, cultural, psychological and physiological benefits provide quality of life for its participants; an aspect less obvious to some in society. These tangible and less tangible benefits are different to those of food and income that have been traditionally associated with fishing. To continue being viable, recreational fishing must minimize its ecological impacts and harmonize stakeholder interactions whilst delivering maximum benefits to the sector. The EIFAC Code of Practice for Recreational Fisheries should facilitate this but it has no formal legal status; it is a voluntary instrument. The challenge is finding the corporate will for its implementation.

Concluding remarks

At its Session in 1996, EIFAC had recommended that the true value of recreational fisheries should be included in decision making processes by taking into account the full economic and social value of the aquatic ecosystem (Hickley and Tompkins 1998). It can be seen that, even many years on, this recommendation remains pertinent. One of the major points of relevance of economic and social value is its contribution to arguments necessary for justifying amelioration of anthropogenic impacts, such as obstructions, pollution and climate change; for example, influencing programmes of measures under the European Water Framework Directive. In such debates, consideration of full economic impact is key, it referring to moving money around and benefiting from it whereas this is not necessarily the case for pure economic value.

It must be remembered that recreational fishing is a pleasure sport and this is the principal reason why future management philosophy should come to rely less on fish ecology and increasingly on social science. Stakeholders will need to embrace the challenge of promoting recreational fishing whilst recognizing that this has to be alongside conservation and protection of the sector's resource.

More people are becoming interested in recreational fisheries management policy formulation, and globalization adds to the complexity of management. Unfortunately, many recreational fisheries organisations, and even government institutions, are focussed on single species group issues. Wider education, vertically and horizontally, amongst the scientists, regulators, fishery owners, managers and the fishing community is essential. Better communication will help the way forward but it has to be taken seriously if it is to be effective. For any new policies and strategies, much can be gained by the development of formal communication plans which are then implemented through robust project management processes. Such an approach is recommended.

The future can be bright. Many stakeholders are already willing to promote and safeguard the enduring social, economic and conservation values of recreational fishing. So, with a little improvement world-wide, it yet might be possible to align the sector to a vision of all waters being capable of sustaining thriving fish populations and everyone having an opportunity to experience a diverse range of good quality fishing.

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Fisheries inspection vessel, Cacheu, Guinea-Bissau. *Photo*: Mikael Cullberg (courtesy of the Swedish Society for Nature Conservation).

FISHERIES MANAGEMENT AND GOOD GOVERNANCE – GLOBAL, REGIONAL AND NATIONAL LEGISLATION AND REGULATION

Denzil G.M. Miller and Marie Jacobsson

Abstract

This paper describes the evolution of the legal framework for managing ocean spaces and conserving marine living resources on the high seas. Consideration is given to the extent to which this framework has been applied in the management of sustainable fisheries. Recent developments are contrasted with implementation of the 1982 Convention on the Conservation of Antarctic Marine Living Resources ("CAMLR Convention") given the Convention's perceived standing as the most advanced and effective regional fisheries arrangement (RFA) currently in place.

Introduction

For more than 300 years prior to negotiation of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), international customary law for ocean spaces drew heavily on Hugo de Groot's (Grotius) *Mare Liberum* (Juda 1996). The key principles of this are generally perceived to be that: **a)** the High Seas are common and cannot be placed under the sovereignty of any state, **b)** marine living resources are inexhaustible, **c)** ocean sovereignty is limited to the adjacent (territorial) sea, and **d)** freedom to fish is a high seas right along with the freedoms of navigation and trade.

Over time, the first two Grotian principles have been modified, largely due to acceptance of a 12 nm wide territorial sea and 200 nm Exclusive Economic Zones (EEZs). It has also been acknowledged that marine living resources are indeed exhaustible. Despite these developments the Grotian concept of *res communis* has prevailed with high seas fisheries in particular being viewed as the property of all – *usus publicus*. Consequently, an expectation of collective benefit from communal ownership of such resources is implied. It would therefore follow that a collective responsibility should ensure that benefits are equally accessible to all.

Compared to prior state practice, UNCLOS effectively expanded coastal state jurisdiction over marine living resources. Consequently, the balance of interests between coastal and flag

1. The opinions expressed are those of the authors and should not be taken to reflect the official views of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) or the Swedish Ministry for Foreign Affairs.

states was directly affected with the duty to cooperate in the conservation and management of such resources becoming a key element of a number of UNCLOS provisions (Molenaar 2000). UNCLOS thus strives to ensure that coastal and flag states exercise their responsibilities in managing marine living resources to the benefit of the resources themselves as well to the commercial interests of their exploiters, irrespective of who these might be. However, it was foreseen that an arbitrarily defined EEZ boundary would not necessarily take into account resources moving ("migrating") from one area to another or "straddling" such a boundary. Special consideration was therefore given to the regulation of straddling stock and highly migratory species (Articles 63 and 64 of UNCLOS respectively). Similar provisions were also developed for anadromous and catadromous species (Articles 66 and 67 respectively). UNCLOS goes on to identify the clear duty of all states to take measures to conserve living resources outside the EEZs on the high seas along with a clear obligation to cooperate in achieving this goal (Articles 116–118).

The UNCLOS provisions did little to prevent increased exploitation of global fisheries resources, particularly by distant water fishing states (DWFS) displaced onto to the high seas from coastal state EEZs. In fact, since UNCLOS was finalized, DWFS involvement has grown to the extent that trends in global marine fisheries show a consistent decrease in the number of fully exploited stocks being fished between 1974 and 2008 (Figure 21 in FAO 2009). The number of underexploited, or moderately exploited stocks, also declined during the same period. By contrast, the proportion of overexploited and depleted stocks steadily rose from about 10 percent in the mid-1970s to nearly 25 percent in 2008. These trends not only reflect ever-increasing efforts to locate new stocks for exploitation, they lead to growing concern that unsustainable fishing exerts a heavy a price on ecosystem productivity as a whole (Pauly *et al*. 2002). The price includes habitat impact, unsustainable by-catches of non-target species, discarding of unwanted catches and general degradation of the marine environment.

Emergence of modern fisheries arrangements

The global community has come to accept that unsustainable fishing essentially reflects a widespread failure in fisheries management (Cochrane, Doulman 2005). Consequently, fisheries are not only more prone to collapse, biologically and economically, the situation benefits no-one, least of all those striving to sustain national, or international, food security (Munro *et al*. 2005).

Post-UNCLOS, international efforts have therefore attempted to enhance effective jurisdictional application of management practices to support sustainable fisheries by advancing a legal framework to address marine living resource over-exploitation directly. A key consideration has been the need to ensure that the ecosystems in which such resources find themselves remain "healthy" (Cochrane, Doulman 2005). The

UNCLOS-associated international legal instruments negotiated during the early to mid-1990s thus built on Convention Articles 61–64 and 116–119. They also provide the legal means to give effect to declarations from the 1992 United Nations Conference on Environment and Development (UNCED), as well as the 2002 World Summit on Sustainable Development (WWSD).

These various legal instruments address a wide range of fisheries-related issues (Miller 2007). Most notably the 1995 United Nations Fish Stocks Agreement (UNFSA) (Anon. 1995, UN 1998: 7–37), together with the FAO Code of Conduct (UN 1998: 51–78), outline provisions for practical and effective management of transboundary fish stocks, as well as fisheries in general. For these reasons, a key UNFSA objective is to facilitate responsible use of fisheries resources on both the high seas and in waters under national jurisdiction. Priority is given to promoting co-operation between coastal states and high seas fishing states on a range of fundamental and technical issues (e.g. compatibility of management measures). In effect, UNFSA aims to implement relevant UNCLOS provisions more effectively to augment the Convention's application (Munro *et al*. 2005).

Like other fisheries agreements, UNFSA addresses biological considerations, and conservation concerns. It institutionalizes a precautionary, and ecosystem-based, approach to marine living resource management (Cochrane, Doulman 2005). This has broadened fisheries management objectives to mitigate negative impacts on the marine environment so preserving marine biodiversity and maintaining ecosystem qualities as a whole.

As a package, post-UNCLOS instruments are not only important in their own right, but particular UNCLOS provisions have provided common elements on which modern regional fisheries arrangements (RFAs) have come to be based. In these terms, finalization of UNCLOS more explicitly elaborated the duties and obligations attached to management of sustainable fisheries in areas under national jurisdiction and beyond (Henriksen *et al*. 2006). Molenaar (2000) has emphasized that **a)** reinforcement of flag state performance, and **b)** promotion of regional co-operation in the conservation of marine living resources are particularly conspicuous elements in this context. While the former will be dealt with later in the section 'Modern fisheries regulation' (below), the latter has both practical and legal implications. In particular, the concept of "real interest" (as referred to in UNFSA Article 8.3) has emerged in many post-UNCLOS agreements (UN 1998: 13). As a key principle, "real interest" promotes regional co-operation for the conservation of marine living resources consistent with UNCLOS Articles 61–64 and 117–119.

The duty to co-operate

The freedom to fish the high seas enshrined in Article 87.1 (e) of UNCLOS is not unlimited. The right to fish is subject to specific UNCLOS provisions that regulate the conservation and management of living resources on the high seas, while simultaneously balancing various interests, e.g. between coastal and other states, and between developing and developed states. Thus, UNCLOS clearly obligates states parties to exercise their rights, jurisdiction and freedoms in a manner that does not constitute an abuse of rights (Article 300); an obligation which is particularly relevant to the implementation of Article 116.

As emphasized by Molenaar (2000), interpretation of the freedom to fish has been confounded by a perception that high seas fish stocks are common property, renewable and spatially unbounded (see also Churchill 1987, p. 3). As already suggested, overfishing can then be viewed as a substantial failure to regulate fishing in strict conformity with UNCLOS conditions. Unsustainable fisheries, attached economic inefficiency, lost opportunities and enhanced potential for conflict over resource-use are the result of such failure.

The International Court of Justice has set an important precedent in providing guidance on the collective duty and responsibility of all states to conserve living resources on the high seas to the benefit of all.[2] The Court declared that *"the former laissez-faire treatment of the living resources of the sea in the high seas has been replaced by a recognition of a duty to have due regard to the rights of other States and the needs of conservation for the benefit of all"* (ICJ Report, para.72 – Anon. 1974). This pronouncement takes the obligation to conserve the living resources of the high seas one step further than the principles outlined in the 1958 Convention on Fishing and Conservation of Living Resources of the High Seas. It is particularly relevant to managing marine living resources in the face of increasing fishing pressure (Anon. 1974, Lodge *et al*. 2007). Taken together with "their treaty obligations" (Article 116 (a) of UNCLOS), Article 117 of UNCLOS emphasizes the duty of all states to take measures and co-operate in conserving living resource on the high seas. Such obligations are reinforced by the right, duties and interests of coastal states in Articles 116 (b), 63.2 and 64-67. Once again, UNCLOS imposes a clear obligation on states to co-operate in managing marine living resource exploitation. To meet the duty to co-operate (Article 117), along with the obligation to negotiate measures with other states, participation is mandated in relevant regional fisheries management organisations (RFMOs) and RFAs (Article 118).

Such provisions are elaborated further in Part III of UNFSA, which expressly details the duty to co-operate in managing and conserving fish stocks to which the Agreement applies, i.e. highly migratory and straddling stocks (Henriksen *et al*. 2006). Under Article 17, this duty is extended to non-RFMO members and non-RFA participants, and from a legal perspective the Article is essentially novel.

The above provisions support the conclusion of Lodge *et al*. (2007) that there is "no freedom to fish contrary to applicable conditions" and that these conditions "include measures laid down by RFMOs, and there is no freedom to undermine any of them". It follows that violation of such conditions may be contrary to international law, the UNCLOS, UNFSA and relevant RFMO provisions or measures, depending on the facts of any specific case. It also follows from the general principle that states should refrain from activities

2. In the *Fisheries Jurisdiction Case*, 1974 (United Kingdom of Great Britain and Northern Ireland *v.* Iceland).

within their jurisdiction that are detrimental to the rights of other states.

Nevertheless, as shown, the right to fish is subject to conditions under general international law. Consequently, a non-RFMO member state is not absolved from taking account of an organization's competency, regulatory area or conservation measures if fishing in that organization's regulatory area. Even if such a state is not bound under the law of treaties by a RFA, other obligations of a more general nature still apply (Lodge *et al.* 2007). For example, if a state persistently allows vessels flying its flag to fish in the regulatory area of an RFMO to which it is not party in a manner that undermines that RFMO's regulatory measures, then that state could be considered derelict in its duty to co-operate in the conservation of the target stocks concerned under Article 17 of UNFSA. While the question of flag state duties will be discussed further, it should be re-emphasized that the right of states to flag fishing vessels has legal responsibilities to other states attached under both UNCLOS and UNFSA, particularly in respect of relevant RFAs in place.

Real interest

Under the UNFSA, the term "real interest" is viewed as a pre-condition for states wishing to participate in RFAs or RFMOs responsible for conserving transboundary stocks (Molenaar 2000). However, it is not expressly defined in UNFSA and its potential application may be viewed from various perspectives.

While there is no definitive clarity on the actual meaning of "real interest in the fisheries concerned", the provisions of UNFSA Article 8.3 clearly indicate that "States fishing for the [fish] stocks on the high seas and relevant coastal States" are specifically considered elegible to participate in relevant RFAs and/or RFMOs. While "real interest" would be implicit in the duty of coastal states to co-operate in a relevant RFA, Molenaar (2000) makes the point that for "States fishing" the actual activity of fishing invokes the duty and right to participate. This would imply that "real interest in the fisheries concerned" has a broader purpose and is not simply limited to the two categories of states referred to above.

The issue of "real interest" is further complicated by linking RFMO participatory rights with allocation of fishing opportunities in an organisation's regulatory area. Following Molenaar (2000), it can then be concluded that the concept of "real interest" has three major implications. First, as shown above, it probably affects the pre-UNFSA balance between coastal and flag state interests; a situation clearly evident during negotiation of the *Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean* – WCPFC (Miller and Molenaar 2006). Second, it may be used to limit RFMO participation to those states intending to fish, or fishing, in the regulatory area. Given current practices in many RFMOs, this appears to be a rather limited interpretation (Molenaar 2000); although recent experience and the recognised need to define criteria for allocating catch to new RFMO members (FAO 2002) may contradict this view. Third, it may reserve particular fisheries for certain types of states. However, under both UNCLOS (Article 116) and general international law, the nationals of all states have a right to fish the high seas; a condition that mitigates this particular view. Moreover, most post-UNFSA RFAs (Table 1) have, in negotiation or provision, tended to reinforce the idea that "real interest" should not be used to limit RFMO participation. Nonetheless, the allocation of allowable catches, or fishing opportunities, can still be applied to limit participation, a situation likely to undermine RFMO legitimacy and the effectiveness of RFAs in the longer term (see the section 'Future challenges', below).

Despite the prevailing lack of definitional clarity, it is probable that the concept of real interest will continue to be applied to assess the legitimacy of new participants' to RFMOs. Conversely, it could be used to bolster RFMO compliance-enforcement by exerting a positive influence to counter detrimental effects associated with vessel reflagging, or the activities of flags of non-compliance. At a minimum, this should ensure a level of flag state performance commensurate with FAO Compliance Agreement provisions (UN 1998: 41–49). This would not only counter the effects of non-compliance, it would provide an implicit pre-condition for linking "real interest" directly to fisheries regulation or compliance (Molenaar 2000).

Whatever the outcome, there is little doubt that "real interest" does affect the balance of interests between RFMO participants, new entrants and non-members. These need to be addressed in a way that provides for non-discriminatory and equitable allocation of fishing opportunities to all states, e.g. as per Article 20 of the *Convention on the Conservation and Management of Fishery Resources of the South-East Atlantic* – SEAFC (Miller, Molenaar 2006). Given the current status of marine living resources globally, the broadened fisheries management objectives and "real interest" concerns emerging post-UNFSA urgently mandate effective measures to manage living marine resource sustainability. Such considerations would mitigate potential and negative marine environmental impacts as a whole, as well as preserve marine biodiversity and maintain vital ecosystem qualities.

Modern fisheries regulation

Both UNCLOS and the UNFSA have become cornerstones for the way in which high seas fish stocks should be conserved and managed. Subsequent fisheries conventions, agreements or RFAs have built on UNFSA provisions in particular and many commonalities are evident in the evolution of all post-UNFSA instruments to date (Table 1).

With space considerations precluding detailed analysis of the information summarised in Table 1, it goes without saying that one of the most important developments has been the explicit need to apply precaution (e.g. Article 6 of UNFSA) in the face of uncertainty arising from incomplete knowledge. This knowledge comprises future fisheries trends, stock productivity, and fishery development, including the role played by economic drivers. An important associated element has been the progressive, and more explicit, recognition that fishing does not take place in isolation and that conserving ecosystem health and marine biodiversity is important to sustain future stock, or species, sustainability in the face of harvesting (Articles 5 (d), (e) and (g) of UNFSA) (Cochrane, Doulman 2005). These considerations are at the centre of the CAMLR Convention (Article II) and have served to distinguish that Convention from many other RFAs (Miller *et al*. 2004).

From Table 1 it is also evident that the international community has gone to considerable lengths to better define flag state duties and outline port state measures post-UNFSA. Port state obligations become progressively more important when flag states do not effectively meet their obligations (Jacobsson 2003), such as those outlined in Article 18 of UNFSA or Article III of the Compliance Agreement (UN 1998: p. 18 and 43 respectively). Recent initiatives have thus tended to promote sustainable fishing congruent with general provisions initially outlined in Article 94 of the UNCLOS, and further elaborated for fishing vessels in Articles 18 and 23 of UNFSA. Nonetheless, other factors affected ocean governance leading up to, and following, adoption of both UNCLOS and UNFSA. These have tended to impact on how well RFMOs respond to the challenge of implementing sustainable management and conservation of the resources for which they are responsible. Four such factors are: **a)** compliance enforcement, **b)** socio-economic expectations, **c)** the role of science, and **d)** uneven manifestation of political will.

Compliance Enforcement

The enforcement, or assurance, of compliance with management measures is pivotal to ensuring that RFMOs effectively discharge their mandates. It is also essential for flag states to effectively control fishing vessels flying their flags (Rayfuse 2004a). The former is a function of inter-state co-operation between relevant RFMO members, while the latter has its origins in the primacy of flag state jurisdiction on the high seas reflected in Article 92.1 of UNCLOS.

Many RFMOs have developed measures to improve compliance by both members and non-members through reciprocal, pre-negotiated, schemes allowing at-sea boarding of member state vessels by non-flag member states (e.g. CCAMLR System of Inspection adopted under Article XXIV of the CAMLR Convention – Rayfuse 1998). Despite such measures, illegal, unreported and unregulated (IUU) fishing continues to take place in many areas, particularly those regulated by certain RFMOs (e.g. CCAMLR). The legal crux of the matter is the simple fact that on the high seas the flag state is the "sovereign" of its own vessels. As a general rule, no third state can take enforcement measures against another state's vessel without the complicity of the flag state. Nevertheless, the willingness to accept non-flag control and enforcement measures can be expressed through pre-negotiated, multilateral, regional or bilateral arrangements. Flag state consent to enforcement action may also be given in response to a specific request by a state (or RFMO) to exercise regulatory control over a vessel suspected of "undermining"

Table 1. Fish Stock Agreement (UNFSA), SEAFC Convention (SEAFC), WCPFC Convention (WCPFC), South West Indian Ocean Fisheries Commission (SWIOFC), South Indian Ocean Fisheries Agreement (SIOFA), South Pacific Regional Fisheries Management Organisation (SPRFMO) and CAMLR Convention (CAMLR Convention) Provisions.*

TOPIC	UNFSA	SEAFC	WCPFC	SWIOFC
Origin	UN Conference on Straddling Fish Stocks & Highly Migratory Fish Stocks (1992–1995). Manage high seas fisheries consistent with UNCLOS (especially Articles 63–64).	Namibia & coastal states post-UNFSA (1996). Replaced ICSEAF to promote sustainable utilization of high seas resources in interests of region's fishing industries.	FFA & USA at UNFSA time in context of USA/South Pacific Fisheries Treaty 1993/94 reviews. Pacific Island states concern on sustainability & equitable economic benefit from region's migratory stocks	Several years of negotiations for a high seas fisheries regime in region evolved into SWIOFC & SIOFA (former focusing on coastal states)
Process name	UN Conference on Straddling Fish Stocks & Highly Migratory Fish Stocks	Meeting of Coastal States & Other Interested Parties on a Regional Fisheries Management Organisation for the South-East Atlantic Ocean	Multilateral High-Level Conference on the Conservation and Management of Highly Migratory Fish Stocks in the Western & Central Pacific Ocean	No specific process other than coastal state negotiations between 2001 and 2004
Organisation name	Co-ordination of RFMO's (New and to be Formed)	Southeast Atlantic Fisheries Organisation (SEAFO)	Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western & Central Pacific Ocean	South West Indian Ocean Fisheries Commission
Agreement name	***Agreement for the Implementation of the United Nations Law of the Sea of 10 December 1982 relating to Straddling Fish Stocks & Highly Migratory Fish Stocks***	***Convention on the Conservation and Management of Fishery Resources in the South-East Atlantic Ocean (SEAFC)***	***Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western & Central Pacific Ocean***	***Statues of the South West Indian Ocean Fisheries Commission (FAO Council Resolution 1/127)***
Agreement area	Global & not defined	High seas areas outside national jurisdiction – approximately FAO Statistical Area 47 bounded at 6°S, 20°W, 18°E & 50°S (Article 3)	Roughly to boundaries of IOTC in west, IATTC in east, CCAMLR in south and 4°S in north. EEZs included (Article 3).	SW Indian Ocean Coastal State jurisdiction waters. From East African coast on 10°N to 65°E then south to equator. On equator to 80°E, south to 45°S, due west to 30°E & north to African coast (Article 1)
Species covered	Straddling fish stocks & highly migratory fish stocks excluding sedentary species under UNCLOS Article 77	Straddling/discrete stocks on high seas, excludes sedentary (UNCLOS Article 77) and highly migratory species (UNCLOS Annex I). Limited past/potential catches. (Article 1. (l)).	Highly migratory stocks per UNCLOS Annex I – skipjack, yellowfin, bigeye & albacore tuna. Good FFA historic catch record (Preamble Article 1s & 2)	All marine living resources (MLRs) (Article 2)
Adoption/Open signature	4/8/1995	20/4/2001	5/9/2000	25/11/2004
Entry into force	11/12/2001	13/4/2003	15/6/2004	25/11/2004
Objective	Ensure long-term conservation & sustainable use of straddling and highly migratory fish stocks through effective implementation of UNCLOS (Article 2)	Long-term conservation and sustainable use of fishery resources (straddling & discrete stocks) in SEAFC Area (Article 2)	Long-term conservation & sustainable use of highly migratory fish stocks in WCPFC Area under UNCLOS & UNFSA (Article 2)	Promote sustainable utilization of marine living resources s in face of members' fisheries management & development problems
General principles	Management of straddling and highly migratory fish stocks by adopting scientifically-based measures, applying precautionary approach, environmental protection etc. including data gathering & conservation measure enforcement (Article 5)	Management of SEAFC Area's fishery resources by adopting scientifically-based measures, applying of precautionary approach, environmental protection etc. (Article 5)	Management of WCPFC Area's fishery resources by adopting scientifically-based measures, applying of precautionary approach, environmental protection etc. including data gathering & conservation measure enforcement (Article 5)	Without prejudice to coastal state sovereign rights promote sustainable utilization of MLRs by improved governance, advice and assistance in respect of management, resource development, data collection, scientific research etc. (Article 4)
Precautionary approach	Details approach & guidelines on application of reference points. Special mention new & exploratory fisheries (Article 6 & Annex. II)	Caution in face of uncertainty & cross-reference to reference points in UNFSA Annex. II & Code of Conduct (Articles 3. (b) & 7)	Identical UNFSA Article 6, including direct reference UNFSA reference points (Articles 5. (c) & 6)	Due regard FAO Code of Conduct principles, including ecosystem & precautionary approach (Article 5)
Ecosystem approach	General principle (Article 5.(d), (e) & (g))	General principle as per UNFSA Article 5 (Article 3. (c), (d),(e) & (f))	General principle as per UNFSA Article 5 (Article 5 (d) & (e))	General principle (Article 5)
Compatibility of measures	Compatibility national & international measures. Co-operation on high seas (Article 7)	Compatibility national & international measures. Avoid undermining UNCLOS Articles 61 & 119 (Article 19)	Compatibility national & international measures. Largely duplicates UNFSA Article 7 and reinforces need to implement WCPFC's principles in national areas (Article 8 & 7 respectively)	No prejudice to coastal state sovereign rights (Article 4) & compatible with UNCLOS Articles 61–64
Contracting party obligations	Not specifically identified. Some details on state obligations in ensuring co-operation under RFMOs or other relevant arrangement(s) (Article 10)	Detailed provisions on, *inter alia*, data collection/exchange/ submission, ensuring effective measures. Co-operation to ensure compliance by flagged vessels & nationals & limitation of access to Party flagged vessels (Article 14)	Outlines obligations. Provisions include prompt implementation of measures, data submission etc., taking measures to ensure compliance by flagged vessels & nationals (including procedures to be followed on alleged violations) (Article 23)	Not detailed
Flag state duties	Only states to authorize fishing vessels in manner not undermining RFMO measures & when able to assume responsibility for flagged vessels. Details measures to be applied & entreats states to ensure MCS measures compatible with any regional system in force (Article 18). Also outlines flag state compliance & enforcement provisions (Article 19).	Ensure flagged vessels comply with SEAFO measures, possess authorization to fish, details measures to give effect to control of flagged vessels & urges need to ensure that vessels do not undermine measures by unauthorized fishing in SEAFC Area & adjacent areas (Article 14)	Ensure flagged vessels comply with measure, possess authorization to fish in all Convention Area, details measures to give effect to control of flagged vessels & urges need to ensure such vessels do not undermine measures by unauthorized fishing in WCPFC Area & adjacent areas & mandates VMS deployment (Article 24)	Not detailed

Table 1, cont.

TOPIC	SIOFA	SPRFMO	C-CAMLR
Origin	Several years of negotiations for a high seas fisheries regime in region evolved into SIOFA & SWIOFC (former focusing on high seas fishing states)	In 2006, Australia, Chile & New Zealand initiated process to address gap in international conservation & management framework for high seas areas of the South Pacific	On adoption of Antarctic Treaty Consultative Meeting Resolution IX-2, negotiation of CAMLR Convention began February 1978
Process name	No specific process other than interested state negotiations between 2001 and 2006	International Consultation on the Establishment of the South Pacific Regional Fisheries Management Organisation (2006+)	Three sessions of Second Special Antarctic Treaty Consultative Meeting, 1978–1980
Organisation name	South Indian Ocean Fisheries Agreement	Commission for the Conservation & Management of High Seas Fishery Resources in the South Pacific Ocean	Commission for the Conservation of Antarctic Marine Living Resources
Agreement name	***Southern Indian Ocean Fisheries Agreement***	***Convention on the Conservation & Management of High Seas Fishery Resources in the South Pacific Ocean***	***Convention on the Conservation of Antarctic Marine Living Resources***
Agreement area	From East African coast on 10°N to 65°E, south to equator, on equator to 80°E, south to 20°S. Due east to Australian coast, south & east to 120°E, south to 55°S, west to 80°E, north to 45°S, west to 30°E, north to African coast (Article 3)	Abutting eastern SOFIA boundary, abutting northern CCAMLR Area boundary, abut outer limits of South American states' maritime jurisdictions in east, northern boundary not yet delineated (Article 4)	Area south of 60°S & south of the Antarctic Convergence, with the latter at 50°S, 0°; 50vS, 30°E; 45°S, 30°E; 45°S, 80°E; 55°S 80°E; 55°S, 150°E; 60°S, 150oE; 60°S, 50°W; 50°S, 50°W; 50°S, 0° (Article I.4). Application in areas of coastal state jurisdiction elaborated (Chairman's Statement)
Species covered	All fishery resources except sedentary (UNCLOS Article 77 (4)) & highly migratory species (UNCLOS Annex I) (Articles 1.(f) & 2)	All fish, molluscs, crustacean & sedentary species, excluding sedentary (UNCLOS Article 77) & highly migratory species (UNCLOS Annex I) (Articles 1.(h) & 2)	Populations of fin fish, molluscs, crustaceans & all other species of living organisms, including birds, south of Antarctic Convergence (Article 2)
Adoption/Open signature	12/6/2006	Under negotiation	20/5/1980 and 1/8 to 31/12/1980
Entry into force	Not yet in force	Under negotiation	7/4/1982
Objective	Ensure long-term conservation & sustainable use of fishery resources in SIOFA Area (Article 2)	Apply precautionary & ecosystem approaches to ensure long-term conservation & sustainable use of fishery resources (Article 2)	Conservation of Antarctic marine living resources (Article II.1)
General principles	Effect UNCLOS duty to co-operate, measures using best scientific evidence available applying ecosystem approach, measures for sustainable use of fishery resources (including rebuilding depleted stocks), precautionary approach & protecting biodiversity (Article 4)	Scientifically & precautionary-based management to ensure sustainable resource use & biodiversity protection (Article 3)	Conservation includes rational use (Article II.2) & harvesting/ associated activities in accordance with precautionary & ecosystem conservation principles to address environmental variability & adverse risk minimization (Article II.3)
Precautionary approach	Due regard UNFSA & FAO Code of Conduct, applying ecosystem & precautionary approach (Article 4. (c))	Due regard UNFSA & FAO Code of Conduct, precautionary approach accounting for best scientific information & international practices (Article 3.2)	Prevent and/or minimise risk of changes not reversible over two or three decades (Article II.3. (c))
Ecosystem approach	General principle (Article 4. (e))	General principle (Article 3. (h), 17.1 (e))	Key objective (Article II.3. (b) & (c))
Compatibility of measures	Encourages co-operation with coastal states on measure compatibility (Article 6.g)) as well as organizations (Article 16) Recognizes rights/obligations under UNCLOS & UNFSA (Article 19)	Promote compatibility with measures in adjacent areas (Article 7.1. (e)) & other relevant organisations (Article 30)	Harmonization of measures with contracting parties exercising jurisdiction in adjacent areas (Article XI & Chairman's Statement)
Contracting party obligations	Outlines duties, including prompt implementation of measures (including for nationals), measures to ensure compliance (timely address violations), data submission etc. & relevant information exchange (scientific, technical & implementation information) (Article 23)	Outlines duties, including prompt implementation of measures (including for nationals), measures to ensure compliance (timely address violations), data submission etc. & relevant information exchange (scientific, technical & implementation information) (Article 22)	Contracting parties take appropriate measures to ensure compliance with C-CAMLR provisions (Article XXI) & promote convention objectives (Article XXII)
Flag state duties	Ensure flagged vessels comply with measure, possess authorization to fish in all SIOFA Area, details measures to give effect to control of flagged vessels & urges need to ensure such vessels do not undermine measures by unauthorized fishing in SIOFA & adjacent areas & mandates VMS deployment (Article 11)	Ensure flagged vessels comply with measure, possess authorization to fish in all SPFRMO Area, details measures to give effect to control of flagged vessels & urges need to ensure such vessels do not undermine measures by unauthorized fishing in SPRFMO & adjacent areas & mandates VMS deployment (Article 23)	Not specifically mentioned, but implicit recognition of flag state rights & obligations in respect of applying inspection & observations schemes (Article XXIV). Commission also required to draw attention of non-parties to activities by nationals or vessels affecting implementation of convention objectives as well as parties attention to activities affecting compliance (Article X).

Table 1, cont.

TOPIC	UNFSA	SEAFC	WCPFC	SWIOFC
Port state duties	Empowers port states to take measures consistent with international law & RFMO provisions (Article 23)	Similar to UNFSA Article 23 – port state measures consistent with international law (Article 15)	Similar to UNFSA Article 23 – port state measures consistent with international law (Article 27)	Not detailed
Compliance and enforcement	Details co-operation in enforcement, sub-regional enforcement co-operation & basic boarding/inspection procedures (Articles 20–22 respectively)	Establishes MCS framework as alternative system under UNFSA Article 20(15). Details for first commission meeting, but interim guidelines provided (Article 16 & SEAFC Annex).	Details MCS framework, including schemes for boarding/inspection, observers & regulating transshipment (per UNFSA Articles 20–25). Also outlines terms & conditions for fishing & information requirements (Articles 25, 26, 28, 29, Annexes III & IV)	Not detailed
Control of nationals	No specific mention. Implied in ensuring national "industries" co-operation (Article 10 (c)).	Specific reference to nationals & industries (no prejudice to Flag State responsibility) (Article 13 (3))	Similar to SEAFC but with some elaboration (Article 23 (5))	Not detailed, but institutes considerations (Article 4) compatible with UNFSA Articles 24–26
Fishing opportunities	Limits resource access to RFMO participants/members. Indicates considerations to be taken into account in determining nature/extent of participatory rights for new entrants (Articles 8 (4) & 11 respectively)	Details considerations for determining fishing opportunities (including real interest) Commission to agree rules (Article 20)	No single consideration of fishing opportunity allocation, but some direction provided (Articles 6.4, 10.1 (g) & 10 (3))	Not detailed
Good faith and abuse of rights	Specific provisions (Article 34)	Subsumed into contracting party obligations (Article 13 (8))	Specific provision (Article 33)	Not detailed
Non-Contracting Parties (NCPs)	Specific provisions emphasizing duty not to undermine RFMO measures & need to adopt regulations consistent with UNFSA (Articles 17 & 33)	Call for co-operation, information exchange, taking internationally acceptable steps to deter NCP activities undermining measures. NCPs enjoy benefits commensurate with commitment to comply with measures (Article 22)	Call for co-operation, information exchange, taking internationally acceptable steps to deter NCP activities undermining measures. NCPs enjoy benefits commensurate with commitment to comply, & compliance record for measures (Articles 6.4, 32)	Not specified, but allows for wide observer participation (Article 8)
Decision-making	Not specified	Consensus with opt out in exceptional circumstances. No provision for breaking deadlock. Immediate resort to dispute resolution provisions (Articles 17 & 23)	Generally consensus, opt out provided in case of voting against decision & capacity to appoint review panel to break deadlock (Article 20)	Decisions taken by member majority under FAO Constitution Article II.10 & Rules of Procedure (adopted 20/4/2005) approved by Director-General FAO as per Article 9
Budget	Not specified	Budget adopted by consensus. Equal for first three years then part equal & part calculated from catch levels. Some recognition of capacity to pay & cost-efficiency (Article 12).	Budget by consensus. Based on assessed contributions as adopted (taking into account equal basic fee & other criteria for remaining portion). Recognize ability to pay. No voting on arrears for two years. Interest payable on arrears. Special fund for developing States (Articles 17, 18 & 30 (3)).	Not specifically mentioned, but subject to Article VI.1 of the FAO Constitution fund to be provided by FAO. Funds may also be sought as necessary (FAO Resolution 1/127 & Article 4. (l))
Dispute resolution	Resolution by peaceful means, includes prevention disputes & definition technical disputes (Articles 27 to 29). Procedures to settle under, *mutatis mutandis* provisions UNCLOS Part XV, other UNCLOS & UNFSA provisions & provisional measures pending settlement (Articles 30 & 31).	As per UNCLOS Part XV & UNFSA Part VIII. By implication former applies to discrete stocks & latter to straddling stocks. Also applies to SEAFC Parties not party to UNCLOS &/or UNFSA (Article 24).	Direct application of UNFSA Part VIII (Article 31)	Not specifically mentioned, but any legal interpretation or dispute treated under Article XVII of FAO Constitution
Developing states	Specific considerations, including recognition of needs, forms of co-operation & provision of assistance (Articles 24 to 26)	Recognition of special needs subsuming provisions of UNFSA Articles 24 to 26 (Article 21)	Recognize qualified special needs of small island developing states. Establish special fund for developing states (Articles 30 & 30 (3))	Specifically recognizes developing state & small island developing state needs (Resolution 1/127 & Article 4)
Real interest	Real interest in fisheries leading to support for RFMO (Article 8 (3))	Perfunctory promotion of co-operation for "real interest". (Preamble). Implicit condition in allocating fishing opportunities (Article 20).	No direct reference, but implicit in pre-negotiation	No direct reference
Transparency	Promotes transparency & co-operation (Article 12)	Not specifically addressed, but wide-participation of observers etc. mandated (Article 8.6 to 8.10)	Promotes transparency & co-operation (Article 21)	Observer participation on request (Article 8)
Additional provisions	Addresses fishing entities (Article 1.3)	–	Promotes regional scientific observer programme (Article 28)	–
Status (16/11/07)	Ratifications/Accessions (67)	Members (3 + EC)	Members (27), Participating Territories (7), Co-Operating Non-Member (1)	Members (14)

*) Adapted from D. Doulman, "A Preliminary Review of Some Aspects of the Processes in the Western and Central Pacific Ocean and the South-East Atlantic Ocean to Implement the UN Fish Stocks Agreement". Paper presented to Conference on the Management of Straddling Fish Stocks and Highly Migratory Fish Stocks and the UN Agreement (Bergen, Norway 1999) at p. 4. D.G.M. Miller and E. Molenaar, "The SEAFC Convention: A Comparative Analysis in a Developing Coastal State Perspective". *Ocean Yearbook* 20: 305–375 (2006).

Table 1, cont.

TOPIC	SIOFA	SPRFMO	C-CAMLR
Port state duties	Similar to UNFSA Article 23 – port state measures consistent with international law (Article 12)	Similar to UNFSA Article 23 – port state measures consistent with international law (Article 12)	Not specified
Compliance and enforcement	Promotes MCS through contracting party duties (Article 10.2, 10.3, 10.4), flag state duties (Article 11.3 (d), 11.3 (e)), port state duties (Article 12.2 (a), 12.2 (b), 12.2 (c) & 12.3)) & special account of developing state requirements (Article 13.4 (d))	Promotes MCS specifically per register of licensed vessels, regulation of transhipment, at-sea/port inspections, addressing IUU, non-compliance of contracting parties & sets default adoption after two years of UNFSA boarding/inspection procedures (UNFSA Article 21 & 22). All to be consistent with contracting party rights to adopt MCS-related measures consistent with UNCLOS & UNFSA (Article 26).	Not specified, but mandated by general invocation to take measures necessary for fulfillment of CAMLR Convention objectives (Article IX.1 (h) & 2 (i)))
Control of nationals	Specific reference to nationals & industries (no prejudice to flag state responsibility) (Article 10.3)	Specific reference to nationals & industries (no prejudice to flag state responsibility) (Article 22.2 to 22.4)	Specific reference only to non-party nationals (Article X.1)
Fishing opportunities	Not detailed. Some consideration for assisting developing states to participate in SIOFA fisheries as per UNFSA Article 25.1 (Article 13.3 (b))	Detailed (Article 19) with provision for developing states (Article 19.1 (e) to 19.1 (g)) & need for consensus decisions on participation (Article 19.2) as well as regular review of such participation (Article 19.3)	Not specified, but can designate various properties attached to allowable fishing (Article IX.2 (a) to (h)))
Good faith and abuse of rights	Specific provision (Article 18)	Specific provision (Article 22.5)	Not specified, but no derogation of rights & obligations under Convention for Regulation of Whaling & Convention on Conservation of Antarctic Seals (Article VI)
Non-Contracting Parties (NCPs)	Call for co-operation, information exchange, taking internationally acceptable steps to deter NCP activities undermining measures. NCPs enjoy benefits commensurate with commitment to comply with measures (Article 17)	Specific account of UNCLOS Articles 116–119 as well as of port or market State involvement (Article 31)	Draw attention of non-parties to activities undermining CAMLR Convention (Article X.1) & each contracting party to promote convention objectives generally (Article XXII)
Decision-making	Consensus (defined as absence of formal objection) for matters of substance, otherwise simple majority. All Commission decisions binding on parties (Article 8)	Generally consensus (i.e. absence of formal objection) or unless consensus mandated, absence of consensus resolved by 2/3 majority voting (Article 14.1-14.5). Other provisions address decisions in subsidiary bodies & do not foreclose inter-sessional decision-making (Article 14.4 to 14.12)	Decision by consensus on matters of substance or simple majority vote for other matters (Article XII). Potential opt-out procedures in relation to measures (Article IX.6).
Budget	Adopted at first meeting with Financial Regulations. Budget contributions to account for economic status of Parties concerned (Article 5.4)	Budget provisions outlined. Lack of agreement mandates previous year budgetary levels maintained until consensus reached (Article 13)	Budget by consensus (Article XIX.1) with suspension from decision-making of two years in contribution arrears (Article XIX.6). Budget contribution based on equal portion & amount harvested (Article XIX.3).
Dispute resolution	Relevant parts of UNCLOS (Section II of Part XV) & UNFSA (Part VIII) apply (Article 20)	Relevant parts of UNCLOS (Section II of Part XV) & UNFSA (Part VIII) apply (Article 34)	Allows for Arbitral Tribunal or in case of failure referral to International Court of Justice (Article XXV and Annex)
Developing states	Specifically recognizes developing state & small island developing state needs (Articles 4. (g), 13)	Detailed in general as per UNFSA Articles 24–26 (Article 16), specifically in relation to TAC/TAE access (Article 18.1 (h)) & fisheries participation (Article 19.1 (e) to 19.1 (g))	Not addressed
Real interest	No direct reference, but "interest" in resources mentioned (Preamble)	No direct reference	No direct reference, but conditions for accession mandate interest in research on, or harvesting of, resources to which CAMLR Convention applies (Article XXIX)
Transparency	Expressly addressed (Article 14)	Expressly addressed & predicated by interest in matters pertaining to the Commission (Article 15)	Not specifically addressed, but observer participation allowed (Article XXII)
Additional provisions	Addresses fishing entities (Article 15)	Addresses conservation management measures (Article 17), establishment TAC/TAE (Article 18), development of new fisheries (Article 20), market-related measures (Article 25), fishing entities (Article 32) & periodic review (Article 29)	Due regard for Antarctic Treaty provisions (Articles III to V) & consistency with UN Charter (Article XXII)
Status (16/11/07)	Members (7)	Under negotiation	Members (25), Acceding/Contracting Parties (9)

RFA conservation measures.

However, two noticeable features confound effective RFMO implementation of compliance enforcement (Rayfuse 2004a). First, no RFA has yet provided for the right of arrest, detention or prosecution by a non-flag state if a flag state refuses, or is unable to take, compliance enforcement action, when the need for such is detected through the boarding and inspection of vessels by non-flag states on the high seas. Second, and following the previous example, it appears that the primacy of flag state jurisdiction itself is the main barrier to effective high-seas compliance enforcement. Here, certain flag states fail, refuse, or are unable to assume, their legal responsibilities for marine living resource conservation on the high seas. Consequently, the persistence of, and damage caused by, IUU fishing have increased consideration of ways to promote non-flag state enforcement when flag states continue to allow their vessels to fish in contravention of RFMO measures in particular (Rayfuse 2004b, Baird 2006).

The above has resulted in a generally common RFMO approach to encouraging both members and non-members to comply with agreed regulatory measures. This includes identifying categories of "co-operating" parties, producing "white" lists of vessels authorized to fish in an RFMO regulated area, developing "black" lists of vessels undermining RFMO measures, adopting catch documentation schemes, promoting co-operative surveillance activities, improving information sharing and negotiating measures aimed at controlling the fishing activities of natural, or nationalized, persons. Examples of such measures are shown in Table 1 and it should be noted that CCAMLR in particular has instituted many of the measures identified.

It should also be noted that measures like those in Table 1 have drawn heavily from, and are consistent with, measures in the FAO International Plan of Action on IUU Fishing, IPOA-IUU (FAO 2001). Other measures adopted to date have included denying landing or transhipment of catches, port state inspections, trade measures and diplomatic demarches (Rayfuse 2004a). Again CCAMLR has effectively implemented many of these (Miller *at al*. 2004, CCAMLR 2007) and it can be said that they constitute legitimate "countermeasures" (Rayfuse 2004a) aimed at combating compliance failures.

Innovative developments offer other ways to improve RFMO compliance enforcement (Lodge *et al*. 2007). For example, global application of long-arm enforcement, such as **US Lacey Act** type legislation, has been effectively used to prosecute individuals who have acted in violation of regulatory measures in one jurisdiction when they enter another (Ortiz 2005). Similarly, best practice procedures are currently being developed by RFMOs such as CCAMLR to regularly assess the effectiveness of compliance enforcement and to enhance RFMO performance as a whole (see section 'Future Challenges').

The UNFSA's entry into force can therefore be seen to have been accompanied by greater global acceptance of the general duty to co-operate in the conservation of marine living resources. This has been achieved through improved enforcement of RFMO measures, either by better compliance or by restraining irresponsible fishing. However, it is not to say that the problem of IUU fishing has been resolved. In this regard, a lack of compliance enforcement capability and a perceived lack of legitimacy attached to RFMO-adopted measures are both key factors contributing to compliance failure(s). Equally, unrealistic socio-economic expectations and inadequate political will compound the problem for many RFMOs.

Socio-economic expectations

Undoubtedly, fishing evolved as a means of providing protein for coastal communities. With the advent of industrialized fishing, an essentially artisanal, or at least relatively small-scale, enterprise became an endeavor requiring large financial investment with considerable profit potential. In fact, profit maximization has been identified as the dominant feature of many industrial fisheries that have failed to date (Munro *et al*. 2005). Grotius' *res communis* could be said to have been superseded by *res individualis*, where the benefits of high seas fishing in particular profit a few, unscrupulous fishers at the expense of the global community and to the detriment of the resources concerned.

Articles 2 and 5 of UNFSA clearly indicate that the Agreement's key objective is to "ensure the long-term conservation and sustainable use" of the fish stocks to which the Agreement applies by adopting measures to provide for the long-term sustainability of these resources and by promoting their "optimum utilization". The concept of optimal utilization implies that the fishery resources concerned are managed in such a way as to ensure that economic benefits accrue to society as a whole over time and not to the fishing industry alone (Lodge *et al*. 2007). Benefits are not only financial in nature, but are also biological in terms of providing future "natural" capital (i.e. viable fish stocks) to be optimally and sustainably utilized with time. Sustained "ecosystem health" is thus vital for providing natural capital (Cochrane 2000); a point well recognised in Article II of the CAMLR Convention.

It therefore follows that the major challenge to implementing an ecosystem approach to fisheries is the need to balance ecosystem sustainability with human socio-economic expectation through effective management of harvesting. As the FAO has indicated (FAO 2003: p. 14):

> ***"The purpose of an ecosystem approach to fisheries is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems".***

This suggests that the best way to promote food security is through sustainable marine living resource use and the equitable optimization of ecological, social and economic benefits for current and future generations.

Lodge *et al*. (2007) have emphasized that the potential conflict of conservation and sustainable use has optimal utilization at its centre for most modern fisheries economies. Put simply, over-emphasizing optimal utilization renders financial gain at the cost of lost natural capital; overemphasizing natural capital leads to loss of financial opportunities. The balancing of the two extremes has been historically complicated.

The expansion of coastal state jurisdiction under UNCLOS not only served to highlight differences in DWFS and coastal state expectations, it also is a classical example of the "prisoner's dilemma" in action (Munro *et al*. 2005, Appendix; Lodge *et al*. 2007). Essentially, Articles 63, 64 and 116 of UNCLOS have been criticized as unclear in identifying the precise rights, duties or obligations of coastal states compared to those of DWFS (Munro *et al*. 2005). Until UNFSA was negotiated, this lack of clarity made it difficult to provide for effective co-operative management of straddling and migratory stocks in particular. In turn, UNFSA itself is unlikely to be effective if co-operative management is not practiced (Munro *et al*. 2005 p. 45). Therefore, the "prisoner's dilemma" remains a very real feature for many high value fisheries if parties feel coerced to seek unilateral advantage through high levels of fishing in the face of obvious communal disadvantages likely to rise from stock losses.

Such considerations affected negotiation of the WCPFC (Rayfuse 1999) by complicating the need to account for both developing state and DWFS aspirations (Miller, Molenaar 2006). Similar complications impacted on negotiation of fishing opportunities under Article 20 of SEAFC. Combined with a need to provide for expressions of "real interest" and for fair access to RFMO participation by new parties as *per* Article 11 of UNFSA, the balancing of socio-economic expectations in many post-UNFSA RFAs has not been easy. Issues such as freedom of trade and a growing need for food security have all played roles in complicating RFA implementation and development in recent years. As Cochrane (2000) states "the general conflict between short-term economic and social objectives and the longer-term objective of sustainability, with the former usually being given priority" has limited the wider attainment of sustainable and productive fisheries. Again, this has been particularly true for high-value fisheries where the potential for IUU fishing is greatest (Sumaila *et al*. 2006).

The emergence of the RFMO regime post-UNFSA has been viewed "as the continuation of a 60-year process to curb the freedom to fish" on the high seas (Lodge *et al*. 2007). A lack of co-operative and resilient management would then be most likely to result with many RFMOs foundering. In this respect, fair allocation of catch to allow for new members and addressing stock uncertainties remain key issues. Finally, the "divide-and-rule" scenario where many RFMOs act independently of one another, often despite common membership, does not facilitate global cohesion or common standards, especially in the case of IUU fishing. It therefore follows that inter-RFMO co-operation could be improved (Lodge *et al*. 2007) and that such co-operation should enhance legal predictability in developing consistent legal precedents and practices.

Role of science

Articles 200 and 201 of the UNCLOS specifically urge states to become involved with exchanging information on, and improving knowledge about, pollution of the marine environment. More specifically, Article 201 encourages the development of "scientific criteria", practices and procedures to deal with pollution prevention, reduction and control. Similar requirements for scientific information or data relevant to the conservation of fish stocks are also outlined in Articles 61.2, 61.5 and 119.2. The latter provisions are further elaborated in Article 5 (b) of the UNFSA to ensure that measures maintaining long-term sustainability of straddling and highly migratory fish stocks are based on the "best scientific evidence available". The standard requirements for collecting and sharing relevant data are set out in Annex 1 of the Agreement.

It has been maintained that the precautionary approach has effectively changed the role that scientific data plays in managing fisheries as a whole (Freestone 1998). As such, action is required once there is an indication, or even presumption, of fishing, or other activities affecting environmental or ecological qualities, especially when these are crucial to maintaining the sustainability of target stocks. The action taken is itself not predicated by scientific certainty, which in turn implies that the "risk(s) of irreversible change or long-term adverse effects of harvesting, and/or associated activities, should be minimised" (Miller 2002).

The need to deal with uncertainty in applying the precautionary approach to fisheries management has been recognised for some time (FAO 1996), and most notably by CCAMLR (Miller *et al*. 2004). It is specifically addressed in Annex II of UNFSA in the form of guidelines for application of precautionary reference points in the conservation and management of the stocks to which the Agreement applies. In this context, the obligation to apply a precautionary approach to fisheries management can now be said to have developed into a legal principle – the precautionary principle. This principle is a fundamental component of the concept of ecologically sustainable development (ESD) and is defined in *Rio Declaration* Principle 15 from UNCED:

> ***"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation".***

Nevertheless, the recognised need to develop ecosystem-based management alluded to previously has complicated matters since both biological and ecological uncertainty increase the demand for more objective and defined scientific approaches (FAO 2003). A lack of such knowledge has often resulted in poor or inappropriate management decisions (Cochrane 2000). Essentially, a lack of clarity surrounding the term "best scientific evidence available" has considerable potential to impact on decision-making if RFMOs come to rely on *ad hoc* or incompletely validated scientific advice.

In the absence of clear procedures for the promulgation of scientific advice to be used in RFMO decision-making, the best scientific evidence available may come to be the most recent scientific results presented. The implication is that such advice would not have been rigorously or scientifically evaluated and may not be objective as a result. At least, CCAMLR has expressly agreed that that its Scientific Committee provides the only source of the best scientific evidence available (CCAMLR 1990, paragraph 7.6). It therefore seems sensible that RFMOs should make every effort to ensure that a scientifically rigorous mechanism is in place so that the provenance of scientific advice offered to the decision-making process is clearly agreed and that an indication is given of the potential risks attached to various management scenarios when scientific consensus is lacking. Most of the RFMOs identified in Table 1 strive to follow such an approach in both structure and form so as to promote informed decision-making.

Political will

Constraints on countries participating in implementation of the 1995 FAO Code of Conduct for Responsible Fisheries can be placed into two major categories – insufficient capacity and political influences (Cochrane, Doulman 2005). These categories are inter-related insofar as the provision of insufficient resources is usually a function of government inability, or lack of will, to provide the necessary infra-structure for managing responsible fishing. As emphasized earlier, the situation is exacerbated by focusing on financial capital rather than the balance between financial and natural capital. The end-result tends to favour short-term socio-economic goals at the expense of longer term sustainable use (Symes 1996).

It should therefore come as no surprise that while "political will" not only reflects socio-economic expectations prevailing in any state, it also plays a significant role in state practices aimed at discharging international duties and obligations for marine living resource conservation. As emphasized by the Implementation Plan of the World Summit on Sustainable Development (WSSD 2002), and more recently by United Nations General Assembly Resolution 61/05 (UN 2007), effective information exchange and capacity building are key elements in facilitating development of global strategies to promote responsible fishing. Rigorous and critical implementation of such considerations is essential for more effective RFMOs, both now and in the future (Lodge *et al*. 2007). Only with global strategies in place will the benefits of the financial and natural capital attached to fisheries be preserved. Citing Arnason (2006), Lodge *et al*. (2007), have emphasized that these benefits could amount to USD 50 billion/annum if world capture fisheries are optimally managed. The consequent boost to the food security of developing and under-developed coastal states is obvious.

Future challenges

Various authors have outlined the challenges faced by RFAs and RFMOs in addressing sustainable management of the fisheries resources and marine ecosystem for which they are responsible.[3] Lodge *et al*. (2007, chapter 11) consider in-depth how RFMO governance mechanisms may be improved at institutional level. Important cross-linkages include promoting consistent decision-making processes, ensuring institutional transparency, unifying the promulgation and use of scientific advice, considering the special requirements of developing states and

3. While some of these have already been considered, particular note should be taken of the summaries provided by Miller *at al*. (2004, Table 12), and Cochrane, Doulman (2005, Table 4).

enhancing co-operation with other relevant international organisations, including RFMOs.

In the above context, IUU fishing may be viewed as the most tangible threat to good fisheries governance since it undermines management measures and compromises the sustainability of legitimate fishing (Vidas 2004, COFI 2005). It also mandates a significant commitment of valuable and often limited resources to counter its effects – a problem of particular significance for developing states and affected RFMOs (MRAG 2005). Finally, IUU fishing serves to compound management uncertainty to essentially intolerable levels (Pauly *et al*. 2002).

While space limitations preclude detailed analyses, it is possible to provide a generic list of the threats being faced by most RFMOs, and the topic areas where co-operation, action and co-ordination could be improved in RFMO day-to-day tasking.

Threats to RFMOs and RFAs

- Failure of flag state enforcement.
- Mismatched resources (i.e. natural capital) and expectations (i.e. economic capital).
- Unrealistic biases due to fisheries subsidies and over capacity.
- Conflicting conservation and socio-economic objectives.
- Inadequate participation by legitimate stakeholders, with "free-riders" (i.e. parties with no, or limited, interests in effective outcomes) influencing decision-making.
- High levels of management uncertainty due to bad or incomplete knowledge.
- Equity and access issues in relation to fishing opportunities, catch allocation and acceptance of new members.
- Lack of standards to quantify ecological values ("natural capital") compared to socio-economic expectations in the management paradigm.
- Instrument implementation fatigue, especially for developing states (Cochrane, Doulman 2005).
- Insufficient human, or logistic, capacity and political will for compliance enforcement, especially in developing states.

Topics to improve co-operation, action and co-ordination

- Development of sustainability benchmarks, including ecosystem approaches to fisheries management and precautionary catch levels.
- Maintenance of ecological and environmental healthy areas, including protected and variably managed areas.
- Effective institutions, i.e. both cost-effective and administratively efficient.
- Common standards, particularly for assessment and management action as well as sanctions for non-compliance.
- More efficient exchange of relevant information, particularly between RFMOs.
- Improved cooperation between RFMOs so as to enhance legal consistency.
- Robust legal provisions, particularly from trade measures and on-water compliance enforcement.
- Objective, rigorous and impartial scientific

advice for more informed political, and management, decisions.

Conclusions

In respect of both threats and topics for improvement, it is notable that CCAMLR has learnt a number of important lessons over the past 25 years, from 1982 to 2007 (Miller 2007):

- Good and tractable science is essential for addressing large management uncertainties.
- Pro-active management and pre-agreed decision rules minimise potential conflict.
- Management action should be realistic, dynamic, flexible and monitorable.
- At-sea observations are an extremely valuable source of essential fisheries information.
- Wide monitoring, control and surveillance (MCS) is essential for effective compliance enforcement, particularly to counter IUU fishing.
- Formal processes are essential for effectively managing new and exploratory ("developing") fisheries, especially in terms of accruing essential data.
- Some potential problems are not solvable in isolation, especially when transboundary effects are taken into consideration. This has required co-operation with RFMOs of similar interests or mandates, especially in geographically adjacent areas.
- Encouraging active co-operation pays dividends in promoting the organization's conservation measures. Notable examples include emergence of the Toothfish Catch Documentation Scheme (Agnew 1997) and a number of states becoming CCAMLR Contracting Parties (Cook Islands, Mauritius and Vanuatu) or Members (Namibia and People's Republic of China) over the past ten years.

Obviously, the CCAMLR list is not universally applicable, given the diverse needs, demands and unique circumstances of the some 30 RFMOs currently in existence, or being negotiated. However, it does reinforce the common view that CCAMLR stands alone internationally as the RFMO that has most thoroughly benchmarked best practice for an ecosystem and precautionary approach to managing fishing on the high seas (Willock, Lack 2006). Together with growing recognition that RFMOs require regular review to optimize performance in executing their respective mandates (UN 2007 paragraph 73, Lodge *et al.* 2007), the 2008 CCAMLR review of that organisation's performance is a benchmark development.

Furthermore, it is noteworthy that various institutions and events recently have had considerable impact on global efforts to co-ordinate and improve RFMO efficiency. Some of these have been of a general nature, such as the Inter-Ministerial High Seas Task Force (HSTF 2006) while others have been more salutary (Anon. 2006) or have focused on specific practical issues. Such issues have included general consideration of RFMO performance, including identification of benchmark standards (Lodge *et al.* 2007), individual review of single RFMO performance (NEAFC 2007) or attempting to improve the organizational efficiency of existing RFMOs (NAFO 2005; Tuna RFMOs 2007). Also, the FAO Regional Fisheries Bodies Secretariat Networks – RSN (FAO 2005, paragraphs 5–7 and 49) and the International Monitoring Control and Surveillance (MCS) Network (MCS 2007) provide fora where practical issues of RFMO implementation are discussed in both an administrative and practical context. The potential of these fora for exchanging information, setting common standards and promoting best-practice should not go unnoticed.

Finally, we have made no attempt here to consider the crucial impetus that national legislation gives to the effective jurisdictional application of measures to conserve marine living resource sustainability in coastal state EEZs and on the high seas. The various examples, both good and bad, of how this prerogative has been implemented are extensive and complex. However, in the CCAMLR context certain, and far-reaching, legislation in the European Union, Australia, France, Spain, New Zealand, Norway, South Africa, the United Kingdom and the United States has greatly facilitated the organization's efforts to combat IUU fishing for toothfish at a global level (Miller *et al*. 2004). It can also be said, that the entry into force of regional arrangements such as the Southern African Development Community Fisheries Protocol demonstrate great promise for improved implementation of RFAs (Miller, Molenaar 2006) at regional level through better co-ordination and standardization of national legislative provisions. FAO initiatives aimed at developing universal port state controls, a global record of fishing vessels and better flag state compliance may be viewed positively in the same light.

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SCIENTIFIC ADVICE FOR FISHERIES MANAGEMENT

Hans Lassen

Abstract

This chapter presents the fundamentals on advice for fisheries management including a discussion of how best to organize the advisory process to assure that the advice is based on 'best scientific practice', is 'free from political influence', and is presented with integrity. Furthermore, the chapter discusses how to assure that the science advice is accepted and respected by all involved in the decision process whether these are politicians, managers or stakeholders.

The International Council for the Exploration of the Sea (ICES) is the intergovernmental organisation that provides scientific advice on fisheries management for the Northeast Atlantic Ocean. This advice is developed through a system of working groups involving data compilation and data analysis, peer review of the findings and formulation of advice as conclusions of the scientific analyses. The chapter is built on experience and considerations made within ICES in organising its advisory services.

Introduction

Fisheries can impact fish stocks significantly and unrestricted fisheries can be detrimental to the fisheries themselves and to the ecosystem. Society therefore regulates fisheries, e.g. FAO (1995) Code of Conduct on Responsible Fishing. Fisheries management includes information gathering, biological advice, management decision, implementation and control and enforcement. The information gathering and the biological advice are the remit of the scientific advice. The Reykjavik declaration, FAO (2001), calls for advice by 2010 to be based on an 'Ecosystem Approach' and hence the scientific advice shall consider all impact from fisheries on the ecosystem. It is recognised that there are many effects from fishing where the long-term effects are only vaguely known. However, it is hoped that these effects are of minor importance relative to the direct effects of removal of target species and by-catch of marine mammals that most advice concentrate on.

Assessment of fish stocks establishes the status of the stock relative to a reference level. This reference level can be defined in terms of spawning stock biomass, abundance indicator or exploitation pressure and such references are established based on historic performance of the stock. The assessment is built on population dynamics of marine fish stocks (Deriso and Quinn 1999).

The EU Green paper on the Common Fisheries Policy (2009) and FAO report to its Fishery Committee (SOFIA 2008) both reported on overfishing and non-compliance with fishing regulations. Demersals stocks in the Northeast Atlantic are overexploited while some of the pelagics are less so, ICES advice (2008). On this background the science advice as part of the management system can be claimed as not being 'right', scientific advice for fisheries management is under pressure and its objectivity and the scientists' integrity is being questioned. This is illustrated by many statements from the industry that the advice is out of touch with reality, that science does not take into account observations by fishermen on high occurrence of say cod, etc.

ICES as an advisory body

The International Council for the Exploration of the Sea (ICES) is an intergovernmental organisation established in 1902 and that among its task has to provide scientific advice on fisheries management. By 1953 ICES established the Liaison Committee as its advisory committee with the words "In order to deal effectively with any problems or enquiries which may be addressed by the Commission to the Council and in order to obtain expeditious action relating to them the Council has set up a special Liaison Committee, which will be empowered to consider and answer in the light of the evidence available to them these and any future questions."

This statement illustrates several important aspects of advice on fisheries management: the advice is based on science evidence, the advice is the collective responsibility of a science community, the advice is developed through a process within the scientific community that assures that the advice is balanced and not dominated by individual points of view, and finally that an advisory system needs to be responsive and timely. These considerations are as valid today as they were in 1953.

Today ICES provides fisheries management advice on international fisheries in the Northeast Atlantic except for tuna fisheries. The receivers of this advice are the governments in 20 ICES member countries and several Partner Commissions such as European Commission (EC) and North East Atlantic Fisheries Commission (NEAFC).

Fundamentals of fisheries management advice

Fisheries management advice informs on the status of the fish stocks and on the expected status under different fishing scenarios. ICES provides such reports annually, e.g. ICES advice (2008). However, the science advice is only useful if it is accepted by all relevant stakeholders and is used by decision makers and by stakeholders. The mantra for fisheries advisory science can therefore be summarised as follows below in four points (after M. Sissenwine, pers. comm.).

Be right, relevant, responsive, and get respected

Making fisheries management advice right
The advice shall be based on 'best science available', i.e. relevant information and appropriate analytical methods used in a consistent manner. The uncertainty in the assessments shall be reflected in the advice. Right does not mean that specific predictions turn out to always be true, but for an advice to be right it must have reasonable predictive power.

Making fisheries management advice relevant
This is about the advice being relevant within the practical and political context. Advice must address management measures that can be implemented from a practical point of view. The advice must include considerations of the practical fisheries and their constraints.

Making fisheries management advice responsive
This is about three things: 1) the institutional arrangement around the formulation of the advice; 2) that the fisheries scientists recognize changes in management needs, in practical fisheries and in ecosystems and 3) that the correct management level is addressed.

Getting fisheries management respected
Even fisheries management advice that is right, relevant and responsive will not be useful unless it is respected (or credible) by those who make decisions and who are affected by these decisions. One of the most important aspects of gaining respect for fisheries management advice is having a track record of being correct in the past. Respect also requires that the users believe that the scientists preparing the advice have no vested interest. This means that the scientists have no agenda of their own except to provide scientific advice that is right, relevant and responsive.

Being right, responsive, and relevant are issues that can be addressed within the science and its organisation itself. Getting the advice accepted among those affected by possible management measures is a problem of a different nature that is addressed through transparency and involvement of stakeholders in the advisory process.

Clearly, gaining respect of the advice is difficult, but respect can be improved by:

1. Investing in research and data collection so that the advice has a good track record.
2. Making the advisory process transparent and involve the stakeholders at an early stage of the advisory process.

3. Making responsibility for the content of the advice as independent of the fishery management policy and decision makers.
4. Communicating the advice effectively.
5. Subjecting the advice to 'peer review', i.e. having advice reviewed by previously uninvolved scientists who are themselves qualified or capable of having prepared the advice.

Involving stakeholders in the advisory process is addressed at both national and international levels. Many countries have established committees and other groups that promote cooperation between science and industry at the working level. While such cooperation in some cases have improved the trust and openness this is not always the case; there are examples, e.g. Ireland in 2005, where the industry has blocked access to sampling catches and landings.

The industry-science committees and groups will normally scrutinise data before these are released. The discard observations may serve as an example where some of these committees have decided that the data are not representative for the fisheries and have decided not to release the data outside a narrow circle. However, such policies are often defying the purpose as the withholding of data is a basis for speculations of what such data might suggest.

At the international level, industry is invited to participate in data interpretation and to observe the advisory process. In USA the advice is formulated by regional councils with both industry and government representation. In Europe the advice is still formulated by a scientific group that is open to observers from NGOs and industry. Also, within EU, seven Regional Advisory Councils with industry and NGOs as members are established as a parallel advisory system. This advisory system takes the scientific advice from ICES and has so far not established a parallel science system.

Many of the controversies over fishery management advice reflect an overall situation of diminished respect for professionals and institutions. The fisheries science institutions therefore increasingly pay attention to getting the advice 'respected'.

The rational decision model in fisheries management

Fisheries management is built on a rational decision model that includes a management decision through a political process informed by relevant information provided by the science system. This decision model is embedded in an institutional framework, e.g. a fisheries commission or national government institutions and this institutional framework includes a system for collection, compilation and scientific analysis of data. Also, the general objectives for management are embedded in the institution.

A science advisory system shall work to certain standards which in bullet point form can be defined:

- Objectivity.
- Best scientific practise.
- Integrity (free from political influence).
- Openness and transparency.
- Quality assurance and peer review.

- National consensus.
- Credibility at the international level.

The task is therefore to build the framework for a rational decision model that lives up to these standards.

Fisheries science provides the science input for this decision model with annual advice identifying the appropriate level of exploitation that meets predefined criteria. In Europe the science framework is built by ICES.

An advisory system must be *efficient and flexible* in order to deliver advice that is timely. The advice is an input to a process that is not defined by science and advice is based on the available information at some point in time. Therefore, there is a conflict between making the management advice both right and responsive. Responsive advice may be based on limited information while increased scrutiny of the advice detracts from responsiveness. It should be recognized that not all advice requires the same level of attention in its preparation; it is not practical to provide the "best" all the time. If scientists are to be responsive to management needs, it will be necessary to accept scientific advice that is 'satisfactory', rather than always expecting it to be the best. Responsiveness also requires processes for preparing advice that varies for different levels of the fisheries management hierarchy. Some fisheries management decisions are made in an interactive setting among managers and interest groups, sometimes on an almost real-time basis. In such cases, involving scientists who can give nearly 'instant' advice, based on their experience and knowledge of fishery management systems, is an integrated part of the interactive process, but it is difficult to assure the quality of such advice, such as by subjecting it to peer review.

An advisory system must provide results that are '*free from political influence*'. International science advisory organisations finalise and adopt their advice through committees which assure that a range of relevant points of view are presented and considered. There are as many attitudes to exploitation of living marine resources among scientists as elsewhere in society and objectivity is approximated through a committee with sufficient width that it is ensured that the different approaches are properly balanced and that no individual point of view dominates the advice. The key instrument to achieve this is that these committees work on a consensus basis among the involved scientists, although the degree, to which this is formalised, varies between organisations. The integrity of advisory committee members is addressed through the nomination process. Within ICES, each member country can appoint one member to the advisory committee. However, it is stressed that the nominee is appointed in 'personal capacity' and not as a representative of his or her country. To stress this point formally the advisory committee works on behalf of the advising organisation not as member of their respective national organisations. The advisory committee works based on 'Chatham House Rule':

> ***"When a meeting, or part thereof, is held under the Chatham House rule, participants are free to use the information received, but***

neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed".

'Chatham House Rule' is adopted to press the point that the conclusions and advice are those of the committee and cannot be attributed to any individual member. Advisory committees work based on consensus and this means that the members are collectively responsible for the conclusions and that the political negotiations can start based on what is established as a common and a shared set of information and conclusions.

The *quality of the assessment*, that is the background for the advice, is checked through peer review assuring that the assessment has a sound science basis on which the final advice can be formulated. This is done in three distinct processes:

1) The first part is the *data compilation and data analysis*. This is done by a group of national experts and is organised within an Expert Working Group. The advisory organisations are based on country membership at government level, e.g. the ICES 1964 Convention which obliges governments of member countries to provide such contributions. Most advisory organisations include a system for nominating participants in these expert groups through a national system and the participants in this process are therefore mostly 'government scientists', i.e. working in a government fisheries laboratory.
2) The second step is p*eer review* of the findings of the expert group. This is done by independent experts not involved with the expert group report to be reviewed. The review shall ensure the quality of the analyses and assessments that are produced by the Expert Group(s) and which form the basis for advice.
3) The third step is the *advice drafting*. The advisory text shall be consistent with the assessment and in accordance with the advisory guidelines. There is an issue of consistency in interpretation: are the same or similar models and frameworks used to address similar issues? And in presentation: is the same or similar language used to describe similar situations? Also, the advice has to be seen from the perspective of the Client, does this answer his question? And is it the 'Best advice'; is it clear; and is it presented in a manner that is appropriate to the Client? At the advice drafting stage critical issues are objectivity and integrity of those involved. It is at this stage that the possibilities for unduly influence are biggest.

No assessment is better than the data allow and the quality of the data is guaranteed by national quality assurance programmes: to assure access to all relevant data, to put the proper interpretation on these data, to apply a consistent analytical method and to draw consistent and comprehensive conclusions from the analysis. This requires an open process among the scientific institutions which is implemented through a set of expert groups. Critical questions include: are these data valid, has the assessment overlooked significant illegal, unregulated and unreported (IUU) fishing when applying the assessment model to data from the commercial fisheries? The assessment systems include special sessions that take up these problems at irregular intervals. The international organisation can check data against general criteria and can compare data originating from different countries.

Objectives of fisheries management

Scientific advice for fisheries management shall provide a background for management decisions and shall therefore be relevant to management objectives. Unfortunately, fisheries management deals with conflicting targets: at least four different kinds of objectives are relevant:

1) Long term economic yield from fisheries. This economic yield can be seen from two different perspectives that do not necessary lead to the same conclusions:
   a) The owner of the fishing capacity (maximal interest of the invested capital).
   b) Society.
2) Long term maximum yield in weight from the stock – Maximum sustainable yield (MSY).
3) Nature conservation with the economic yield as a secondary target.
4) Regional politics with the main objective to maintain fisheries as the basis for employment. This is particular important in regions where alternative employments are few.

Such considerations will often lead to conflicting conclusions and the advice on appropriate management actions will differ dependent on which of the above perspectives are considered of key importance. The relevant perspective depends on the society, the fishery, the habitats which the fisheries impact. The advice shall be developed in the context of international agreements and guidelines to which the clients for the science advice are committed, notably the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, the World Summit on Sustainable Development (WSSD) implementation plan, the FAO Code of Conduct for Responsible Fishing and the Convention on Biological Diversity. The clients have different legal frameworks that the advice must be observed to be relevant, e.g. within the Europe Union the Common Fisheries Policy (CFP), relevant parts of the Water Framework Directive, as well as any other EU policy or measure pertaining to the marine environment. The advice shall reflect the latest policy developments under these policies such as emphasis on an Ecosystem Approach, and in the case of EU fisheries policy, long term management plans and a fleet based management of mixed fisheries.

To be internally consistent, advice on fisheries management must refer to well-defined targets. As these targets are rarely, if ever, defined explicitly by the political system, fisheries science has taken upon itself, beyond the remits of classical science, to define such targets. This analysis is not done in a vacuum but takes its starting point in the political texts that are unclear on how to balance conflicting objectives. Fisheries science offers an interpretation within which the advice is provided. This step is significant as this defines fisheries science as a normative science rather than being descriptive.

Fisheries management advice is normally based on one of three principles:

1) An *adopted management* plan. In some cases such a management plan is evaluated relative to one or several of the objectives discussed above.
2) Long term yield in weight (*Maximum sustainable yield* – MSY).
3) *Precautionary approach* – avoiding fishing pressure that will impair the productivity of the stock in particular the recruitment.

An adopted management plan removes the task of defining an objective from science but leaves science with the problem to evaluate whether such a plan is in accordance with principles laid down in relevant international agreements. In principle, when the advice is formulated consist-ently with a management plan the science input is reduced to a technical evaluation of the status of stock and calculation of what the management plan implies under the observed stock conditions. Below I offer some comments on the two other considerations: Maximum sustainable yield and the Precautionary approach.

Maximum sustainable yield (MSY)

This concept is embedded in the convention of several management organisations, e.g. the International Commission for the Conservation of Atlantic Tunas (ICCAT) and is promoted by the UN WSSD (2002) implementation Plan.

The model focuses on the yield and the advice based on this model will be a set of fishing mortalities that will maximize the yield (F_{MSY}). This advice may take stock-recruitment or interactions between species into account. The maximum yield that is derived is obviously model dependent and the concept becomes difficult to deal with in a multispecies context; in such a model the maximum of a stock will depend on the fishing strategy on another stock. Maximum yield on all stocks combined will obviously depend on the value attached to each stock and the value attached to different size classes – using the total catch is just to assign the same value to all species and size groups. The simplest version of this model is the Yield per Recruit model.

The MSY concept is often mistaken as being closely linked to the single species model in population dynamics but of course it can be used in a multispecies context. However, in such contexts the concept presents difficulties because of the additional problem by obtaining consensus on values of different species and size groups.

Precautionary approach

ICES' implementation of the Precautionary approach is based on Annex II of the Straddling Fish Stocks and Highly Migratory Fisheries Agreement (1995) and is not a full implementation of the Precautionary approach as e.g. defined through the FAO code of Conduct on Responsible Fisheries (FAO 1995). Annex II focuses on maintaining the reproductive capacity of a stock by keeping the spawning stock above a reference point (B_{lim}) with high probability. While the Maximum sustainable yield model advises on the best fishing mortality (F_{MSY}) the Precautionary approach defines upper bound on the fishing mortality (F_{pa}) based on lower boundaries on the spawning stock biomass and includes a buffer to account for natural variability and assessment uncertainty. When outside these limits, management is expected to react and bring the stock back inside precautionary limits.

The Precautionary approach focuses on the stock-recruitment relation and postulates that above some limit spawning stock biomass recruitment is not influenced by the amount of spawn but is controlled by the carrying capacity of the ecosystem in which the fish live. While the Maximum sustainable yield includes the fishing mortality as the direct control, fishing mortality is an indirect control in the Precautionary approach model.

The associated decision models for MSY and Precautionary approach are illustrated in Figure 1.

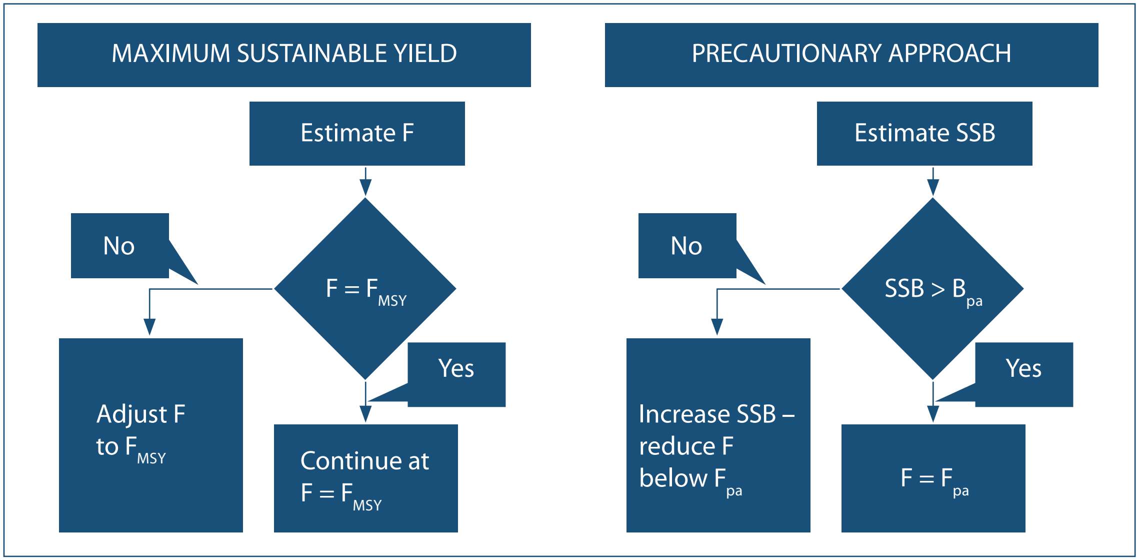

Figure 1. Comparing formulation of fisheries advice under the objective of Maximum sustainable yield (left) and Precautionary approach (right). F is the estimated fishing mortality and SSB the estimated spawning stock biomass (see explanations of technical terms below).

Ecosystem approach

Management based on an ecosystem approach is a multi-objective problem. FAO (2003) defines an Ecosystem Approach Management like this:

An ecosystem approach to fisheries strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their inter-

actions and applying an integrated approach to fisheries within ecological meaningful boundaries.

The Ecosystem approach does not in itself define the multi-objective function and management objectives will vary between ecosystems in response to the human activities and the biological processes in the ecosystem.

ICES (2004) defined how the organisation will implement the Ecosystem approach. The advice will be confined to those effects where a reasonable clear cause-effect relationship can be established and in practise this is in many cases restricted to the removal of the commercial target species in the fisheries. Advice based on an ecosystem approach would go through the following steps: **1)** list the impact from fisheries in decreasing importance, **2)** agree on which impacts shall be considered in the advice and how strong an impact that can be accepted, **3)** estimate the boundaries within which fishing can be allowed for each type of impact, and **4)** conclude on this set of boundaries within which overall boundaries fisheries should be allowed to operate. This 'ecosystem approach' process is not fully implemented yet, however, there is an increasing interest for considering also by-catches of marine mammals, sea birds and sharks. Also, discards of undersized commercial fish get increased attention.

The ICES scientific advice operates implicitly with a set of hierarchical objectives where the first consideration is the status of the fish stocks. The level of fishing activities that follow from such considerations will have other effects, such as by-catch of marine mammals, sea birds, etc., and it is checked if the effects are within acceptable boundaries.

An ecosystem approach leads to area-based management within which all fisheries and in a wider perspective all human activities that affect the marine ecosystem are considered. An often quoted candidate for ecosystems on a global scale is the Large Marine Ecosystem (LME); see Sherman *et al*. in this book *(http://www.edc.uri.edu/lme/clickable-map.htm*). This system divides the world's oceans into 64 ecosystems. The advice in the Northeast Atlantic largely follows this system and operates with six ecosystems (Barents Sea, Waters around Iceland and Faroe Islands, North Sea, Celtic Sea, Gulf of Biscay and Iberian Coastal, and the Baltic Sea). While many fisheries and stocks are confined to such rather small scale there are very significant fisheries on blue whiting, Atlanto-scandian herring (esp. Norwegian spring spawning stock), horse mackerel and the mackerel stock of the Northeast Atlantic, which cross these boundaries. These fisheries constitute 30–40 percent of the landings from the Northeast Atlantic Sea.

Organising the science advisory system

Fisheries Regulatory Commissions deals with fish stocks shared among the members of the regulatory body, the oldest such commission is the Pacific Halibut Commission from 1923, see *http://www.iphc.washington.edu/halcom*. Tuna fisheries are very distinct from fisheries for most pelagics and demersal fish and there is a separate system of tuna commissions, e.g. tunas in the Atlantic are assessed and managed through the International Commission for the Conservation of Atlantic Tunas (ICCAT), see *http://www.iccat.int*. In the Northeast Atlantic fisheries management is done through *inter alia* European Commission (EC), North Atlantic Salmon Commissions (NASCO), Northeast Atlantic Fisheries Commission (NEAFC), and Joint Norwegian-Russian Fisheries Commission (JNRFC). All these commissions get their science input from ICES.

The European scientific advisory system is unique in a global context because ICES already at the start of its existence in 1902 was given the task to provide information/advice on the status of fish stocks in the North Atlantic. The preferred model in other regions is a science body embedded in the regulatory organisations, e.g. ICCAT and the Northwest Atlantic Fisheries Organisation (NAFO).

Fisheries management procedure

Science advice in fisheries management includes the following elements (Figure 2):

1) *Documentation* of the impact of fisheries on the ecosystem and on the fish stocks in particular – this requires a standardised system collecting fisheries statistics and sampling the catches and landings.
2) *Analysis* of the data and drawing conclusions on the status of fish stocks and of the ecosystem.
3) *Peer reviewing* of the analysis and its conclusions.
4) *Development* of advisory text and proposing appropriate management actions to achieve a desired stock status or some other target.
5) *Communicating* the advice.

Clearly, traditional science will only deal with the first three bullet points above; the fourth involves political aspects that are not part of objective science. Even so, the advice is where science meets regulation of human behaviour and where the scientific input may become of importance.

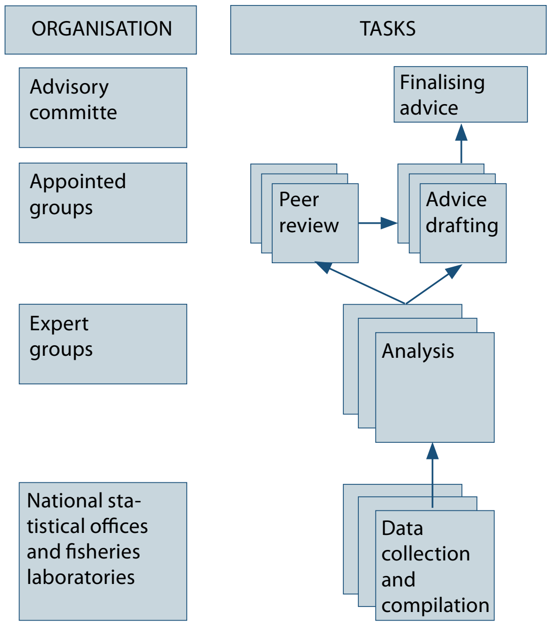

Figure 2. Organisations and elements of an advisory system for fisheries management advice as implemented by ICES.

Finalising and adopting the scientific advice is mostly done through committee work. Within ICES the advice is finalised at an advisory committee with one representative from each of the ICES member countries. Other organisations such as NAFO and ICCAT have similar arrangements for their Scientific Councils.

From a rational to a political decision model

Fisheries management has not achieved the targets desired by society, e.g. EC Green paper (2009). The explanations why these objectives are not met include imperfect implementation of management decisions, e.g. major non-reported landings that lead the scientific analysis astray, but also that the fisheries react to management measures in unexpected ways. In this perspective the scientific analysis with its focus on the biological system is too narrow and ignores that fisheries is a human activity on which social and institutional structures, economics and technological possibilities and constraints all influence the activity.

We are about to leave the rational decision model and replace it by a 'political' model. The rational model includes a common ground of information, data and analysis that are shared and accepted by everybody involved. Based on this common ground there is a joint effort in finding an optimal solution or compromise that in some respect can be considered optimal. The political model that is emerging does not include such a common ground of shared information and 'joint optimality' is no longer relevant. 'Knowledge' becomes an argument in the political process as part of the negotiation process. There is still data and information collection and compilation but this is done by the individual parties and knowledge is not shared except over the negotiation table.

Fisheries management is often fire fighting in a crisis. The decision system is sluggish and it is often possible to reach a decision only if all players can be convinced that the situation presents a crisis with which it is necessary to deal. This changes the focus from the problem as such and replaces it with the 'spin' it is possible to put on the issue. This is a part in the postulated change from a rational to a political decision model.

In the decision structure used at present it is not discussed who the legitimate stakeholders are. In the emerging political model it becomes of interest to consider what constitutes a legitimate stakeholder, i.e. that he can demonstrate the necessary political backing. This can obviously be done through demonstrating backing from a significant group among those involved in the fisheries. But a stakeholder can also be accepted as legitimate as a result of a political or media campaign financed by interest groups that are not directly involved in the industry and whose basis is a rather undefined 'common concern'. A special issue is the role that can be assigned to science in this decision model; can science maintain its role as an objective information provider and can the scientists maintain the integrity that is expected of them today?

The debate will therefore include five central themes:

- Appointment and acceptance of legitimate 'stakeholders'.
- Accept and sharing of the knowledge base on which we shall make decisions.
- Scientific input as shared objective knowledge or as arguments in the negotiation process;
- Which decisions are relevant for the system.
- Are decisions determined by an individual stakeholder that has the means to force his agenda to the negotiation table and all the way to decision and implementation?

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Technical terms used in this paper

B_{lim}	Limit reference point for Spawning stock biomass (SSB).
B_{pa}	Precautionary reference point for Spawning stock biomass (SSB).
B_{MSY}	Spawning stock biomass (SSB) that is associated with Maximum sustainable yield (MSY).
F	Instantaneous rate of fishing mortality. When fishing and natural mortality act concurrently, F is equal to the instantneous total mortality rate (Z) multiplied by the ratio of fishing deaths to all deaths. Expressed on an exponential scale: F = 0.5 means that 1-EXP (-0.5) = 39% are removed.
F_{lim}	Limit reference point for fishing mortality.
F_{MSY}	Fish mortality consistent with achieving MSY.
F_{pa}	Precautionary reference point for fishing mortality.
MSY	Maximum sustainable yield. The largest average catch or yield that can continuously be taken from a stock under the present environmental conditions.
SSB	Spawning stock biomass. Total weight of all sexually mature fish in the stock.
Sustainable	Can be sustained. In the light of ICES interpretation of Precautionary approach.
Fisheries	Management that keeps stocks(s) above B_{lim} and fishing mortality below F_{lim} with high probability using B_{pa} and F_{pa} as reference points in evaluating assessment results.

Swedish trawler. *Photo*: Peter Funegård.

IMPLEMENTING THE ECOSYSTEM APPROACH TO FISHERIES

Gabriella Bianchi, Kevern L. Cochrane and Marcelo Vasconcellos

Abstract

The Ecosystem Approach to Fisheries (EAF) is a logical and comprehensive framework for fisheries planning and management. Countries already implement some aspects of EAF under conventional practices, but often in an insufficient, reactive and unstructured manner. Countries have not systematically identified the major deficiencies in existing fisheries management and what priority actions are required to reduce risks to the natural system and fishing communities. The formalization of EAF management plans for all fisheries in an ecosystem can contribute to such a systematic planning exercise. There is no 'one size fits all' for EAF; in practice, as with conventional fisheries management, different approaches will be required for different types of fisheries.

The key message is that it is achievable, even with limited capacity and information, but will require adaptation of attitudes and practices. The ecosystem approach is a convergence of conservation and human development concerns. Although a common understanding of the concept is developing, and despite the good progress made in the incorporation of its principles in policies at international and national levels, there is still much to be done to make these principles operational in the practical management of fisheries, especially in developing countries and RFMOs.

While limited knowledge should not stop implementation of EAF, the more limited the knowledge the more conservative (precautionary) will the management measures be. Risk assessment is a common tool in business and industry at large. Similar tools can usefully be applied within an ecosystem approach, both in data-rich and data-poor situations. In order to achieve the dual objectives of socio-economic benefits and environmental sustainability, it is essential to include socio-economic and institutional considerations.

EAF builds on existing fisheries management and can be implemented incrementally. However, what may be required is a radical change in thinking and attitudes towards ecosystems, ecological relationships, stakeholder involvement, and collaborative frameworks. Ecosystems are complex, but applying the ecosystem approach is fairly straightforward.

Background

During the past decade the concept of an ecosystem approach to fisheries (sometimes also referred to with other denominations such as ecosystem-based fisheries management) has been increasingly used in policy statements by fisheries management and environmental agencies, both governmental and non-governmental, at the national and international levels. At the same time, there has been widespread confusion regarding what an ecosystem approach actually entails, and perceptions and use of the expression have been very different, ranging from the idea of the need to base management of human activities on a detailed understanding of ecosystems structure and functioning (often used by natural scientists to obtain funding in oceanography and marine biology or as an argument used by fisheries manager to demonstrate the impossible task of implementing it), to the perception that the use of Marine Protected Areas (MPAs) is synonymous with EAF. Notwithstanding good progress in many places, this confusion has significantly hindered the progress of the approach.

There are various definitions; FAO (2003) defines an ecosystem approach to fisheries (EAF) as follows:

> *"An Ecosystem Approach to Fisheries strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries."*

This definition clearly addresses both human and ecological well-being and merges two paradigms, that of protecting and conserving ecosystem structure and function and that of fisheries management that focus on providing food, income and livelihoods for humans. In fact the application of EAF represents the ultimate effort to implement sustainable development concepts in fisheries, to be achieved through democratic and transparent practices that take account of diverse societal interests and using mechanisms that allow participation of stakeholders in the planning and decision-making processes. Issues of sustainability are also linked to the principle of intergenerational equity, also a fundamental principle of EAF (FAO 2003).

Concept development

Societal concerns regarding man's use of natural resources have been reflected in international instruments for the past 40–50 years and the concept of ecological sustainable development, the foundation of EAF, is reflected in the international instruments along three main (inter-related) strings of the international policy arena (Turrell 2004), environmental, legal and fisheries management aspects. The legal string goes through the UN Law of the Sea Convention (UNCLOS 1982), the environmental string through the UN Conference on Environment and Development (UNCED 1992) and the fisheries management one guided by FAO, has the Code of Conduct for Responsible Fisheries (CCRF, FAO 1995) as a key milestone.

Concerns for environmental degradation due to human development were first placed on the global policy agenda in 1972, at the UN

Conference on the Human Environment, held in Stockholm and culminated with the WSSD in 2002 where a commitment was made to implement an EA to fisheries by 2010 (WSSD, Plan of Implementation, paragraph 29 d). The principles relevant to an ecosystem approach to fisheries were later defined in 1998 outlining the Convention on Biological Diversity (CBD) definition, twelve guiding principles and five operating principles of an ecosystem approach (COP decision V/6, 2001).

The legal string through the United Nations Law of the Sea (UNLOS) has provisions for sustainable use of target stocks, taking also into account non-target species and species interactions. The UN Fish Stock Agreement (1995) notes the importance of preserving biodiversity, maintaining integrity of marine ecosystems and minimizing risks. As part of this string, the United-Nations open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS) was appointed by the United Nations General Assembly (UNGA) in 1999 to "deal specifically with developments in ocean affairs and the law of the sea". In 2006, UNICPOLOS dealt specifically with "ecosystem approaches and oceans", with the aim to build a common understanding on EA and to close implementation gaps (UNGA 2006).

FAO is one of the UN specialized agencies dealing with the main production sectors within food and agriculture, fisheries being one of them. Responding to concerns and problems within the fisheries sector but no doubt also inspired by the developments that were taking place in the environmental arena, FAO started the process of expanding the fisheries management paradigm in 1992. The resulting non-binding Code of Conduct for Responsible Fisheries was adopted in 1995. Its key principles are related to the need for management to conserve ecosystems, for sustainable exploitation that focuses not only on target species, but also deals with non-target species and associated ecosystems, for taking responsible action also in the absence of scientific evidence and basing decisions on the best scientific evidence, for taking account of traditional knowledge, for being transparent and using precaution in decision-making.

Aware of the difficulties experienced in incorporating the above principles in day-to-day fisheries management, the need was felt for initiating processes and activities that would facilitate their implementation. The Reykjavik Conference for Responsible Fisheries in the Marine Ecosystem (October 2001) can be considered as an attempt to build a bridge between the commitments on sustainable use that countries had agreed to over the years and their actual implementation within the fisheries sector. In this sense Reykjavik 2001 can be considered as a major step towards making operational the principles of sustainable development in fisheries. It resulted in a declaration where countries committed to "an effort to reinforce responsible and sustainable fisheries in the marine ecosystem ... to individually and collectively work on incorporating ecosystem considerations into that management to that aim" (FAO 2001). The Conference lead to the first FAO guidelines for the application of EAF in 2003 (FAO 2003), followed by a simplified version (FAO 2005).

In relation to the incorporation of environmental concerns in fisheries management, three main phases can hence be detected at the global level (Bianchi, in press):

- the phase of raising *awareness*, with its roots in the Stockholm Conference (1972) and culminating with the Earth Summit (1992),
- *convergence* between international fisheries management objectives and international environmental concerns, with the developments of international instruments at sectoral level, such as the CCRF (1995), and
- a third phase, that of commitment to *implementation*, as stated, for fisheries, in the Reykjavik Declaration.

EAF in practice

In response to the call at the Reykjavik Conference, and inspired by the experiences made by Australia in developing fisheries management practices consistent with principles of ecological sustainable development, the FAO guidelines (FAO 2003) provide a framework for planning and managing fisheries in a way that is consistent with EAF, including being participatory and transparent. The planning process consists largely of examining existing or developing fisheries to identify key priority issues to be dealt with by management in order to be consistent with an ecosystem approach. The main steps of the planning process are presented in Figure 1, showing how high level policy goals, that are often too general to be useful in day-to-day management, can be translated into operational objectives and decision rules for actual implementation.

A fundamental step of this process is to identify the key issues that are recognized by the various stakeholders as requiring attention by man-agement as a matter of priority. This process is carried out in a structured way, following three major categories; ecological and social well-being, and the 'ability to achieve' – a category that includes governance issues but also drivers external to the fisheries systems (Figure 1). The identification process results in a number of issues, the priority of which is set through a process of qualitative risk analysis (if possible also semi-quantitative or quantitative, according to data and information available). This process is innovative compared to conventional fisheries management, as it is holistic in considering various aspects of environmental and social sustainability. It should also be applied in a participatory way, use informal and traditional knowledge and combine bottom-up with top-down approaches, the balance between the two depending on the type of fisheries and social conditions. The subsequent steps in the process summarised in Figure 1 are identifying how management can actually deal with the priority issues, including identification of operational objectives (i.e. targets), the management tools that are most appropriate to achieve these, and assessing the costs and the benefits of alternative management options. The results of these steps provide the basis for the development of fisheries management plans. The process described here it is not different from conventional fisheries management. However,

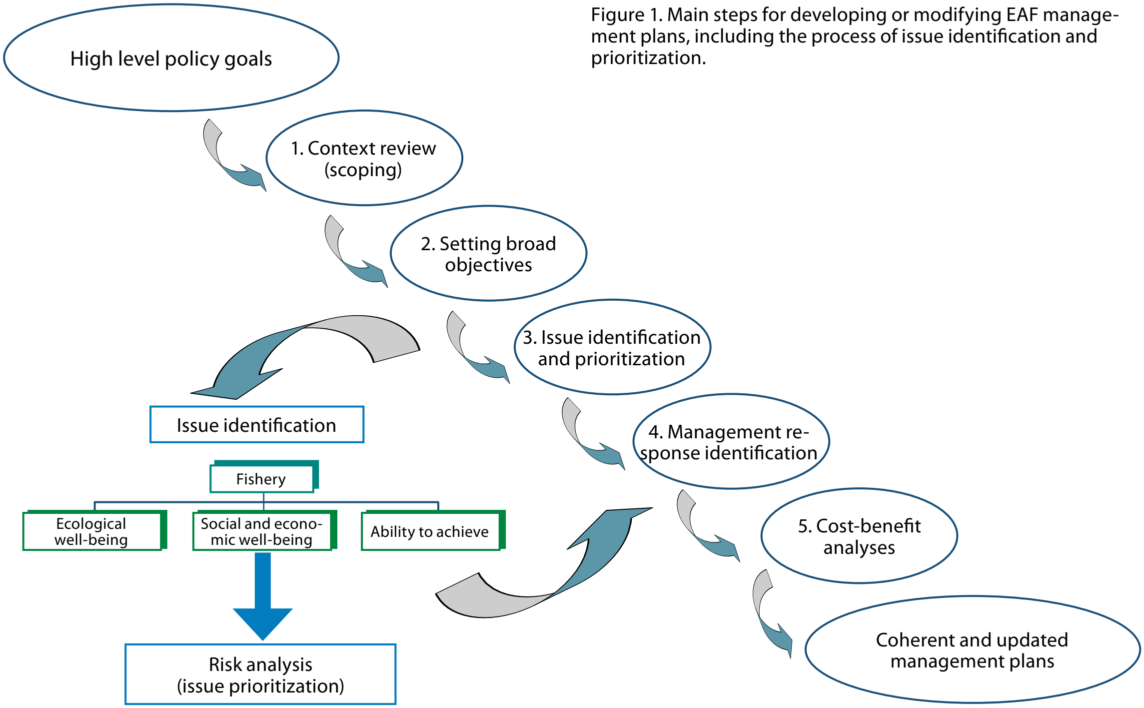

Figure 1. Main steps for developing or modifying EAF management plans, including the process of issue identification and prioritization.

a few important differences can be highlighted, one being the expanded scope of the fisheries management concerns and of the type of issues EAF management plans deal with, and perhaps also because of this, a more explicit need to develop fisheries management plans, often not felt under conventional fisheries management.

Progress in implementation

The political commitment by countries to implement EAF is undoubtedly gaining momentum. In 2007, there was broad agreement amongst the Member countries of FAO Committee on Fisheries "that EAF was the appropriate and necessary framework for fisheries management" (FAO 2007a). Many reported on the progress that was being made, but developing countries, because of the institutional capacity required for EAF, needed greater support through awareness building and direct technical assistance to help build their national capacity.

In 2006, two international meetings reviewed progress made in the implementation of EAF at the national, regional and international levels. The 7th meeting of UNICPOLOS (2006) concluded that while the approach had a broad acceptance, there was a wide perception that in most cases not enough knowledge was available to get started. While it was felt that the meeting had contributed to demystifying the concept, major challenges were seen to exist, particularly at the regional level, and related to fitting RFMOs into cross-sectoral approaches to management. The Conference on Implementing the Ecosystem Approach to Fisheries (Bergen 2006) recognized that many countries had already adopted measures consistent with EAF, and in this sense good progress was underway. However, these were often piecemeal actions, focused on addressing key ecological impacts of fishing and not the result of a more comprehensive effort towards EAF implementation (Bianchi *et al.*, in press).

A few countries have undertaken thorough processes towards full implementation of ecosystem-based approaches. Since 1996, the United States has taken steps to implement EBFM (Ecosystem-Based Fisheries Management), with the Congress asking NOAA to incorporate ecosystem principles into fisheries conservation and management (Tromble, in press). Since then, a number of activities, including stakeholder consultations at various levels have taken place. These have lead to a number of specific EBFM measures, including to quantify and minimize by-catch, define essential fish habitat, and designate numerous marine protected areas, such as bottom trawl closures in certain areas. Comprehensive Fisheries Ecosystem Plans have been developed for some regions, including Chesapeake Bay, the Western Pacific Archipelago, the Atlantic Seaboard and Gulf of Mexico, and the North Pacific. It is however recognised that ecosystem approaches have not been more extensively implemented, because the science, data and models to effectively incorporate ecosystem effects into decision-making have not been adequate.

Australia has been one of the forerunners in the development and application of ecosystems approaches to fisheries and has been active in this field for over a decade (Fletcher *et al*. 2005). In the early 1990s Australia started a process of Ecological Sustainable Development (ESD) across all areas of government, which also had implications for fisheries and other sectors exploiting aquatic resources. The main elements were to define and implement harvest strategies for target and by-catch species in every fishery, undertake an ecological risk assessment and ecological management response for every fishery, implement large scale spatial management (including MPAs for conservation purposes, improving data collection and communication capacity for the EBFM approach (McLoughlin *et al.*, in press). Integration of all relevant elements of the ecosystem approach for Australia's 21 Commonwealth managed fisheries started in early 2007.

Canada's approach is area-based and entails defining broad eco-regions with ocean and costal management areas nested within. Planning follows guidelines developed at the national level (Mageau 2006). For each area, ecosystem objectives are set addressing ecosystem structure, function and physical-chemical properties of the system. Two approaches are applied: a bottom-up (activity-based) involving identification of the activities that impact most and setting ecosystem objectives for them, and a top-down approach that identifies key ecosystem properties or components. Both approaches make use of all available interdisciplinary knowledge and their application is now being tested.

In Norway, in addition to piecemeal fisheries management, initiatives consistent with the principles of responsible fisheries have been taken during the past decade, such as reducing by-catches in the shrimp fisheries, managing target stocks taking into account predator/prey interactions, or protecting vulnerable bottom habitats from trawling. A more holistic approach was developed for the Barents Sea, rich in natural resources both living and non-living. A cross-sectoral management plan has been developed for this region, including setting goals and targets, through consultations with all the relevant stakeholders. A committee has been established with representatives from all relevant government agencies, responsible for identifying appropriate management measures, which receives advice from a 'Management forum' consisting of researchers and users.

Progress is also being made by regional fisheries bodies but, at the Secretariats of Regional Fisheries Bodies (RFBs) noted in 2007 that "the issue of incorporating ecosystem considerations into RFB decision-making remains under development" (FAO 2007b). A common problem was concerns about explicitly including EAF principles in RFB Conventions or Agreements because there is a widespread perception that it is difficult to define what is really intended by EAF. However, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was one of the first RFBs to elaborate the Approach and many recent regional agreements now include general references to an EAF. The misperception that EAF is difficult to define is discussed later in this chapter.

Within the context of regional fishery bodies, measures to implement EAF have included taking management actions to protect sharks, seabirds, turtles and dolphins, to protect vulnerable habitats by closing fishing around seamounts or in certain areas of particular concern, and to monitor lost and abandoned fishing gear. As an example, the Western Central Pacific Fisheries Commission (WCPFC) is reviewing an ecosystem risk assessment process, as the start of a broader process, and CCAMLR has a programme to monitor selected indicator species in particular areas as a measure of ecosystem health (FAO, 2007b).

FAO has also been working with governments to facilitate capacity building for EAF to selected countries mainly through small case studies and workshops examining the needs and priorities for EAF implementation. The case studies, such as the management of tuna and shark fisheries in Papua New Guinea, small-scale coastal fisheries in Brazil, and pelagic fisheries in the Lesser Antilles, are instrumental to assist countries in making EAF operational, as well as to understand the types of issues and constrains for EAF implementation at the local and regional level. Such initiatives require donor support and the ones just described are only possible because of extra-budgetary support provided through a number of Trust Fund Projects funded by the Government of Japan. Another major programme funded by the Government of Norway, aims at facilitating the application of EAF in African coastal countries and globally. Activities are under way in the Gulf of Guinea, in coastal countries of the South Western Indian Ocean and off Northwest Africa.

The Benguela Current large marine ecosystem – a regional example

The three states comprising the Benguela Current large marine ecosystem are probably a unique example in that the issue is being addressed in a systematic manner at both the national and regional scale. Much of the progress in recent years has been made within the scope of the GEF Benguela Current Large Marine Ecosystem Project (BCLME) which included a project on ecosystem approaches for fisheries management in the BCLME. It examined the progress that had been made in the region in implementing EAF and considered the feasibility of full implementation, at least across the most important fisheries in the ecosystem. The project was a cooperative effort by BCLME, the management agencies of Angola, Namibia and South Africa, and the FAO.

The project addressed a total of ten fisheries including the major demersal and small pelagic fisheries in each country as well as the artisanal fishery in Angola and the rock lobster fishery in South Africa. It used the Australian ESD approach, as promoted in the FAO Guidelines on EAF (FAO 2003), to identify and prioritise issues that needed to be addressed for implementing EAF and to develop appropriate management responses. Decisions and recommendations were based on the best available information, but consideration was also given to research needs to reduce uncertainty.

The project established that progress had already been made in all of the countries in addressing a number of important ecosystem issues including, for example, reducing by-catch of seabirds and turtles, managing fishing mortality to take into account the impact of different fisheries targeting the same species, and establishing closed areas and MPAs to address particular objectives. However, these efforts had largely been uncoordinated and there were still many issues requiring attention. As a result, the number of issues identified together with a range of stakeholders varied from 20 to 96 across the different fisheries, with between 25 and 66 percent of those issues considered to be of high or extreme priority (Cochrane *et al*. 2007).

The types of issues identified varied considerably from fishery to fishery but there was also substantial commonality. The most urgent needs were:

- by-catch issues across commercially and ecologically important species as well as species of conservation concern;
- ensuring adequate protection of critical habitat from damage by fishing or other human activities;
- addressing the vulnerability of coastal communities arising from their high level of dependence on fishing and fish products;
- improving governance, in particular capacity for research and management, by improving consultation with stakeholders and through greater application of co-management.

There are several stocks and species that are shared between two or all three of the Benguela Current countries, which therefore requires a coordinated and cooperative approach to manage activities that affect them. These are among others hake, sardine and horse mackerel, as well as species of conservation concern such as a number of seabirds, turtles, and deep-sea sharks.

Some of these issues are already being addressed and reasonably rapid progress can be anticipated in implementing suitable management measures or structures to remedy the problems. Overall, there is a high level of commitment in all three countries to implement EAF as a basic requirement for the sustainable use of marine resources. Nevertheless, it is recognized that the national fisheries agencies and the recently established Benguela Current Commission should adopt a coordinated and holistic approach in the development of management strategies that recognize and reconcile, as far as possible, the conflicting goals of all stakeholders, both those within and those outside the fishery sector. There are also serious concerns within the countries about current management capacity and whether it will be sufficient for the task (Cochrane *et al*. 2007).

Lessons learned

Experience with the application of EAF in different settings has shown that it is a logical and comprehensive overarching framework for fisheries planning and management. By exploring the operational implications of the approach through case studies, it was possible to conclude that countries have already started implementing some aspects of EAF under conventional practices. Protection of coastal habitats and water quality, banning destructive fishing practices, the use of closed areas, season and gear restrictions to reduce by-catch, and special measures to protect species of conservation concern are common, even if often insufficient, amongst countries. However, progress has generally been made in a reactive and often unstructured manner, responding to specific international agreements, advocacy pressure, trade requirements or immediate crises, rather than as a result of a comprehensive, ecosystem-wide analysis for planning and priority implementations. As a result, countries have not systematically identified where the major deficiencies in the existing fisheries management strategies lie and what priority actions are required to reduce risks to the natural system and fishing communities. The formalization of EAF management plans for all fisheries in an ecosystem can contribute to such systematic planning exercise.

There is no 'one size fits all' for EAF, a reality that makes it impossible to provide a concise, easily understood definition of the approach. In practice, as with conventional fisheries management, different approaches will be required for different types of fisheries. For example, the detailed approach for a small-scale multi-species fishery will need to be very different to that for a single-species industrial fishery – for ecological, human and governance reasons. Similarly, in many coastal and inland fisheries the impact of other water and land users are likely to be much more significant than in the case of offshore fisheries, putting greater emphasis in those cases on the need for implementation of EAF to take place within the broader framework of water resource and land use.

Through promotion and consideration of EAF, awareness has been raised of the need to address ecological questions that until now have been ignored by conventional target resource-oriented approaches, such as the indirect impact of fisheries on marine ecosystems. Issues such as the trophic impact of removing prey and predators, and other ecosystem components are being explicitly identified and the means to address these issues are evolving, e.g. through advances in the modelling of marine ecosystems (Plaganyi 2007). Notwithstanding, experience shows that very often the ability to mitigate the direct impact of fisheries (e.g. impacts on the target and by-catch species, impacts on the habitat) will already make a substantial contribution to ecologically sustainable fisheries. However, without accounting for the different dimensions of these direct impacts, even an apparently simple and direct problem cannot be solved optimally. For instance, a technological solution (gear modification) proposed to mitigate the by-catch of an endangered species could cause increased risks of affecting other species in the ecosystem, or putting fishers out of work because of the losses incurred by the gear change, if such a solution is not evaluated in a wider (ecosystem) context that takes into account the ecological, social and institutional dimensions of the problem.

Successful implementation of EAF will depend on a series of factors; some of them are not novel. A common feature of EAF is that decision making in fisheries management needs to address widely divergent desires and needs, and the often conflicting values and goals of the different stakeholders. Well-established mechanisms for stakeholder participation in decisions is one of the fundamental requirements for properly acknowledging these diverse needs and values, for integrating knowledge, and legitimizing management actions. In the Benguela ecosystem, for instance, transparency and participatory management and decision-making were considered urgent priorities if national and regional policies and objectives for fisheries in the region were to be achieved. There are different ways of promoting stakeholder participation in decision-making, and it is not the scope of this chapter to propose any best course of action. It is however a challenging issue especially in situations where co-management arrangements are not already established, where fishers and other stakeholders are not well organized or where there are power imbalances that impede an equitable representation of all interests at stake.

Disjointed programmes and actions by government institutions (in the same country or between countries, as the ecological scale changes) also represent a major constraint, and it is only through an enabling political environment, with an appropriate legal framework and ministerial coordination, that an EAF can be successfully implemented. It is not uncommon to have fisheries-related issues dealt with in a country by ministries with different and sometimes antagonistic views about the importance of sustainable use of marine resources and their conservation. Furthermore fisheries are in many instances affected by other human activities in the coastal zone such as urban and industrial development, port activities, tourism, off-shore mining and oil industries, etc. The management of these sectors typically falls under different government departments, which tend to work in isolation from each other. Institutional obstacles and even rivalry can in these cases become an important impediment to EAF implementation. To overcome these obstacles, governments have to find ways to promote a dialogue between the different institutions, establish operating procedures through formal institutional arrangements, where individual roles and functions are well defined, so that problems are addressed at different scales, simultaneously and not in isolation.

Through practical implementation, important misconceptions or myths (Murawski 2007) are being addressed. One such misconception is that EAF can only be addressed after enough knowledge has been acquired about the functioning of marine ecosystems. On the contrary, experience shows that firm steps can be taken even in data-poor situations. Consensus on the sources of problems affecting the sustainability of a fishery can be reached through well-facilitated discussions between managers, scientists, fishers, conservationists and other interest groups. Through this process priorities are identified, and with that crucial knowledge gaps are highlighted, providing a focus for allocating the, often limited, available resources for management and understanding the problems that affect the fishery the most. The problem of implementing EAF in data poor areas lies particularly in the choice of management interventions, where the lack of understanding of the consequences of management interventions increases the risk that decisions will have undesirable outcomes. In practice the limited knowledge will affect the ability to predict the adverse effect of decisions and consequently will require that a considerable degree of precaution is exercised when making decisions. Careful consideration of precautionary measures, the monitoring of the effects of such measures and the adoption of adaptive management strategies are crucial in such situations.

Another common misconception is that the ecosystem approach to fisheries is only about the ecological impacts of fisheries and does not account for human dimensions of fisheries management. Here the approach suffers from a name that is often misunderstood, in the sense that human dimensions are often dissociated from "natural" ecosystems in some common usages. Contrary to that view, EAF is primarily about managing human activities, and its implementation requires that the full set of social and economic objectives and issues are identified and prioritized to be reconciled with the ecological issues. The importance of the socio-economic and institutional dimensions of EAF cannot be overemphasized since many of the issues affecting the sustainability of a fishery have their roots in ill-functioning institutions and communities. As put by Jentoft (2000), as much as "viable fisheries communities require viable fish stocks" it is also true that "viable fish stocks require viable fisheries communities". Issues of poverty, lack of well defined access rights, uncoordinated institutions, poor enforcement, to name a few, figure as important socio-economic and institutional problems affecting the sustainability of fisheries that need to be addressed by an EAF.

A recurrent question in the implementation of EAF refers to whether there is an optimal scale of work, and how one can scale up or down between local and regional (ecosystem) levels of decision making. Experience shows that the scale necessary for EAF can vary depending on diverse factors, such as the issues of concern, the objectives of the fishery, the management jurisdictions, etc. Despite the fact that much progress can be made working at the local level, i.e. a fishery or community, it is the work at congruent ecological boundaries (normally at a larger, regional scale) that will ultimately determine the sustainability of the fishery in the long run. Working at regional scale presents, however, many challenges because of the increased complexity of issues, institutions and stakeholders, and the increased costs involved in promoting synergies among governmental and non-governmental organizations, industry and interest groups in a region. The experiences from the Benguela Current large marine ecosystem discussed earlier have demonstrated this challenge. While working at the local level offers the ideal conditions for establishing participatory, stakeholder-driven, management approaches to local problems, any locally proposed solutions will have limited impacts if they are not properly legitimized at national level or if they can be easily be over-ridden by political and ecological changes occurring at the larger (regional) scale. Experience therefore shows that a successful implementation of EAF will require that policies, management strategies and actions are integrated across the different scales within the over-arching ecosystem boundary necessary to encompass the core ecosystem interactions. That means, for instance, ensuring that any proposed broad-scale policies have explicit links to management at the community level, promoting ways of connecting local management experiences in a region (specially when fisheries target shared stocks) through networks for the sharing of information, estab-lishing national/regional sustainability benchmarks around which local communities can organize their management programmes, the zoning of marine and coastal areas.

It is also apparent from experience that there is a need to create incentives to facilitate implementation of EAF. Incentives are any factor that affects individual choice of action and can be either coercive or encouraging. For example economic incentives could include fines for unacceptable practices, or rewards such as market accessibility. Incentives can be classified as: legal, institutional, economic (including market-based), and social (de Young and Charles 2007). In the case of the Benguela countries, some possibilities for suitable subsidies included: improved communication between stakeholders, policy makers and management; making scientific information available as a basis for negotiation with stakeholders; co-management; eco-labelling; allocation of long-term user rights; and alternative livelihoods in cases where fishing capacity needs to be permanently reduced. The most appropriate incentives will vary from case to case.

A common problem, at least for many developing countries, in implementing EAF is insufficient capacity. This is also a concern for many regional fishery bodies (FAO 2007b). In the case of the Benguela countries, for example, capacity limited the ability to achieve effective conventional management across all fisheries and this limitation would be exacerbated considerably as the management agencies and stakeholders attempted to broaden objectives and management actions to implement EAF (Cochrane *et al.* 2007). In the Benguela countries, lack of capacity was considered to be particularly serious in relation to research and management but also extended to other services such as policy, economics and social sciences. Also at the institutional level, there is a widespread need to develop resource management structures that involve the main stakeholders, including co-management. This need is closely linked to capacity because, in general, the best if not the only option for management agencies to increase capacity will be to involve the stakeholders in all aspects of management, including monitoring, planning and implementation. An integral part of greater involvement of stakeholders is the parallel need for improved communication with them, both inside the fishery sector and with stakeholders in other sectors that are impacting on, or are impacted by fisheries, for example the oil and offshore mining industries, tourism and coastal zone development, including the government departments responsible for those activities.

Experiences in Australia and the Pacific have shown that EAF must be understood as a risk-based management process, not an excuse for undertaking more detailed research. Furthermore, the analyses carried out so far have shown that lack of good governance is considered a high risk, not the lack of ecological data (Fletcher, in press). The experiences of FAO described earlier in this paper have led to a similar conclusion.

Finally, while the authors wish to stress the need for and feasibility to implement EAF, on the basis of the best currently available knowledge, greater effectiveness and robustness will undoubtedly be possible in almost all cases if current uncertainties can be reduced by focused research. This should include long-term monitoring of key variables necessary for tracking the set of indicators that will be required for effective and sustained implementation of EAF. Discussion of research within the context of EAF frequently opens a Pandora's Box of claims and counter-claims about the priorities for research addressing any possible aspect of marine, environmental and human science. A key challenge in developing a realistic and cost-effective research programme is to filter out the most important priorities necessary for improving the implementation of EAF. Given the common constraints on funding for research and monitoring, these priorities should be clearly linked to the EAF objectives, both short-term and long-term, and could be selected through a combination of risk and cost-benefit analysis, similar to that recommended in the FAO guidelines for prioritizing EAF issues. In general, social and economic research in fisheries is lagging far behind biological and ecological research, and there is a widespread need to give serious attention to boosting capacity in these research areas.

Conclusions

EAF has been recognized and adopted as the best framework for fisheries policy, and there has been good progress in putting it into practice in a number of parts of the world. The key message is that it is achievable, even with limited capacity and information, but will require adaptation of attitudes and practices if it is to be realized on a broad, global scale. Some key insights and conclusions that have emerged from experiences:

In the international policy arena, the ecosystem approach embodies the convergence of conservation and human development concerns and shows the way these can be dealt with. Although a common understanding of the concept is developing, and despite the good progress made in the incorporation of its principles in policies at international and national levels, there is still much to be done to make these principles operational in the practical management of fisheries, especially in developing countries and RFMOs. In developing countries, where conventional fisheries management has frequently yet to be achieved, meaningful progress will require substantial international assistance.

There is no 'one size fits all' for EAF, a reality that makes it impossible to provide a concise, easily understood definition of the approach. The application of the EAF needs to be tailored to the specific ecological, social and cultural conditions in each specific geographical area.

The broadening of fisheries management and the need to include stakeholders in the decision making process imply the requirement for extensive communications between stakeholders, researchers and managers. New mechanisms of interaction need to be developed, which are truly interactive and exploratory of options to properly acknowledge the diverse needs and values, integrate knowledge, and legitimize management actions.

While limited knowledge should not stop implementation of EAF, the more limited the knowledge the more conservative (precautionary) will the management measures be. Therefore, increased funding to research should also be encouraged with the view to optimize resource utilization.

Application of the precautionary approach in recognition of knowledge limitations will cause substantial short and medium term social and economic problems, particularly in small-scale fisheries in developing countries where there is a high, immediate dependence on fisheries for food-security and livelihoods. In such cases, responsible means to reduce that dependence, including realisation of alternative livelihoods, will be a pre-requisite for implementation of EAF.

Risk assessment is a common tool in business and industry at large. Similar tools can usefully be applied within an ecosystem approach; ecological risk assessment related to human well-being, ecosystem conservation and sustainable use should be a core tool, relevant and applicable both in data-rich and data-poor situations.

In order to achieve the dual objectives of socio-economic benefits and environmental sustainability, it is essential to include socio-economic and institutional considerations in EAF planning and implementation. Fair and equitable sharing of benefits is also a key characteristic of EAF needing serious attention.

People tend to respond more to incentives than to commands. Therefore, objectives and incentives need to be aligned in order to facilitate successful implementation of EAF.

Cost-benefits analysis should always be undertaken when considering alternative management strategies. The issue of distribution of costs and benefits among fishers, and between them and society, as well as between generations is a central issue behind perceptions and social responses.

EAF builds on existing fisheries management and can be implemented incrementally. However, what may be required is a radical change or revolution in our thinking and attitudes towards ecosystems, ecological relationships, stakeholder involvement, and collaborative frameworks. Ecosystems are complex, but applying the ecosystem approach is fairly straightforward. Experiences that are emerging from case studies suggest that EAF can be kept simple, starting with existing institutional structures and knowledge, and modified and improved as we go along.

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ILLEGAL, UNREPORTED AND UNREGULATED FISHING

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Abstract

This paper reviews the threat of illegal, unreported and unregulated (IUU) fishing to long-term sustainable fisheries and the range of activities and initiatives that have been launched to address such fishing. Following the introduction, where it is stressed that IUU fishing is an economic and environ-mental crime, some global and regional initiatives to combat IUU fishing are discussed. The focus then moves to flag state responsibility and performance, highlighting the failure of some flag states to exercise effective control over their flag vessels, in accordance with international law, as the root cause of IUU fishing. The increasing prominence of port states to combat IUU fishing and prevent the movement of IUU-caught product into international trade is considered in the next section. The following part addresses the central role of capacity building and technical co-operation if IUU fishing is to be beaten. The final section notes the impact of IUU fishing on developing countries, both from a fishing and trade perspective. The paper's conclusion encourages the greater use of incentives via compensation to curb IUU fishing, noting in part that it has served to rally governments and all stakeholders in the fisheries sector against it.

Introduction

Since 1999 the international community has been grappling with IUU fishing in an increasingly focussed manner. Although not a new issue[2], the incidence and impact of IUU fishing in marine and inland capture fisheries is high and increasing.[3] Its scope, intensity and the ongoing international concern has caused the matter to be addressed in the United Nations General Assembly (UNGA) and its resolutions on sustainable fisheries, sessions of the FAO Committee

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2. See, for example, an assessment of IUU fishing in the Pacific Islands in the 1980s (Wright 1994). Throughout the 1990s the United Nations General Assembly also addressed the issue of unauthorized fishing in zones of national jurisdiction. Consideration of this issue was primarily driven by small-island developing states and a number of supporting countries. A recent press report claims that there have been significant increases in illegal fishing in the Central Pacific Ocean, including in French Polynesia, Cook Islands and Kiribati (Fiji Times 2007).
3. The World Conservation Union, for example, has claimed that 20 percent of the world's fish landings are illegal and the proportion is increasing (The Telegraph, 2008).

on Fisheries (COFI), the 2002 World Summit on Sustainable Development, the Organization for Economic Cooperation and Development (OECD) Fisheries Committee, the Ministerially Led Task Force on IUU Fishing on the High Seas (High Seas Task Force 2006) and numerous other ministerial initiatives at global[4] and regional[5] levels. Some of these initiatives have spawned important regional activities and programmes of action such as the 2004 Lake Victoria Fisheries Organization regional plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing on Lake Victoria and its Basin (LVFO 2004) and the 2007 South-East Asian regional plan of action to promote responsible fishing practices (Governments of Indonesia and Australia 2007).

Once viewed in many countries as an administrative offence, IUU fishing is now generally considered to be an economic and environmental crime.[6] This is because IUU fishing involves trespass and theft, both of which contribute to the increased degradation, vulnerability and demise of fish stocks. There is also a growing swell of international opinion that countries are at liberty to restrict or ban the import of IUU-caught fish because it is considered to be stolen product. Restricting imports of IUU-caught fish is not an impediment to international trade and such action is deemed to be consistent with World Trade Organization rules.[7]

Assessments of IUU fishing indicate that its impact on some fish stocks of high social and economic importance including southern and northern[8] bluefin tuna, Atlantic Ocean and Baltic Sea cod[9], Barents Sea cod[10] and miscellaneous demersal species in the Gulf of Guinea in West Africa has been dramatic, especially in situations where stocks were already in poor condition because of intensive fishing and overfishing (FAO 2007a).[11] Many of these stocks have been subject to unbridled IUU fishing which has undermined national and regional efforts to manage fisheries in a responsible and long-term sustainable manner. In turn this situation has created and contributed to major challenges for countries and

4. The FAO Ministerial Declarations relating to IUU fishing in 1999 and 2005.

5. For example, ministerial-level meetings held in Europe, the Pacific Islands, Indian Ocean, South East Asia and Southern Africa.

6. Economic and environmental crime is well established with respect to pollution and wildlife and is subject to national prosecution and international interventions by Interpol. In fisheries more and more countries (e.g. Australia, Canada, United Kingdom and United States of America) and the European Union consider IUU fishing to be a criminal activity. A statement by Commissioner Joe Borg, European Commission for Fisheries and Maritime Affairs, at the High-level Conference on Eradication of Illegal, Unreported and Unregulated Fishing, Lisbon, Portugal, 29 October 2007 made it clear that IUU fishing is an "... economic and environmental crime".

7. Sweden, for example, made this point in its presentations at the High Level Conference on Eradication of Illegal, Unreported and Unregulated Fishing, Lisbon, Portugal, 29 October 2007.

8. Northern bluefin tuna has been subject to extensive IUU fishing in the Mediterranean Sea, including in and around breeding grounds. In recent years, catches of Northern bluefin exceeded the International Commission for the Conservation of Atlantic Tunas (ICCAT) quotas by significant amounts. In 2007, the European Commission implemented a recovery plan for bluefin tuna in the eastern Atlantic Ocean and the Mediterranean Sea.

9. According to a spokesperson for Commissioner Joe Borg, European Commissioner for Fisheries and Marine Affairs, 40 percent of cod taken in the Baltic Sea is harvested illegally (International Herald Tribune 2008).

10. It was stated that 100,000–160,000 tonnes of cod annually is fished illegally in the Barents Sea (Pickerall 2006).

11. The 2007 State of World Fisheries and Aquaculture points out that for stocks monitored by FAO about 50 percent of them are fully exploited with no room for expansion; a further 25 percent are underexploited or moderately exploited and could perhaps produce more while the remaining 25 percent are overexploited, depleted or recovering from depletion, yielding less than their maximum potential owing to excess fishing pressure. The report adds that these percentages have been relatively stable for some time and that the wild capture potential from the world's oceans has probably been reached. This situation reinforces calls for greater precaution and more effective fisheries management to rebuild stocks (FAO 2007a).

regional fisheries management organizations or arrangements (RFMOs) as they have sought to enhance the conservation and management of stocks. Moreover and significantly, IUU fishing jeopardizes efforts to restore and maintain healthy biodiversity and ecosystems.

The root cause of IUU fishing is the inability or unwillingness of flag states to exercise effective control over the operations of fishing vessels flying their flags.[12] This lack of control has fostered the rise of "flags of non-compliance" enabling IUU fishers to operate with freedom and impunity, often targeting fisheries in developing countries where management is precarious and monitoring, control and surveillance (MCS) programmes are fledgling and weak.

The European Commission's 2007 strategy on IUU fishing, which extends its 2002 Action Plan, underlines the lack of flag state control as being a primary contributing factor to IUU fishing (European Commission 2007a). In a departure from previous policy the Commission intends to "blacklist" both countries that fail to meet their international obligations under international law and IUU fishing vessels. In future, imports of fish from "blacklisted" countries and vessels will not be accepted for sale in the European Union. A key aspect of the new strategy is the requirement for flag state certification for all fish prior to importation. The flag state must certify that fish was harvested legally and that the vessel landing the catch held the required authorizations and quota. The Commission has stressed that the strategy will be applied in a fair and transparent manner, with sanctions being increased substantially to act as a deterrent for IUU fishers.

National, regional and global estimates of the quantity of product being taken by IUU fishers and the amount of fish entering trade have been attempted. However, some of the estimates are based on "brave" assumptions with "heroic" extrapolations to arrive at global estimates. FAO has not attempted to estimate IUU fishing levels because of the inherent difficulties involved and the belief that RFMOs are better placed to make such estimates. Some RFMOs such as the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and the International Commission for the Conservation of Atlantic Tunas (ICCAT) have developed and refined estimates for IUU-catch levels in their respective convention areas. These estimates enjoy a high degree of international respect and confidence.

Globally, the annual value of IUU-caught fish could be as high as EUR 10 billion (European Commission 2007b). One striking estimate for the European Union is that some 500,000 tonnes of IUU-caught product, valued conservatively at EUR 1.1 billion, is imported annually through ports, by air and by road.[13] According to a UK industry source a significant proportion of this fish comes from West Africa and is transshipped

12. For a comprehensive review of the interface between "flag of non compliance" and IUU fishing, see Gianni and Simpson 2005.
13.Statement by Commissioner Joe Borg, European Commission for Fisheries and Maritime Affairs, at the High-level Conference on Eradication of Illegal, Unreported and Unregulated Fishing, Lisbon, Portugal, 29 October 2007.

through a single port in the Canary Islands.[14] In Japan the implementation of ICCAT's traceability measures has blocked market access for illegally caught high-valued, sashimi grade tuna from the Atlantic Ocean. The measures are considered to have been instrumental in reducing the amount of IUU fishing for tuna in the ICCAT convention area.

Galvanizing action

In 1999 COFI and the FAO Ministerial Meeting on Fisheries gave FAO a clear mandate to proceed with the development of a voluntary, soft-law instrument, within the framework of the 1995 FAO Code of Conduct for Responsible Fisheries. Intended to combat IUU fishing in a multi-pronged manner, the 2001 FAO International plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing (IPOA-IUU, FAO 2001), following an intense negotiation process, was endorsed by COFI in 2001.

Implementation of the IPOA-IUU focuses primarily on action by different categories of states: all states, flag states, coastal states, port states and states acting in common through RFMOs. Depending on their particular roles in fisheries, states are encouraged individually and collectively through RFMOs to adopt and implement a suite of consistent and mutually reinforcing measures. The instrument also promotes action to combat IUU fishing through the use of internationally agreed market-related measures, while supporting, and drawing support from, other international fisheries instruments.

Importantly, the IPOA-IUU urges countries to develop national plans of action to combat IUU fishing (NPOAs-IUU). They are seen as the cornerstones underpinning concerted and coherent national action against IUU fishing. From a practical perspective, their development enables countries to undertake a gap analysis to determine what is already being undertaken and what needs to be done. In elaborating NPOAs-IUU countries are urged also to engage in an "inclusive" process, by means of encouraging wide stakeholder "buy-in". Moreover, to ensure that they are living documents, countries are encouraged to review and revise their NPOAs-IUU on a regular basis. This process has the advantage of enabling countries to identify the most cost-effective strategies to increase the effectiveness of their plans and to ensure that they remain relevant and up to date.

Regional cooperation and collaboration is essential to combat IUU fishing. This is because of the sophisticated and highly mobile nature of IUU fishers who draw their strength from, and rely upon, "flags of non compliance", "ports of convenience" and weak regional cooperation. IUU fishers are highly organized, with access to excellent fisheries and market intelligence. Within a region they have the capacity to move quickly from one fishing area to another taking advantage of countries not exchanging information concerning IUU fishing and related activities. IUU fishing vessels also move rapidly from one region to another, thus reinforcing the need for enhanced inter-regional cooperation among RFMOs. The rapidity with which IUU fish-

14. Statement by an industry representative at the Second IUU Fishing Update and Stakeholder Consultation, Royal Institute for International Affairs, Chatham House, London, 9 May 2006. A similar statement was made in the New York Times (2008). Subsequently, an Italian press report echoed this view (La Stampa 2008).

ers switch operations underscores the need for countries and RFMOs to exchange information on a real time basis.

The IPOA-IUU encourages countries to cooperate regionally and to harmonize policies and activities. It urges countries to take action to enhance the role of RFMOs so that they can address IUU fishing in a more realistic, robust and transparent manner especially with respect to, *inter alia*, ensuring compliance with, and enforcement of, policies and measures adopted by RFMOs, giving effect to the duty to cooperate by applying the conservation and management measures adopted by a RFMO, or adopting measures consistent with RFMO measures and ensuring that flag vessels do not undermine such measures. Through measures intended to eradicate IUU fishing, some RFMOs including, for example, CCAMLR and North East Atlantic Fisheries Commission (NEAFC), have been successful in reducing its incidence and impact on resources.

Subsidies and fleet overcapacity

Subsidies and fleet overcapacity contribute to IUU fishing. Vessel construction and operational subsidies foster fleet expansion and the maintenance of overcapacity. Primarily because capital is underutilized, many vessels operators in overcapitalized fisheries are likely to seek out IUU fishing opportunities to supplement incomes. If vessels are displaced from these fisheries because of tightened management measures, there is a high probability that they will turn to IUU fishing if they are sold and if they do not secure alternate fishing authorizations. The ongoing mismatch between national and regional subsidy programmes and fisheries management, coupled with the failure of some countries to decommission vessels that are no longer authorized to fish, is a serious concern and one that facilitates IUU fishing.

In FAO the interface between IUU fishing and the management of fishing capacity was considered at a technical consultation in 2004 (FAO 2004a). Its major recommendations, which some countries and observers considered to be weak and lacking specificity in view of the severity of overcapacity and the global threat posed by IUU fishing, were reiterated to a large extent in the 2005 Rome declaration on illegal, unreported and unregulated fishing adopted by the Ministerial meeting on fisheries on 12 March 2005 (FAO 2005a).

A 2007 meeting convened by the Asian-Pacific Fishery Commission (APFIC) also addressed the relationship between fleet overcapacity and IUU fishing (FAO 2007b). The meeting agreed on a set of conclusions and a "call to action" to translate policy and instruments into concrete action. The key messages from the meeting to governments was that fleet overcapacity and IUU fishing threaten economic development and food security in South East Asia and that tackling overcapacity and IUU fishing proactively would deliver concrete benefits throughout the fisheries sector and in the economy at large.

Flag state responsibility and performance

Convincing "flag of non-compliance" states to meet their obligations under international law is a difficult task in the face of other considerations such as the income generated from the sale of flags. They are normally sold for modest amounts and it has argued that revenue derived from their sale is small and on balance, probably inconsequential, given the poor international publicity that issuing a flag of non-compliance creates (Swan 2002). A 2003 FAO meeting brought together countries operating open registries, and it adopted a number of recommendations for the more effective application of flag state control over fishing vessels with a view to reducing the incidence of IUU fishing (FAO 2004b).

While there are quite rapid developments on other fronts to address IUU fishing, action to promote enhanced flag state responsibility is not being ignored. At the instigation of the Ministerially-led Task Force on IUU fishing on the High Seas, and with the endorsement of COFI in 2007, it was agreed that guidelines on flag state performance should be considered particularly with respect to the development of criteria to ascertain whether flag states take their fisheries-related responsibilities seriously. The Governments of Canada and Iceland in cooperation with the European Union convened an initial meeting to address these issues in March 2008. It is expected that FAO will undertake further work in the area, utilizing the outputs from the Canada meeting.

Many RFMOs have developed vessel lists for non-compliant vessels and fleets and have commenced coordinating them (e.g. CCAMLR, Northwest Atlantic Fisheries Organization [NAFO], NEAFC and SEAFO). The tuna RFMOs including CCSBT, Inter-American Tropical Tuna Commission (IATTC), ICCAT, Indian Ocean Tuna Commission (IOTC) and the Western Central Pacific Fisheries Commission (WCPFC) have also moved towards coordinating their lists. At a meeting in February 2008 the tuna organizations agreed, *inter alia*, to proceed with a study of unique identifier systems for tuna fishing vessels, taking into account the outcome of the FAO's 2008 Expert Consultation on the possibility of establishing a single global register of fishing vessels (Tuna RFMO Chair's Meeting 2008). The tuna organizations will advise FAO on the policy aspects of developing and maintaining such a register.

It is well recognized that vessels operating under "flags of non-compliance" reduce the effectiveness and impact of RFMOs. IUU fishers impose real costs on them, on their members through higher contributions and on legitimate fishers through reduced catches and higher costs. IUU fishers reap the benefits of the work of RFMOs and, in an opportunistic way, make no contribution to management.

This situation has prompted a proposal that RFMOs should levy charges on countries issuing "flags of non-compliance" whose vessels fish in a RFMO convention area, as compensation for the theft and damage to resources and as a penalty for not exercising effective control over their flag vessels and undermining RFMO efforts to conserve and manage resources in a long-term sustainable manner (Gianni 2004). Reportedly, such a compensation-based approach is being considered also by countries that have been subject to IUU fishing. Seeking compensation for damage to fish stocks is consistent with the emerging international view that these incentives are the most effective means for discouraging IUU fishing.

Port state measures

Port state measures are a powerful cost-effective set of "tools" available to countries to combat IUU fishing. While not losing sight of the importance and complimentary nature of the IPOA-IUU's "toolbox", international attention has swung noticeably in favour of the port state as a front-line defence against IUU fishing. Although one of the least developed "tools", port states measures alone, and in combination with traceability schemes, implemented nationally on a harmonized regional basis have the potential to reduce the volume of IUU-caught fish entering international trade. It is recognized that if fishers are unable to transship or land IUU-caught product, or if the transaction costs associated with its laundering for sale through legitimate market channels are sufficiently high, the financial incentive to engage in IUU fishing will be eroded. Importantly, tight port state measures and traceability schemes have the wide support of the fishing and processing industry. Such support makes the implementation of these measures easier.

Central to reducing the profitability of IUU fishing is the need to make the movement of illegally-caught product from the vessel to shore to the consumer's plate more onerous. Port states are in a position to do this by ensuring that only legally-harvested fish is landed and that opportunities and loopholes for laundering illegal catch are closed. Countries are encouraged to implement effective port state controls and not permit IUU-fishing vessels to use their ports for any purpose.[15] Moreover, countries should discourage other countries in a region from operating "ports of convenience" as they undermine, frustrate and neutralize regional efforts to prevent, deter and eliminate IUU fishing.

In 2005 COFI endorsed a soft-law instrument, the FAO Model Scheme on Port State Measures to Combat IIU Fishing (FAO 2005b). Intended to facilitate a standardized approach to the implementation of port state measures to prevent, deter and eliminate IUU fishing, the Model Scheme provided for key actions by port states to ensure that IUU-caught fish was not imported or transshipped. The technical annexes to the Model Scheme were detailed and provided valuable guidance to countries about the information to be provided by foreign fishing vessels prior to entering a port, inspection procedures, the results of port inspections, the training of port inspectors and information systems for port inspections.

15. The exception is for cases of *force majeure*. A 2007 FAO regional workshop on port state measures in the Indian Ocean was told of cases where known IUU fishing vessels had entered a port in the region on the grounds of *force majeure* and had then attempted to offload catch.

Building on the IPOA-IUU and the Model Scheme, and taking account of calls from the UNGA and COFI, FAO started work in 2007 to elaborate a binding international instrument on port state measures to combat IUU fishing. If and when adopted, the instrument will extend and strengthen international law on port state measures in respect of vessels engaged in IUU fishing.[16] The timetable for the completion of the draft of the instrument is the session of COFI in March 2009.

Many RFMOs are moving quickly to take port state measures to combat IUU fishing. They have a fundamental role to play in harmonizing measures among members especially for inspection standards and procedures. Some RFMOs have already incorporated the principles of the FAO Model Scheme into resolutions and other measures (e.g., NEAFC [NEAFC 2007], WCPFC, NAFO, SEAFO and ICCAT) and other organizations are expected to follow suite.

The retail and restaurant industries are playing an increasing important role in a growing number of countries (e.g. Canada, Japan, UK and USA) to promote more responsible fisheries behaviour. Many supermarket chains have adopted certification practices for sourcing product from sustainably managed fisheries and from suppliers that can guarantee that fish has not been harvested by IUU fishers.[17] This action by retailers is welcomed as a means of blocking flows of IUU-caught fish into international trade. In some instances retailers have opted to source product only from industrial fisheries and from countries that have a demonstrated track record for sound fisheries management (e.g. Iceland and New Zealand). On the down side this practice has led to a degree of prejudice against exports of fish from developing countries because they have difficulty in meeting certification requirements.

Capacity building and technical cooperation

Capacity building and technical cooperation is a high priority for both developing and developed countries if IUU fishing is to be contained and eradicated. Like their developed country counterparts, developing countries need well-trained and capable personnel, strong institutions and resolute governance. It is therefore in the self interest of developed countries to provide technical assistance to bolster capacity in developing countries. FAO gives high priority to capacity building because developing and developed countries should attempt to have allied, if not equivalent, capacities to address IUU fishing. It is also recognized that at the regional level, action to address IUU fishing is only as strong as the weakest link in the chain

The IPOA-IUU highlights the special requirements of developing countries to implement policies and measures to combat IUU fishing. The IPOA-IUU urges FAO and other international

16. The 1982 Convention on the Law of the Sea addresses port state measures in article 218 with respect to pollution while a vessel is in port. It is silent on the use of port state measures for fishing vessels to support conservation and management measures that involve issues such as IUU fishing.
17. See a discussion of these issues in Oloruntuyi *et al*.

agencies to cooperate with developing countries to support training and capacity building and the provision of financial, technical and other forms of development cooperation. It proposes that such assistance might be used to support countries elaborate NPOAs-IUU, review and revise national legislation, improve and harmonize fisheries and related data collection, strengthen regional institutions, and strengthen and enhance integrated MCS programmes, including the implementation of satellite monitoring systems. Similarly, the Model Scheme requests countries to ensure that they have properly qualified personnel to carry out its functions.

In 2003, the FAO embarked upon a global series of regional workshops to broaden and deepen the implementation of the IPOA-IUU. They were completed in 2006. Their purpose was to develop and strengthen national capacity so that countries would be better placed to elaborate NPOAs-IUU. The workshops sought to raise awareness about the deleterious effects of IUU fishing and the need for countries to act in a concerted and decisive manner to combat such fishing, provide a comprehensive understanding of the IPOA-IUU, its relationship with other international fisheries instruments and its relevance to the fisheries situation in participants' countries; define more clearly steps that fisheries administrations should take to develop NPOAs-IUU and share information about the merits of harmonizing measures on a regional basis to prevent, deter and eliminate IUU fishing. In total, 232 persons from 98 developing countries, representing 52 percent of FAO's members, received training.

Following COFI's endorsement of the Model Scheme in 2005 a further series of capacity building workshops were initiated to assist developing countries enhance and strengthen the implementation of port state measures. These workshops are in line with UNGA calls relating to "... the critical need for cooperation with developing countries to build their capacity..." (in port state measures, UN 2006). The purpose of the port state measures workshops is to develop national capacity and promote bilateral, sub-regional and/or regional coordination so that countries will be better placed to strengthen and harmonize port state measures and, as a result, implement the relevant IPOA-IUU "tools" and the Model Scheme and contribute to the development, and subsequently implement, of a legally binding instrument on port state measures. They are conducted in partnership with RFMOs and other organizations with a view to ensuring a degree of follow-up and continuity after the training exercises are completed.

Impact on developing countries

IUU fishing has significant impact on fisheries in developing countries including small-island developing states (SIDS).[18] All of these countries are not well placed to combat IUU fishing because of capacity limitations. With frail MCS

18. Most small-island developing states are especially vulnerable to IUU fishing because they have large EEZs relative to their land areas, limited means to regulate and control access to their EEZs and a high dependence on fish for food, national income and for social and economic development.

programmes and persistent IUU fishing in their exclusive economic zones (EEZs), countries are required to take steps to strengthen MCS, usually at considerable cost. This improvement entails diverting resources from competing activities, leading to lower funding levels for other priority areas such as science and management.

Some developing countries and in particular SIDS, as a means of raising revenue and as a result of inadequate national harvesting capacity, authorize foreign vessels to operate in their EEZs. Revenue from this licensed fishing generates important cash flows for governments. SIDS tend to be targeted systematically by IUU fishers. Their activities weaken and destabilize fisheries management and deprive countries of revenue and food, increasing their vulnerability to food insecurity. This is especially evident in countries where semi-industrial and industrial vessels operate on the same or adjacent fishing grounds as small-scale and artisanal fishers.

In addition to widespread poaching in their EEZs, developing countries are likely to encounter increased difficulties and higher costs associated with the more rigorous import conditions being contemplated or already imposed by market countries. While these conditions are expected to have a significant and positive impact on reducing the amount of IUU-caught fish entering international trade, developing countries are likely to bear much of the increased costs associated with these measures. The burden for demonstrating that fish being offered for sale internationally has been harvested legally through traceability schemes, will fall squarely on the exporting countries.

Conclusion

Few capture fisheries in the world have remained isolated from IUU fishing. It affects all inland and marine capture fisheries irrespective of their scale, location and gear type, and apart from its adverse impacts on legal fishers and stocks, contributes to food insecurity and loss of national income. Moreover, IUU fishing imposes financial costs on governments and RFMOs as they seek to minimize its effects. States that operate open registries and that fail to exercise effective control over their flag vessels in accordance with international law should compensate countries and RFMOs for the harm inflicted on resources and the additional costs incurred in trying to curb IUU fishing. From all accounts IUU fishing is a profitable undertaking, a point recognized by the European Commission in its new policy on IUU fishing. Consequently, measures to combat it should be incentive-based. This is the case with port states measures and traceability schemes; they seek to make the marketing of IUU-caught product more difficult, thereby reducing the financial returns and the incentive for fishers to engage in IUU fishing.

Countries and RFMOs have initiated a wide range of measures against IUU fishing, with the IPOA-IUU providing the primary focus for action. It contains a logical framework for steps to be taken against IUU fishing, having strong linkages among its various measures (e.g. the development and use of vessels lists and the implementation of port state measures). Some components of the IPOA-IUU are being elaborated in more detail and the proposed binding agreement on port state measures, which will extend international law, will provide a basis for strengthened national and regional efforts to block the flow of IUU-caught fish to international markets.

For developing countries, IUU fishing is a double-edged sword. On the one hand they are impacted significantly by IUU fishing because of their limited capacities to prevent it. On the other hand, with the rise of traceability schemes they may face the loss of market opportunities because of technicalities in meeting the rigorous requirements of these schemes. The provision of ongoing technical assistance to enable developing countries to meet these requirements is crucial, as are other measures to combat IUU fishing, including enhancement of fisheries governance in a broader context. Indeed, the existence of poor governance and the propensity for officials to behave corruptly encourages IUU fishing, especially when companies and their IUU fishers find protection and safe havens in "port of convenience".

On a more positive note, an important and encouraging consequence of the rise of IUU fishing is that for the first time the international community and all sectors of industry have rallied unanimously against it. IUU fishing has roused and excited opposition like no other fisheries issue in the past. All stakeholders including coastal states, fishing states, importing states, governments, RFMOs, the fishing industry, retailers, restaurants and civil society have joined forces to try to minimize its effects and to eradicate it.

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GOVERNANCE AND DECENTRALIZATION REFORMS IN SMALL-SCALE FISHERIES – AN AFRICAN PERSPECTIVE[1]

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Abstract

Relying on a framework that highlights different dimensions of 'decentralization', this paper reviews fisheries co-management programmes as they have been implemented over the last 20 years in sub-Saharan Africa. It shows that in most cases, fisheries co-management programmes failed to improve governance, but simply altered the distribution of power and responsibility amongst the different stakeholders. In this new context, the co-management programmes were implemented often at the detriment of the direct end-users (fisherfolk) who benefit from those reforms only in a limited number of cases. Challenging the current narrative that presents participation as the central condition for governance reforms, the review instead highlights the importance of downward accountability. The paper concludes with a series of recommendations.

Introduction

Today, decentralized governance is the overarching paradigm in development and public policy arenas. Decentralization and community involvement are present as necessary conditions for effective development (Rondinelli *et al*. 1989, Manor 1999, World Bank 2002). Consequently, a large number of programmes and policy reforms promoted by international development agencies and NGOs have been carried out recently in many developing countries, with the explicit objective to support decentralization reforms (Manor 1999). Applied to a wide range of domains and economic sectors, these reforms have also been described or labelled under a wide range of terms, such as democratic decentralization, participatory development, devolution, indigenous management, user-participation, co-management, etc (Ribot 2003).

In the development literature, the arguments in favour of participation and decentralization are not simply based on economic and administrative efficiency. They are often associated with promises of progress in public accountability, environmental sustainability and empowerment of

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poor and vulnerable groups (Manor 1999, World Bank 2002). Amongst other things, decentralization is therefore perceived as one possible solution for the improvement of rural population livelihoods and even as a means for poverty alleviation (Crook and Sverrisson 1999). The most common argument is that decentralization is by definition a mechanism of 'inclusion' and 'empowerment'. Because it involves bringing government closer to the governed, in both the spatial and institutional senses, decentralized governments, it is said, will be more knowledgeable about, and hence more responsive to, the needs of the poorest and marginalized people. This mechanism of inclusion is expected to lead to empowerment and pro-poor policies and outcomes (Crook and Sverrisson 1999, Manor 1999).

In small-scale fisheries, after several decades of a strong-centralized management approach, 'decentralization' has also become the new paradigm (Pomeroy 2001, Viswanathan *et al.* 2003). Following the view of influential scholars who advocated for governance reform, the consensus in the policy discourse is now largely in favour of fisheries management decentralization, either in the form of co-management or community-based fisheries management (CBFM) reforms (Pomeroy and Rivera-Guieb 2005). Almost every country in the developing world has now explicitly endorsed co-management or some form of CBFM as one of its main national fisheries policy objectives.

However, as will be argued in the next section, governance reforms in fisheries seem to have followed an internal, independent process that has evolved, for its main part, parallel to the shift in governance paradigm that has characterized the other socio-economic sectors in the course of the 1980s.

Origins of 'decentralization' in fisheries

The consensus on decentralization reform in fisheries has been largely influenced by the 'community-based' approach. According to this paradigm, the existence of 'pro-social norms' shared by individuals within the community ensures the superiority of local governance over other systems (see, for instance, Folke *et al.* 1998). In particular, it is asserted that local governance, through 'moral economy' and social self-regulatory mechanisms, will guarantee the economic efficiency, social equitability and environmental sustainability of the system. Although these three aspects – efficiency, equitability, sustainability – are sometimes assumed to occur simultaneously, one central feature of this paradigm is the emphasis put on the capacity of the community to use and care for the surrounding natural resources in a 'sustainable' way:

> "The value and wisdom of [community-based management] lies in its recognition that communities, by whatever definition we use, are potentially the best resource managers, since they have the biggest stake in the sustainability of natural resources." (Rivera and Newkirk 1997, p. 74.)

Under the community paradigm approach, the rationale for decentralization is therefore a pragmatic one. Local people are more familiar with a given area than outsiders (including the staff of central agencies who are located in the often distant capital city), and local communities have a broader understanding of the environment and, in particular, of the specificities of the local ecosystems and natural resources they depend upon. Furthermore, it is frequently argued that local participation ensures self-interest, without which management efforts and investments are likely to fail.

One of the inspirations for such influence has been the 'discovery' by anthropologists and others, in the 1970s, of traditional systems of fisheries management practiced by local communities in Oceania, Africa, Latin America, North America, as well in Japan (Berkes 1989, McCay 1993). By the beginning of the 1980s, statements regarding the desirability of reviving or adapting traditional community institutions of fisheries management to meet modern needs were being made in a number of influential papers published by the Food and Agriculture Organization, the World Bank and ICLARM. By the early 1990s, those ideas had become the received wisdom as far as the management of artisanal fisheries was concerned.

The theory, however, that played a pivotal role in the shift of paradigm in fisheries sciences away from a centralized management system to community-based – and then co-management – approach is the theory of common property regimes (CPR). Although one primary impetus of the CPR analysts has been to denounce the conclusions promoted by Garrett Hardin in his article *The tragedy of the commons* (Hardin 1968)[2], their underlying intention was also to promote decentralization and local-level management reforms. For instance, Ostrom's very influential work *Governing the commons, the evolution of institutions for collective actions* (Ostrom 1990) has been in fact written in tandem with her participation in the "Decentralization: Finance and management project" sponsored by USAID.[3] Similarly, Berkes, in his book *Common Property Resources*, leaves little doubt about the actual motives of his research:

> "The major area of emphasis here is on communal resource management systems. The 'tragedy of the commons' model overemphasizes the solutions of privatization and central administrative controls at the expense of local-level controls and self-management. This book attempts to redress the balance, inviting resource managers and development planners to integrate local-level management ('planning with the people') into the existing common-property resource-management framework." (Berkes 1989, p. 2.)

In addition to Berkes and Ostrom, many other scholars have been instrumental in the reorientation of the fisheries governance paradigm over the past 20 years (e.g. Pomeroy 1991, Sen and Nielsen 1996). It is recognised that the policy consensus in favour of fisheries decentralization has now been accepted in a large number of de-

2. See, for instance, Feeny *et al.* (1996).
3. cf Ostrom (1990, p. xvii).

veloped countries (e.g. Denmark, Netherlands, Canada), but also in an increasing number of developing countries, in Africa (e.g. Uganda, Mali, Malawi, Senegal, Ghana), in Southeast Asia (e.g. the Philippines, Malaysia), and in other parts of the world (e.g. the Fiji Islands).

The conventional approach to co-management: a plea for more participation

In fisheries literature, the most frequently quoted framework used to analyze decentralization – and, in particular, its co-management form – is the framework proposed by McCay and Berkes (McCay 1993, and Berkes 1994) – see Figure 1. The core idea of the 'McCay-Berkes' framework is that co-management is characterized by various partnership arrangements distinguished from one another by the "degrees of power-sharing and integration of local and centralized management system" (Pomeroy and Berkes 1997, p. 466). Depending on these different levels of power devolution, five major generic types of co-management arrangements can be defined: Intrusive, Consultative, Cooperative, Advisory, and Informative – to which the two classic types of management, i.e. centralized and community self-management, can be added. In its 'extended' version (e.g. Pomeroy 1995) the framework includes seven degrees of power-sharing, associated with seven types of management arrangements (Table 1).

The McCay-Berkes framework is useful to compare fisheries co-management arrangements and a large number of comparative analyses that were proposed in the literature have indeed used

Figure 1. McCay – Berkes co-management framework (redrawn from McCay 1993), distinguishing different degrees of participation (power-sharing) between end-users and centralized management institutions.

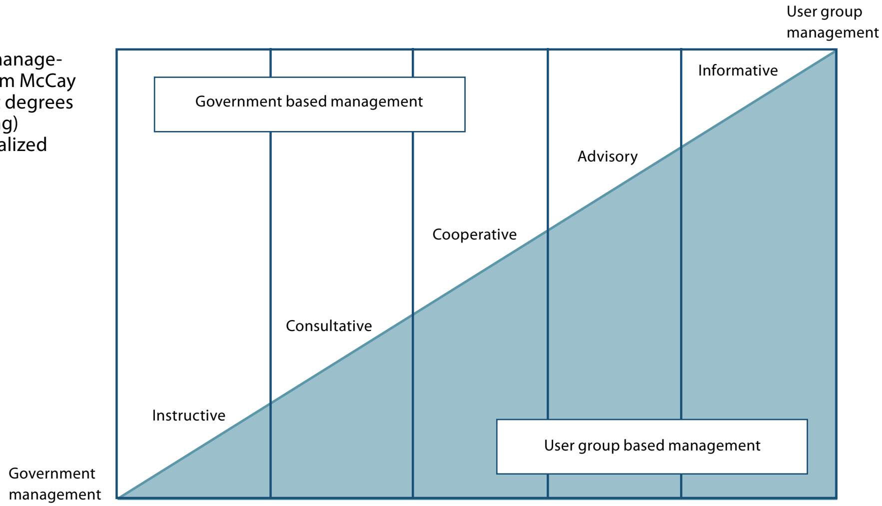


Table 1. Typology of fisheries management arrangements.
Source: McCay (1993) and Berks (1994), modified by Pomeroy (1995).

Type	**Description**
Type A(+): Centralized management	The state takes all decisions of policy and does not engage in dialogue with fisheries stakeholders.
Type A: Instructive	There is only minimal exchange of information between government and users. This type of co-management regime is only different from centralized management in the sense that the mechanisms exist for dialogue with users, but the process itself tends to be government informing users on the decisions which they plan to make.
Type B: Consultative	Mechanisms exist for governments to consult with users but all decisions are taken by government.
Type C: Cooperative	This type of co-management is where government and users cooperate together as equal partners in decision-making. For some authors this is the definition of co-management.
Type D: Advisory	Users advise government of decisions to be taken and government endorses these decisions.
Type E: Informative	Government has delegated authority to make decisions to user groups who are responsible for informing government of these decisions.
Type E(+): Self-governance and self-management	Communities or other stakeholders take decisions about fisheries management and do consult or inform government or state laws.

this framework for this purpose.[4] However, the classification on which it is built is merely descriptive. It does not offer any analytical 'handles' for identifying or assessing the underlying mechanisms associated with the changes induced by co-management reforms. Consequently, using this framework for anything other than a descriptive purpose may be misleading. In particular, because the core element which structures the framework is based on a gradient of power-sharing, using this framework as an 'explanatory tool' leads to considering the degree of power devolved as the key (explanatory) factor and may in particular lead analysts to associate failure(s) of co-management with too little devolution/participation.

Reviewing the literature reveals, indeed, that most co-management studies conclude that there is generally not enough participation in the ongoing fisheries reforms and regret that too little responsibility is passed down to the community. Pomeroy, for instance (2001, p. 135), claims that "Many attempts at decentralization have not delivered a real sharing of resource management power". One reason for this perceived failure is that "Fisheries administrators may be reluctant to relinquish their authority, or portions of it, and governments are often opposed to decentralization" (Pomeroy 1993, p.14–15). This is echoed by Sverdrup-Jensen and Nielsen (1998, p. 11), who comment, "Under the present management arrangements situation, user groups will often be

4. See, for instance, the many papers on fishery co-management in the Proceedings of the Bi-Annual Conferences of the International Association for the Study of Common Property, available on-line at *http://www.indiana.edu/~iascp/past.html*.

patronized in possible disputes with government. The latter seems generally reluctant to devolve power and bestow legal rights and authority in fisheries management to user groups". As Chirwa (1998, p. 69) points out, "The [Fisheries Department's] position of patronage means that the local user communities are the recipients rather than the initiators of decisions. They, themselves, are managed, together with their resources, by the Fisheries Department."

The level of devolution is, however, only one dimension to consider within the process of participation. As emphasized by Cohen and Uphoff (1980), many other important criteria should also be taken into account when evaluating a governance reform, e.g. the *kind* of participation (participation in decision-making; in implementation; in benefits, in evaluation) or *how* the process occurs (the basis of participation, its form, its extent, its effects) – see Table 2. In other words, assessing the participation process – and in the present case the fisheries co-management process – through the degree of participation or the level of devolution is not sufficient. This mono-dimensional conceptualization of the process reduces governance reform to the degree of participation and does not necessarily capture the main factor(s) explaining the degree of success or failure of decentralization reforms.

Table 2. Cohen and Uphoff's (1980) classification of participation.

Types of participation	Participation in decision-making Participation in implementation Participation in benefits Participation in evaluation
Who participates	Local residents Local leaders Government personnel Foreign personnel
How is participation ocurring?	Basis of participation Form of participation Extent of participation Effect of participation

This point was confirmed empirically by Neiland and Béné (2003) who conducted a review of 50 case-studies of fisheries across 39 countries. Using the information provided by the literature, they analysed the management systems of these fisheries and assessed in particular the performance of each of the 50 fisheries, using three criteria: economic efficiency, ecological sustainability, and social equity. At the same time, they categorized these fisheries by the degree of participation of their stakeholders in the decision-making process, using the seven categories of power-sharing as defined by McCay and Berkes – see Table 1 above. Their analysis shows that there is no tangible correlation between the level of devolution of responsibility in the fishery and the actual performance of the fishery. In other words, the degree of participation did not explain the performance of the fisheries: some fisheries characterized by highly centralized management system were doing well, while other, more participatory, fisheries were unable to generate good management outcomes – and vice versa.

In fact, as Brett notes, "Maximum participation may not always be possible or efficient" (2000, p. 1). Each fishery in each society has its own 'balance point' on the scale of management intervention and "Some fisheries are more effectively managed by governments or intergovernmental bodies [while] some are more effectively managed by local communities and non-government bodies, with various mixtures in between" (Adams, 1996, p. 339). Thus, advocating for a systematic strong participation by the fishery community may not be the correct approach and the issue of *how much* power is shared may be the wrong question. Instead, issues of *how* this power is shared and *who* receive(s) this power may be more important.

The need for a new analytical framework

From a political science perspective, a governance reform may take several forms, involve various agents and induce changes of different intensities at different levels. Broadly speaking, three main types of reforms are relevant to the discussion of co-management and governance reforms in fisheries: devolution, deconcentration and decentralization.

Applied to the fisheries context, each of these types of reforms leads to different patterns of empowerment over fisheries resources (Figure 2). *Devolution* refers to the transfer of rights and responsibilities from the government to representatives of user groups at the local level (fisher organizations or alike). *Deconcentration* involves changes in governance where the decision-making authority is transferred to lower-level units of bureaucracy or government line agency (provincial and/or district level of the Department of fisheries), while *decentralization* induces transfers of decision-making authority and financial

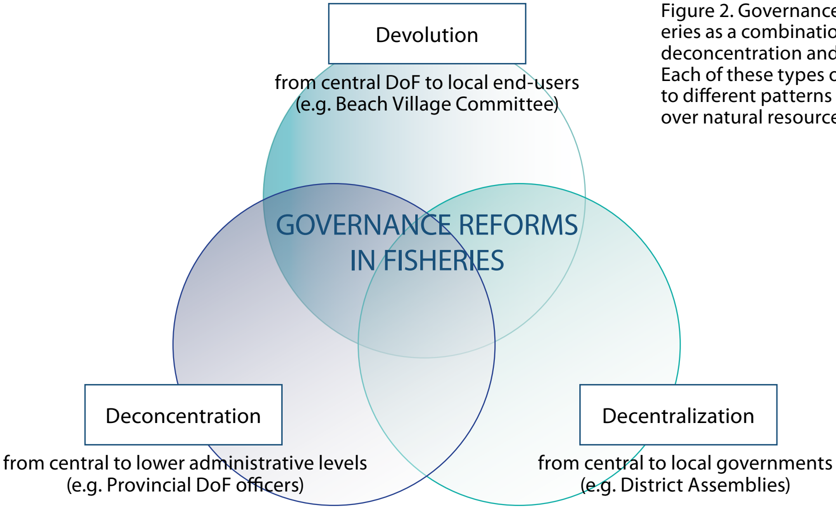


Figure 2. Governance reforms in fisheries as a combination of devolution, deconcentration and decentralization. Each of these types of reforms leads to different patterns of empowerment over natural resources.

capacities related to the fishery management to lower (provincial, district or communal) levels of government bodies. In this framework, note that co-management as conventionally defined in the fishery literature refers to devolution reform.

In many instances, one may argue that the conceptual distinction made here is quite theoretical and may not reflect the empirical reality. In particular, fishery reforms may appear to be a combination of these three types of reform.[5] Overall, however, the distinction is useful as it provides a relevant analytical framework to explore some of the main changes that are induced by the redistribution of power amongst the fishery stakeholders. In particular, it draws attention to the following key question: which actors are empowered with natural resource uses and management decisions? As recalled by James Ribot, this question is critical since experience has shown that "whether the transfer of natural resource power within or into the local institutional landscape promotes or undermines representative, accountable and equitable processes depends on which local actors are being entrusted with discretionary powers over natural resources" (Ribot 2003, p. 55).

Lessons from Africa

Drawing upon the analytical framework described above, a series of five fishery governance evaluations were conducted simultaneously in five African countries: Cameroon, Malawi, Niger, Nigeria, and Zambia, with the specific objective to assess the various co-management programmes that have been – and are still being – implemented in these countries (Béné *et al*. 2008).

Synthesizing the findings of these five evaluations into one single message might be quite uneasy, as the overall outcomes of the co-management programmes that they reviewed are rather complex and 'patchy'. In fact, no clear consensus seems to emerge. Some analysts would certainly prefer to emphasize the few success stories that have occurred amongst those co-management projects, but a more rigorous assessment would also highlight some of the less successful outcomes of these co-management experiences. Ultimately, however, the core issue is about governance and the central question remains: Has co-management, as it has been implemented so far in Africa, improved the governance of small-scale fisheries for the benefit of the fisherfolk?

From the information collected by the five assessments, it seems that the answer to this question is: "not necessarily". While one can hardly dispute that the new governance system introduced by co-management was genuinely intended at improving the governance in fisheries, in practice, however, the outcome has not systematically been positive. In the majority of the co-management programme reviewed by the five documents, the reforms – most of which had been donor-driven and top-down in implementation – failed to effectively *improve* governance. Instead, they simply *modified* the status quo by altering the distribution of power and responsibility between the main fisheries stakeholders.

5. For instance, direct users (fisher representative and/or local Department of Fishery, DoF) may be invited to lead the new management commission created by the local government as part of the newly-decentralized management of the fisheries.

In particular, an interesting result that emerged from the five reviews is the fact that deconcentration is predominant over devolution in the majority of the co-management programmes that were evaluated. If one accepts that the five countries included in this assessment provide a reasonable representative 'sub-sample' of the rest of African fisheries, it seems therefore that in many countries the establishment of fishery co-management has led to a partial redistribution of power toward the local (provincial/district) levels of the Department of Fishery (DoF). Overall this finding means that, although co-management has been recurrently presented in the literature as the way to devolve power towards the end-users of the fisheries, in reality the 'balance' is still very much in favour of some form of government control – essentially through the DoF. What the reviews of the five countries showed, however, is that this control is becoming increasingly deconcentrated, probably as a result of the continuous pressure imposed by the donors on the governments to show some forms of "good governance".

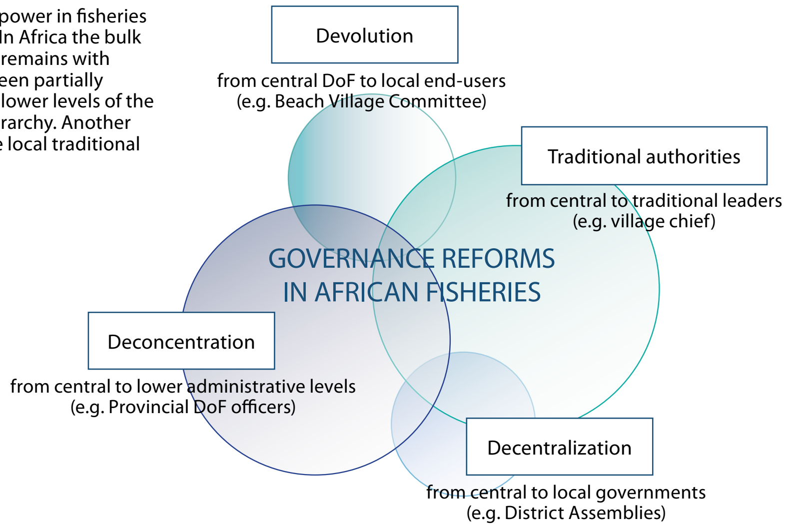
The DoFs have not been the only stakeholders that benefited from the reforms. In the 'fluid' context of rapid institutional changes created by the co-management reforms, the traditional local authorities (village chiefs and alike) have also been usually quite successful at moving forward their own agenda. However, the institutional 'paths' through which these traditional authorities have managed to enter into the new landscape are varied and complex. In some cases, this resulted indirectly from constitutional or leg-islative changes induced by the decentralization that is implemented – sometimes simultaneously with with, but – independently from co-management reform. This has been the case in Niger for instance, where traditional authorities have been included *de jure* in the decentralization process, thus allowing these traditional leaders to regain or reinforce their past influence. In other cases, this resulted from their own capacities to interfere and 'capture' part of the financial and/or political power that was being delegated through the co-management process, using their own existing influence and network, or sometimes through strategic alliance with other local elites or the local DoF staff.

The last important result highlighted by the five reviews concerns decentralization. Although decentralization reforms have been widely promoted in a large majority of countries in Africa (with the notable exception of Nigeria), the reviews showed very little evidence of any positive interactions between small-scale fisheries and the new local government bodies that were created through these decentralization reforms. At 'worst', no effective integration of the small-scale fisheries in the agenda of the local authorities takes place; at 'best' the relationship is reduced to the taxes that are levied by the local governments – or some of their decentralized agencies – in order to extract some of the rent generated by the fishery sector.

In this context, it should not come as a surprise to hear that the real beneficiaries of the co-management reforms have rarely been the actual end-users of the resources, i.e. the small-scale fishers and fish processors. In fact as evidenced through the five assessments but also some of the older literature (e.g. Hara *et al.* 2002), many of these fishers (in particular migrant fishers) have often been excluded from the new co-management arrangements. Instead, the reforms opened 'opportunity windows' for other actors (mainly at the local level) to reshape the institutional landscape in ways that allow them to reinforce their own socio-political, institutional or economic power, often at the detriment of the legitimate end-users of the resource. This 'instrumentalisation' of the co-management (as initially described by Viswanathan *et al.* 2003), is not really surprising, as it simply reproduces the social process frequently described in political economy through which one group of actors (usually the most powerful, local elite) shape the institutional landscape to create a new status quo favourable to their own interests.

Revisiting the framework presented in Figure 2 with these different conclusions leads us to a modified representation of the governance reforms as they have effectively been taking place in small-scale fisheries in Africa (Figure 3). At the present time, it seem fair to say that the bulk of the power still remains with the DoF, but has been partially delegated to lower levels of the hierarchy. This new arrangement is beneficial to the top level of the administration as it successfully transfers the load of the monitoring and enforcement to the lower-level representatives (local staff), while maintaining the main responsibili-

Figure 3. Share of power in fisheries co-management. In Africa the bulk of the new power remains with the DoF but has been partially transferred to the lower levels of the administrative hierarchy. Another major player is the local traditional leaders.



ties and power at the top level through strong upward accountability mechanisms. The other major beneficiaries of these reforms are the traditional local leaders who have received another large part of this 'decentralized' power through *de jure* decentralization legislation or through *de facto* coercion or collusion with the local DoF staff. Finally, the real 'losers' are the end-users (fisherfolk) who have gained only partial control over the resources.

Conclusions

A series of conclusions emerges from this analysis:

Moving beyond the co-management paradigm

One of the most fundamental (and urgent) challenges for the academic and donor communities in the next few years will be to move beyond the current co-management narrative, recognizing that the existing model (crystallized in the McCay-Berkes framework) does not provide an adequate framework to tackle the more fundamental issues impeding the sector in its attempts to move toward improved governance. "More participation" is not the panacea. In fact, such a view tends to reduce the issues to an overly simplistic one-dimensional problem, while governance reforms in fisheries are in reality a much more complex, multi-dimensional process.

Participation, yes but more importantly accountability

Ensuring or enhancing the participation of the end-users and other legitimate stakeholders in the decision making process is important – as correctly pointed out by Berkes (1989), Ostrom (1990), Pomeroy (1991), and others. The involvement of these end-users is expected, in particular, to increase their sense of responsibility and ownership, thus facilitating the self-enforcement of the management system and, in principle, the 'sustainability' and equity of the system. However, as highlighted by many experts (e.g. Devas and Grant 2003), participation without downward accountability is not effective. The involvement of every individual fisher in the decision making-process (that is, direct democracy) is not possible as it would increase *ad infinitum* the transaction costs of the political process. One has therefore to rely on indirect democracy, using representatives of the different stakeholder groups. What recent political and social sciences research on decentralization has shown, however, is that, any direct devolution of power to these representatives is likely to become a source of misuse and abuse, unless these representatives are strongly downwardly accountable to the rest of the community (Agrawal and Ribot 1999, Ribot 2003).

Focusing on implementation issues

Co-management – and more broadly governance reforms – are high on the agenda of most African countries. It would therefore be misleading to present the failure of co-management reforms as the consequence of lack of official political will. Co-management failure comes essentially from implementation failures. There is therefore an urgent need for academics to turn their attention toward the context-specific nature of co-management implementation. While this has been highlighted many times, there is no 'one sizes fits all' solution and the success (or failure) of a co-management programme will essentially depend on local details: the integrity of the local DoF staff and traditional leaders, the balance between the different ethnic and/or socio-cultural groups of fishers (e.g. migrant versus indigenous), the presence of local NGOs, and in particular the pre-reform relationship between all these different groups and individuals. Note that very little in these failures/successes has to do with the resource itself. Most of the issues are institutional.

Recognizing the political economy of co-management reforms

In direct relation to the point above, it is crucial to recognize that the socio-institutional landscapes where governance reforms in general and co-management in particular are implemented are not 'empty'. These landscapes are in fact the result of a constantly evolving political process that reflects the current distribution of power between different actors (essentially at local level) and their control over the resources. The introduction of co-management has been perceived – and instrumentalized – by these different actors as an new opportunity for them to continue to shape the socio-institutional landscape in a way that allows them to pursue or even increase their political, social or economic advantages. In this continuous (open or more subtle) struggle, the poorest and most marginalized of the fishing community have generally been the losers as they usually enter the game with some disadvantages.

The recognition of this political economy dimension has strong implications for the way co-management should be planned and implemented. In particular it means that a good understanding of the current 'landscape' and of the current interactions between the different groups likely to be directly or indirectly involved (or excluded) by co-management is essential before the first step of the reform is actually initiated. This preliminary analysis should help predict the changes that are likely to occur as a result of the reform, and thus provide appropriate guidance and recommendations on how to limit the 'unexpected' and/or negative effects.

The 'unavoidable' traditional leaders

Although this is not exclusive to Africa – as many Pacific fisheries also seem to be in the same situation – African small-scale fisheries are largely still under the strong influence of the local traditional leaders. While co-management could have been one way to reduce this influence (if one wished to do so), field data reveals that it has in fact been rather the opposite. Because co-management projects were usually poorly prepared to face this issue[6], these traditional leaders have usually been one of the groups that systematically managed

6. We recall that this issue of traditional leaders was totally absent from the initial McCay-Berkes framework. Interestingly, it has emerged in the African literature (see e.g. Sverdrup Jensen and Nielsen 1998, or Hara *et al*. 2002).

to strengthen their local power during the establishment of co-management arrangements. This situation means that a large part of the success (or failure) of these co-management reforms depends on the *bon-vouloir* of these traditional leaders. In particular trying to ignore or bypass these traditional leaders would almost systematically prompt some retaliation.

The influence of these traditional leaders is not, however, necessarily always negative. In some cases, they have been key players ensuring the success of co-managements projects. When this happens, it is, however, essentially the result of their own integrity and commitment, rather than the consequence of the co-management arrangement itself. Until clear downward accountability mechanisms are embedded into the process, co-management projects will always depend on the personal commitment and capacities of a few key actors, leaving the overall project's fate – and its impact on the whole community – entirely in the hand of these few leading actors.

Reconsidering the balance between decentralization and devolution

As evidenced in the five assessments considered here, but also through other sources (e.g. Hara 2006), fishery co-management projects have so far suffered from poor, or even inexistent, relationships with the broader decentralized governance structures. Several reasons may be brought forward to explain this situation. Historically fishery co-management has been promoted – at least in its early stages – independently from decentralization (Berkes 1989, Pomeroy 1993). The fishery literature is also known to be usually remarkably sectoral in its analysis and links to rural development or other domains (e.g. water management, agriculture) are generally poor. On the other 'side' of the equation, small-scale fisheries are usually not considered as an important or relevant sector by planners and decision-makers. This situation has certainly contributed to the current rent-seeking predatory behaviour adopted by many local government agencies vis-à-vis the small-scale fisheries.

This predatory relationship does not have to become a general rule. A more equitable relationship is possible where both parties (the fishery and the local government) could benefit from one another through a much strongly integrated approach. Better supported small-scale fisheries could clearly contribute to local economic development, thus supporting more effectively the objectives of the local government through revenue generation, but also – perhaps more appropriately – through employment (labour buffer), food security and economic empowerment of women. Ironically local levels of decision making are known to be much more favourable for integrated planning than higher (national) levels. Local government should therefore be in a much better position to integrate and account for the aspirations and needs of the small-scale fisherfolks than the national planners. It is therefore the responsibility of the fisheries stakeholders (starting with the DoFs) to make this integration effective for the benefit of the resources and the end-users.

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INNOVATIONS IN FISHERIES CO-MANAGEMENT, AND THE CHALLENGE OF MOBILITY

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Abstract

The Sustainable Fisheries Livelihood Programme (SFLP) of the FAO, with financing from the UK, carried out two sub-regional pilot projects on fisheries co-management, one in inland waters (Burkina Faso, Côte d'Ivoire, Mali and Ghana) from 2003 to 2006 and one in the marine coastal area (Congo, Gabon, Guinea and Mauritania) from 2004 to 2006.

Co-management attempts mostly focus on improving fish-stock management, requiring people to reduce fishing activities, without offering any interim benefits. Thus incentives are not taken into account. The SFLP approach to co-management was instead based on embedding fisheries management in a development context, recognising that local institutions for resource management could also be used to mobilise finance and services in support of fishing communities. It gives priority to an enabling legal framework and appropriate institutions.

Using the Sustainable Livelihoods Approach (SLA) in resource governance, SFLP has demonstrated that the transaction costs of a shift to co-management can be offset by parallel investments in poverty reduction. The linkage between co-management and local development allowed community-based fishery organisations and fishery departments to integrate resource management requirements with local development processes.

Co-management requires a supportive political and legal environment. Appropriate systems for communication between stakeholders must be built to encourage community participation. All components of the rural communities must have equitable representation in co-management institutions, to take all interests into consideration.

Capacity building (adult literacy, micro-finance, alternative income) help detach fishing communities from the resource to some extent, and lays the foundation for poverty and vulnerability reduction in fishing communities. The capacities of government officers and local community groups should also be strengthened. Functional and effective co-management institutions give the framework and the tools for dialogue with authorities and organisations. At the end of the

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project the fisheries sector was integrated in poverty reduction strategies in most of the SFLP's countries.

Fishing communities are complex with regard to living conditions, composition, social organisation and their strategies to ensure livelihoods. One of these strategies is migration, a phenomenon as complex as the communities themselves. SFLP has reached a better understanding of the reasons behind fisheries migratory movements along the coast of West Africa. The improved knowledge is needed to inform fisheries management policies and poverty reduction strategies in fishing communities. Among the many reasons that make fishing people migrate, economic factors (search for markets, opportunities to save for future investments, security lines, etc.) are without doubt the most important ones.

Introduction

Co-management arrangements are a way for fisheries departments to improve efficiency and reduce costs, or a response to reduced resources due to poor property rights, and the perception that this is a main cause of poverty (Pomeroy 1997, Lowry 1999). Experience from around the world shows that the following conditions are important to successful fisheries co-management (adapted from APFIC/FAO 2005):

1. An enabling policy and legal framework, and continued government support;
2. Effective institutions and linkages;
3. Real participation by resource users and other stakeholders, avoiding elite capture and exclusion of minority groups;
4. Incentives for individuals to participate.

In the Central Africa region, co-management arrangements have been successfully used in forestry (Nguinguiri 2004) but there are no well-documented fishery examples. In West Africa, on the other hand, there are several examples including some of the earliest fisheries co-management arrangements in the world (Sverdrup 1998). In most of these cases, co-management was government-based, and user groups were not given the necessary authority through enabling legislation. Hence the co-management was not institutionalised.

Earlier co-management attempts in the region – and indeed most co-management programmes worldwide – were focused on improving fish-stock management, with the assumption that poverty could be reduced solely or primarily by improving the state of fish resources. This inevitably required people to reduce their own fishing activities, without any form of interim or collateral benefits. Thus incentives were not taken into account, except in the form presumed future benefits from higher fish catches and more secure community-based aquatic property rights. In the context of poverty and high levels of vulnerability, this has often proven insufficient incentive to gain the cooperation of communities.

The FAO/SFLP approach to co-management was instead based on embedding the need for fisheries management in a wider development context, recognising that collective-action institutions for resource management could also be used to mobilise finance and services in support of other aspects of peoples' lives besides resource management. The SFLP approach incorporates broader development functions and gives priority to an enabling legal framework and appropriate institutions. Experiences show that co-management can be effective and sustainable in the context of poverty.

The overall strategy was to promote improved resource management in conjunction with a development support process. As well as ensuring the sustainability of fishery resources in the lakes and coastal zones, a key objective of the two pilot projects was to contribute to poverty reduction in fishing communities. A co-management based approach was developed on the basis of the SLA (Sustainable Livelihoods Approach) analytical framework to assess and address the multiple dimensions of poverty in fishing communities and the principles of the FAO Code of Conduct for Responsible Fisheries, to ensure management actions were compatible with responsible fisheries principles.

Building an enabling policy and legal framework

For the ongoing decentralisation to be achieved, governments have to put in place appropriate capacity and systems for implementation, including the institutional and legal framework and supportive regulations and guidelines to facilitate the process at the central, intermediary and local levels. All these initiatives relate to how to approach and handle poverty reduction and service provision to fishing communities in a development context. In addressing these issues the SFLP also incorporated consideration of environmental entitlements (including rights to land and water), equity concerns (including gender equity) and the mechanisms generating social exclusion (including conflict between migrants and residents). This was conducted together with the poverty alleviation policies with the support of many partners, through Poverty Reduction Strategy Papers (PRSPs).

However, despite the general decentralisation movement, real decision-making power and resources have not always been reallocated to local communities. New instruments for local management institutions that could cooperate with local authorities were needed. The pilot projects contributed to creating a legal environment that was conducive to co-management, and to the participation of fishing communities in decision-making in local development. When needed new legal, administrative and institutional arrangements were developed, but in most SFLP countries it was a matter of using and interpreting – as well as updating when required – existing laws and procedures.

The pilot projects supported the emergence of recognised local fisheries organisations that addressed both resource management and poverty reduction. By highlighting the synergies, SFLP contributed to the mainstreaming of small-scale fisheries in local and national development policies. Hence, the fishery communities became more audible, and their concerns more visible, better understood and better considered by policy makers and development partners.

The new institutions address the three dimensions of poverty – vulnerability, marginalisation and social exclusion – within fishing communities.

1. *Vulnerability* – Access to health services and secure fundamental rights was improved. Fishing communities were integrated in HIV/AIDS and other endemic diseases initiatives; and co-management institutions took the lead to sensitise and involve fisheries community members and other stakeholders in the process (e.g. Congo, Gabon and Mauritania).

2. *Marginalisation* – Institutions were developed considering rights to work, rights of migrants and gender equity. Migrants and women are members of socio-professional and co-management organisations and participate in decision making process.

3. *Poverty* – The strategy was diversification, education, micro-finance and partnership development. Fishing management committees organised development initiatives forums to attract funding by NGOs (Burkina Faso and the Gambia). The fisheries sector was integrated in PRSPs in most of the SFLP countries. Fisherfolk organisations established partnerships with micro-finance institutions and diversified their livelihoods in various non-fishing activities including agriculture, livestock, petty commerce and handicraft. Trainings in literacy, basic accounting and organisational development played a facilitating role.

A major limitation of the work, however, was a lack of time and resources to build on these incipient achievements and to ensure that improved linkages with development processes at meso and macro level translated into measurable gains. In some cases, the required policy and legal reforms were not completed due to lack of time. Further support to these innovative and important initiatives is required.

Building effective institutions and linkages

The most common form of co-management builds on grass root structures including socio-professional organisations at the micro level, made up mainly of the different components of the community (fishermen, women fish processors, village heads, fish traders, etc.) and multi-sector organisations at the meso level (local government, district, division) which include representatives from fishing communities, local administration, NGOs and socio-economic institutions (micro-finance and others). Advisory services may also be provided by central government institutions, or even by international organisations – e.g. inputs into research. The inclusion of the poor and other marginalised groups (women, migrants) into the co-management institutions is a key issue for poverty reduction.

Two examples, one in Burkina Faso (inland) and one in Guinea (marine) illustrate the co-management institutions created and their linkages with wider development activities. The local fisheries institutions built up at the local level in the two countries represent the majority of resource users in their communities, have legal status and through their collaboration with NGOs, micro-finance institutions (MFIs) and institutions in charge of local development are establishing links between co-management and the development process. They are a vital channel for representing their members, and have the opportunity of influencing policies and decision-making.

In Burkina Faso, two management committees were set up, one on Lake Bagré, and the other on Lake Kompienga, comprising the territorial administration, the decentralised technical administrations, consular chambers, NGOs, MFIs, representatives of traditional rulers, and representatives of socio-professional associations. The committee has a legal and legitimate status. It has helped increase awareness among national authorities of the interests of fishing communities. The committee approves the co-management plans, and creates specialized commissions to address specific management issues such as surveillance, local fisheries management fund, training, protection of fish habitats and of the water banks. The fact that all co-management structures have legal status and legitimacy helped to restore confidence between the administration and the fishing communities, and to ensure the effective participation in the co-management process.

In Guinea, the formalisation of the fishing communities' participation in fishery resource management led to the establishment of legally-recognised community based institutions. These bodies carry out duties such as participatory surveillance, monitoring and evaluation through ad hoc bodies recognised by the Guinean authorities. These small-scale fisheries consultative councils give advice on matters related to fishery resource management and local development activities. The fishers are now no longer passive onlookers, but players in a participatory process: Their representative bodies participate with regional and national bodies in formulating fishery management measures for coastal areas, as well as in monitoring the implementation and in participatory surveillance. The communities are now fully involved in decision-making in fishery management and other matters of interest to them. The legal recognition of fishers' right irrespective of nationality has resulted in migrant fishers becoming involved in fisheries management.

Enabling effective and equitable participation

Since the co-management experience is still in its early stage in most of West and Central Africa countries, it became necessary for the SFLP to initiate an institutional capacity building strategy, so that the different partners involved – fishing communities in particular – can participate effectively in decision-making and protect their interests. Participatory appraisals gave a better understanding of the causes of poverty in fishing communities (poverty profile) and helped ensure that marginalised groups (women, migrants) are included in the institutional process, and have equity in their access to the resources and profit sharing. Three factors – illiteracy, difficult access to credit and weak organisational capacities of fishing communities – were found as the major reasons behind the low participation level of rural communities in decision-making, and especially in fisheries resource management.

Therefore, SFLP addressed community development issues, concerning human capacity development, such as numeracy and literacy training (especially but not only of women), improving access to health information and services, and the development of technical skills (such as improvement in fish processing techniques, particularly fish smoking as a means of reducing post-harvest losses, and of support for alternative income generating activities). They also emphasised building social capital, for example through development of professional organisations, and modest investment in physical capital, such as development of community infrastructure. For coastal fisheries, migration of fisheries communities makes building capacity initiatives more complex. In the countries involved, the majority of fishers are migrants.

The improvement of the educational level and organisational skills of the beneficiaries had a positive impact on various aspects of their livelihood assets:

- **Improvement of the organisational capacities of fishing communities –** Adult literacy programs helped to create new socio-professional organisations and improve the capacities of existing ones. Today, more than half of the managers of fishermen's and women fish processors' groups and associations in the pilot project sites are educated. An understanding that the informal nature of the associations is a handicap has led to their being legalised. With official status, the associations were able to apply for microfinance, which enabled training and loans. Moreover, capacity-building helped the stakeholders share the same vision of co-management and understand the link with decentralisation and local development policies.
- **Improved information flow –** Capacity-building has given more reliable reports from meetings with delegates of fishing and other stakeholders (projects, administrations, etc.). Information sharing has improved, as have the discussions ensuing from them. All these promote a better understanding of the issues at stake, as well as the involvement of one and all.
- **Emergence of a democratic spirit –** Community-based organisations are beginning to assign representatives of the fishing communities on the basis of their skills and ability to defend their interests. Birthright (traditional rights to deference/reference) is gradually being replaced by the promotion of competence and efficiency.

Incentives to participate in co-management, in the context of poverty

There is a need to ensure that users groups will continue to collaborate and contribute their time and effort to the co-management process. These efforts depend not only on government support, but also on the incentives that cooperation and participation offer. Returns to co-management may not appear in the short term. The costs may be the only visible outcome, such as reduced access to resources, more rules regulating access, the need to invest in monitoring and enforcement, and for time in decision-making and consensus-building. To overcome these, and sustain people's participation, either expected future benefits must be very great, or some short-term incentives – positive changes that are associated with a transition to co-management – must be visible too. This requires careful attention to how collective action can address some of the capability and assets deficits that people experience, at the same time as resource management institutions are developed. The kinds of activities that can be associated with a co-management programme include:

• **Enhancement of financial capital –** Access to microfinance institutions in the context of co-management is a good incentive. Fishing communities that have undergone the adult literacy programmes, and in particular the women, have had new livelihood opportunities available to them. Thanks to capacity building in the pilot project, they have become better organised and hence eligible to loan schemes offered by microfinance institutions. Also, negotiation skills gained from training activities made them able to convince their partners easier than before and to advocate their cases.

• **Alternative income generating activities –** Fishing communities, like all rural communities, tend to diversify their activities to deal with the risks of uncertain returns – if opportunities are economically viable and conditions enable access to them. The imperative to diversify is greatest when fisheries resources are overexploited and incomes from them decline, or become more variable. Enabling diversification can be seen as a fisheries management measure, and a key part of any co-management process. Promoting new income generating activities helps to improve the overall income of households, but, in the context of fishery management, their most notable effect lies in the fact that they create alternatives to fishing, thereby raising the opportunity costs of entering the fishing and opportunity income of leaving it.

Income generating activities help to improve the productivity of women fish traders and women who process fish products for a living. They also help to reduce the exclusion of women in the production systems. Fishermen, on their part, acquire equipment, a fact that may lead one to think that fishing effort will increase as a result. However, what has often been observed is that the loans are actually used to purchase fishing materials that comply better with the regulations. In these cases, fishermen are investing in both their own livelihoods and in the responsible governance of the resources that sustain them. This is an indication that incentives for fisheries management can be fostered through the reduction of uncertainty and vulnerability.

• **Vulnerability reduction –** Vulnerable people with uncertain futures are likely to have less incentive to participate in fisheries co-management that requires short-term restraint for long term gain. This is particularly the case in communities experiencing high levels of morbidity and mortality as a result of accidents at sea, and AIDS-related illness. In such cases, raising the community's awareness of HIV/AIDS and other sexually-transmitted diseases, and addressing safety at sea become a key part of an investment in co-management.

• **Incentives linked to policies –** Where the SFLP conducted co-management pilot projects, more attention was paid to fishing community concerns by policy makers, than elsewhere. Training in participatory approaches, such as the sustainable livelihoods approach (SLA), were provided for civil society technical partners (NGOs) and the public sector officers. The development of multiform strategic partnerships has also resulted in the fishing communities' concerns being reflected in local development. Multifunctional institutions (IMF, health, decentralisation, food security, PRSP, education, etc.) addressed both poverty reduction and resource management, and joined their assets. The synergy boosted constitutes an incentive for policy markers to support co-management. Working with multifunctional institutions provides resource users with partners whose complementary actions can help to improve different dimensions of their livelihood.

The challenge of migration to devolved fisheries management

Acknowledging that migration is one of the strategies that fishing communities often use in order to secure their livelihoods, the SFLP pilot project carried out a migration evaluation study. It was based on case studies in the four participating countries (Congo, Gabon, Guinea and Mauritania) and in other countries in the subregion, two considered to be countries of emigration (Benin and Senegal) and one country of immigration (Cameroon).

Who migrates and why

In the West and Central Africa region, coastal countries allow entry to migrant fishing communities from neighbouring countries without any restrictions and it would appear that this relatively open access to resources favours increased migration for fishing. However, as it is generally recognised, migrant communities are not homogenous and also within a single community a variety of fishing migration patterns may be found.

Internal migration takes place between fishing settlements within the same country in order to follow fish stocks or to take advantage of certain facilities or fish prices for during particular periods of the year. It can be short-term, long-term or permanent; the duration varies according to country and the dynamic fluctuations characterising fisheries sector.

International migration is usually a long-term phenomenon. Fishers from Benin, Ghana and Nigeria moved to the countries in the south of Gulf of Guinea (Cameroon, Congo and Gabon) many years ago and some are there since several generations (Atti-Mama 2006). Migrating fishers with employment contracts do not necessarily always work for the same employer but can change fishing boat and type of fishing that they engage in from one season to another. In spite of long periods abroad, these migrants tend to keep in contact with their home countries by visiting

DEFINITIONS

Short-term migration: Lasts for at least a few weeks but less than a fishing season.
Seasonal migration: Fishing people, sometimes including family members, stay in foreign fishing settlements for one or two seasons and then return home for a certain amount of time.
Long-term migration: Fishing people settle abroad for several years (20–40 years or sometimes more), but eventually return to their home country.
Permanent migration: Second or third generation fishing people that end up being assimilated into the local population and in most cases also take the host country's nationality.
Contractual migration: Migration that is motivated by an employment contract that has been formally established in the country of origin. The duration of the contract may be for one or several years and the fisher makes visits to his home country during this period (circular migration).

from time to time, participating in religious or cultural ceremonies. Not all international migration is permanent or long-term, however. Once settled in their country of destination, migrants may combine several different migration strategies and make shorter or longer trips away from their home base.

Women have a special status in the migration process. During short-term migrations, wives do not usually go with their fishers husbands. For long-term migration, many women follow their husbands on their travels. In the country of destination, the majority of women works in fish processing and marketing and hence support their husbands' work. Women may also contribute to the financing of fishing activities by lending their savings to fishers. Some women become boat owners which facilitate their access to fish for processing and marketing. For those who do not migrate but stay in the home country, some of the money sent back by their husbands will typically be invested in small businesses allowing them to gain a certain independence during the absence of their husbands.

Children also take part in migration and those who travel, both boys and girls, are of all ages and could be fishers or fish workers (processors, canoe builders), training to become fishers or fish workers, of school age or younger (Sall 2006). There tends to be a lack of appropriate schools and education facilities in the often remote areas where migrants settle (Ngo Likeng 2006, Sall 2006). Even in urban areas and when parents manage to enrol their children in public or private schools, there is often a lack of monitoring and support that makes successful education difficult. Frequent travelling, the inauspicious fisheries environment and requirements for extra labour or help disrupt children's schooling. Children who stay behind in their home countries tend to attend school but are deprived of the presence and support of their parents.

In spite of the importance of fisheries migration at the level of national economies (employment, food security, etc), there are only limited statistical data available on the phenomenon, both in host countries and in the countries of origin. Barely a handful of countries have figures that allow for an assessment of the magnitude of migration (see Table 1). From these data, it can be noted that in most of the countries, migrants represent the majority of the fishers.

Table 1. Percentage of fishers who are migrants.

Country	Percentage
Benin	55
Cameroon	81
Congo	42
Gabon	80

The reasons why fishers and fish workers decide to migrate are various and relate to environmental, social or economic factors. Fish workers that decide to emigrate do so for a number of reasons; either their difficult current situation pushes them to leave, hoping for a better life elsewhere, or there are factors attracting them to a new place, e.g. the possibility to increase their income or the access to new resources. These two sets of dual factors – "push" and "pull" – are summarized in Table 2.

Table 2. Reasons for migration.

"Push" factors	"Pull" factors
Avoid social obligations	Cheaper inputs, e.g. gear, nets, fuel
Conflicts	Instrumental reasons, e.g. earn enough money to get married, retire, allow for investments (fishing equipment, housing), etc.
Social pressure: remittances	Better fisheries and fish stock abundance
Reduce consumption at place of origin	Better livelihoods: safety net (internal migrations)
Reduction in fish stock abundance	Better socio-economic facilities/infrastructure
Poverty	Easy social integration (social and cultural networks)
Political instability in countries of origin	
Lack of socio-economic infrastructures	
Lack of alternatives activities to fisheries	
Environmental degradation (draught, salification of agricultural areas, etc.)	

Integration of migrants

For settling in with the host community, unattached or free migrants count on being able to use existing social network of compatriots who have already established themselves in the new country. Contractual migrants are usually isolated from the communities in the host country, often living in camps, and generally returning home at the end of their contract.

In some cases the newly arrived migrant is introduced to the traditional chief or village head against the payment of a symbolic tithe (Ngo Likeng 2006, Ovono Edzang 2006, Atti-Mama 2006). This system of payment would indicate that the open and free access to resources is a relative concept. If the migrant failed to respect the procedure, a conflict could ensue. In one case, it turned out that the tithe was not paid to the traditional chief but collected by a group of more or less permanent foreign migrants. By doing so, they did in fact strip the locals of their traditional authority over the resource and the act not only jeopardised the relation between migrants and locals but also severely threatened the sustainability of the resource.

Integration of migrants into recipient communities is not always easy. Several authors explain that most native and foreign communities live next to each other but do not work together or collaborate. They do not belong to the same society and hence do not share the same concerns. As a consequence, there are misunderstandings that often lead to conflicts, and marginalisation and exclusion of immigrants. The overt or latent conflicts involving migrants are often associated with shared exploitation strategies. Conflicts do generally not occur when immigrants and natives use different gear (Atti-Mama 2006). On the other hand, conflicts can be aggravated if there is competition for access to the same resources. Generally, native fishers tend to claim that foreigners use destructive fishing practices and they also blame them for depriving local fish processors of their production by giving priority to their foreign wives (Solie 2006).

A lack of confidence in the local government on behalf of immigrants is reported in all the countries studied (Benin, Cameroon, Congo, Gabon, Guinea, Mauritania and Senegal). Migrants often feel that they are – rightly or wrongly – harassed by the immigration authorities, the police and the fisheries surveillance administration. Moreover, they feel threatened by initiatives in many countries to develop the coastal area.

Migrant fishers and fish workers contribute to the economic development of their host countries, by creating additional employment within the sector, by transferring technologies to local fishers and by supplying local markets with fishery products and generating export earnings. While being conscious of their status, suffering from marginalisation and exclusion, they expect recognition on behalf of their host community and the authorities of their new country as well as a certain level of social equity. It is the responsibility of the host government to take the initiative to legitimise the status of immigrants. Other actions that would also be needed in order to achieve cohesion include the improvement of migrants' access to basic social services and their inclusion in decision-making processes. It is thus a question of finding mechanisms for improving the involvement of migrant fishers in the formulation and implementation of fisheries management policies, and in local development and poverty reduction strategies. This can be achieved through the creation of policies that are inclusive and promote participatory resource management.

The SFLP experience

In the countries that participated in SFLP's PP2 on coastal co-management (Congo, Gabon, Guinea and Mauritania), socio-professional associations and consultative groups consisting of both local and foreign migrants were established. Some migrants held posts in the new organisational structures that were put in place. However, continued support from the fisheries administration and those involved in local development would be necessary in order to sustain these initiatives.

Most countries participating in the SFLP exercise have recognised the necessity to legally allow for the participation of small-scale fishers and fish workers in resource management and the need to adapt their national fisheries legislation accordingly. Such revisions of the legal provisions were seen as opportunities to address the integration of migrants and, for example, in Guinea the approach was followed successfully leading to a formal recognition of fishing communities and also implicitly to the involvement of migrants in resource management and local development. To varying degrees, similar developments have been noted in other countries.

Migrant fishing people also benefited from a number of activities initiated by the SFLP, including the strengthening of their capacities and knowledge in areas such as literacy, hygiene and health, environmental management, organisational development, lobbying and negotiation skills. These activities constituted important incentives in the empowerment process.

Lessons learned

Co-management can be sustainable if the political and legal environment is supportive and provides rights for the communities to participle to decision making. Setting up co-management is a long process that requires support from all stakeholders and incentives to sustain the process.

Functional and effective co-management institutions give the framework and the tools for dialogue with authorities and organisations. They can help ensure that fishing communities get access to basic social services, and other development action. In this way, the communities' negative perception of management committees that discourage irresponsible fishing practices will be counterbalanced by providing services that will help to improve livelihoods.

All components of the rural communities must have equitable representation in co-management institutions, to take all interests into consideration, and ensure that the measures put in place have a sustainable effect on the lives of the most underprivileged social groupings. However, the most vulnerable people must be given very special attention through a gender and class-sensitive approach.

Appropriate systems for communication between stakeholders must be built to encourage community participation in policy discussions. This builds the confidence of partners, gives transparency, and legitimacy to the decisions taken. A common approach can be reached, as well as acceptance of development measures, social dialogue and the mobilization of resources for the benefit of the communities. Providing information to and raising the awareness of the decision-makers helps ensure that national policies and programmes, such as the prevention of serious diseases (e.g. malaria and HIV/AIDS), poverty reduction policies (PRSP), and decentralisation, take the fishing communities' concerns into account.

Poor fishing communities draw most of their livelihoods from fisheries resources, a fact that may end up compromising the co-management actions. Capacity building (adult literacy, access to micro-finance, income generating activities) help detach fishing communities from the resource to some extent. The promotion of new sources of income also reduces fishery-dependence, and new opportunities are often enhanced by increasing the capabilities of the poor. Even investments in production equipment are not always detrimental to resource management; it has been observed that when fishing communities are supported by management committees, new fishing gear complies better with the regulations.

Capacity building lays the foundation for poverty and vulnerability reduction in fishing communities. A higher educational level (adult literacy) helps to improve awareness and social engagement. It also builds self-confidence in and involvement in projects of common interest like the management of fisheries resources. The capacities of government officers and local community groups should also be strengthened, as they too, are learning new ways of working in a multi-stakeholder context.

Migration constitutes an opportunity both for the host country (contribution to local and national economies, and to food security) and for the country of origin (fund transfers from abroad). The establishment of measures for the protection of the specific rights of migrant fishing people can constitute an opportunity for introducing local co-management mechanisms.

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Photo: Dan Tilander, Swedish Board of Fisheries.

AQUACULTURE DEVELOPMENT – THE BLUE REVOLUTION[1]

Rohana Subasinghe

Abstract

Aquaculture, the farming of aquatic organisms, is the fastest growing food producing sector in the world, since the 1990s. Aquaculture now accounts for nearly half of the world's food fish production and is expected to overtake the contribution by fisheries in the coming years. The sector is expected to bridge the demand and supply gap for global aquatic animal food in the coming decades, created by the increasing population and stagnant production from fisheries, to meet the growing global demand for nutritious food fish, and to contribute to the growth of national economies, while supporting the sustainable livelihoods of many communities. Aquaculture plays an important role for efforts to eliminate hunger and malnutrition and for global development by improving incomes, providing employment opportunities and increasing the returns on resource use. The sector is expanding in a sustainable manner. The continuity of this trend will only be possible if the sector's socio-economic benefits accrue to a large social spectrum. This is a major challenge for politicians and policy makers. Creating an "enabling environment" for the aquaculture sector to maintain its growth whilst meeting societal needs and preserving the natural resource base it needs, is the paramount requirement, which requires significant political will, sustained policy, public sector support, and investment.

Introduction

Global aquaculture production has grown rapidly during the past four decades, contributing significant quantities of fish for human consumption. Aquaculture is still the fastest growing food producing sector in the world (Figure 1), and now accounts for nearly half (47 percent) of the world's food fish.[2] With its projected growth, aquaculture will in the near future produce more fish for direct human consumption than capture fisheries.

Although aquaculture originated as primarily an Asian freshwater food production system, fish farming has now spread to all continents, encompassing all aquatic environments and utilizing a wide range of aquatic species (Table 1). From an activity that was principally small-scale, non-commercial and family-based, aquaculture now

1. Data and information provided in this chapter have been derived either from FAO publications or reports from FAO reviews and analyses.
2. In this document "food fish" or simply "fish" refers to production of aquatic animals (fish, crustaceans, molluscs, echinoderms and amphibians). Aquatic plants are considered separately.

Table 1. Global aquaculture production by major species in 2006.

Environment	Species	Scientific name	Volume (tonnes) 2006
Freshwater	Silver carp	*Hypophthalmichthys molitrix*	4 358 686
Freshwater	Grass carp	*Ctenopharyngodon idellus*	4 010 281
Freshwater	Common carp	*Cyprinus carpio*	3 172 488
Freshwater	Bighead carp	*Hypophthalmichthys nobilis*	2 394 252
Freshwater	Crucian carp	*Carassius carassius*	2 097 188
Freshwater	Freshwater fishes nei	*Osteichthyes*	1 887 224
Freshwater	Nile tilapia	*Oreochromis niloticus*	1 770 913
Freshwater	Roho labeo	*Labeo rohita*	1 332 430
Freshwater	Catla	*Catla catla*	1 330 633
Freshwater	White amur bream	*Parabramis pekinensis*	594 287
Freshwater	Pangas catfishes nei	*Pangasius spp*	499 513
Freshwater	Chinese river crab	*Eriocheir sinensis*	474 959
Brackish water	Whiteleg shrimp	*Penaeus vannamei*	1 913 616
Brackish water	Giant tiger prawn	*Penaeus monodon*	496 476
Brackish water	Milkfish	*Chanos chanos*	462 870
Brackishwater	Nile tilapia	*Oreochromis niloticus*	217 793
Brackish water	Flathead grey mullet	*Mugil cephalus*	214 825
Brackish water	Freshwater fishes nei	*Osteichthyes*	187 388
Brackish water	Banana prawn	*Penaeus merguiensis*	96 833
Brackish water	Cyprinids nei	*Cyprinidae*	84 706
Brackish water	Penaeus shrimps nei	*Penaeus spp*	83 001
Brackish water	Fleshy prawn	*Penaeus chinensis*	51 135
Brackish water	Japanese hard clam	*Meretrix lusoria*	46 720
Brackish water	Red seaweeds	*Rhodophyceae*	44 253
Marine	Japanese kelp	*Laminaria japonica*	4 923 618
Marine	Pacific cupped oyster	*Crassostrea gigas*	4 592 239
Marine	Japanese carpet shell	*Ruditapes philippinarum*	3 074 059
Marine	Aquatic plants nei	*Plantae aquaticae*	2 405 677
Marine	Wakame	*Undaria pinnatifida*	2 364 263
Marine	Laver (Nori)	*Porphyra tenera*	1 506 102
Marine	Yesso scallop	*Patinopecten yessoensis*	1 361 629
Marine	Zanzibar weed	*Eucheuma cottonii*	1 299 642
Marine	Atlantic salmon	*Salmo salar*	1 285 634
Marine	Marine molluscs nei	*Mollusca*	1 255 388
Marine	Warty gracilaria	*Gracilaria verrucosa*	1 056 811
Marine	Sea mussels nei	*Mytilidae*	975 426

Source: Global Aquaculture Production 2006, FAO Fishstat Plus database.

includes the large-scale commercial production of high-value species that are traded at the national, regional and international levels. Although aquaculture production remains predominantly Asian and is still largely based on small-scale operations, there is a general consensus that aquaculture has the potential to meet the growing global demand for nutritious food fish and to contribute to the growth of national economies, while providing support to sustainable livelihoods of many communities.

Production trends[3]

Global aquaculture[4] production increased to 51.7 million tonnes in 2006, with a value of USD 78.8 billion, from a production of less than a million tonnes in the early 1950s. When aquatic plants are included, the world aquaculture production in 2006 was 66.7 million tonnes in weight and USD 85.9 billion in value (Figure 2).

The share of aquaculture in total global production of aquatic animals[5] continues to grow, from 3.9 percent by weight in 1970 to 36.0 percent in 2006 (Figure 3). During

3. This section is taken from the issue 40 of the FAO Aquaculture Newsletter (FAN), September 2008.
4. Unless otherwise stated, aquaculture production in this article refers to aquatic animals (excluding aquatic plants).
5. Aquatic animals in this article include fish, crustaceans, molluscs and amphibians.

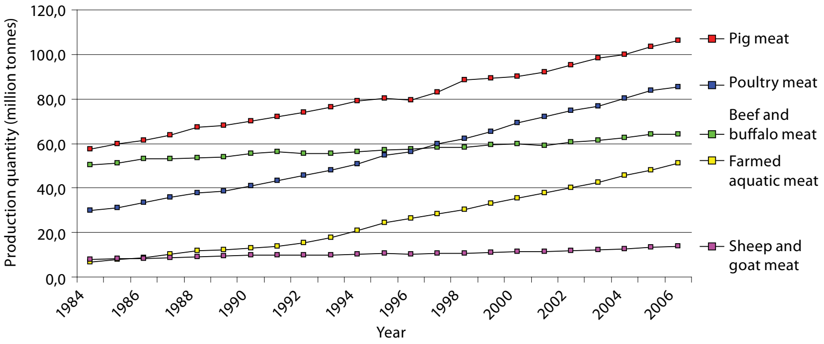

Figure 1. Terrestrial and aquatic meat production 1984–2007. The world production of meat in 2006 in million tonnes: Pig meat 106.4, Beef and Buffalo meat 64.2, Poultry meat 85.3, Farmed aquatic meat (aquaculture) 51.2 and Sheep and Goat meat 13.8 million tonnes.

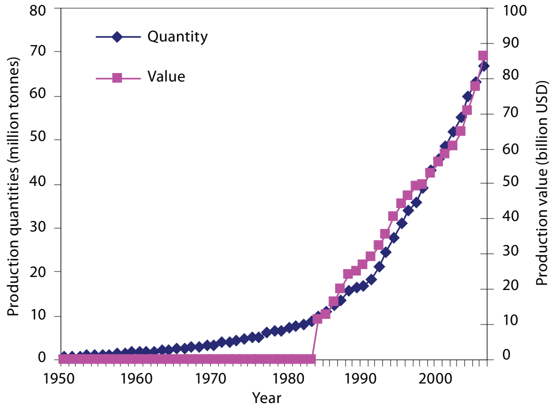

Figure 2. Global aquaculture production from 1950 to 2006 (including plants). The global aquaculture production including plants in 2006 was 66.7 million tonnes with a value of USD 85.9 billion.

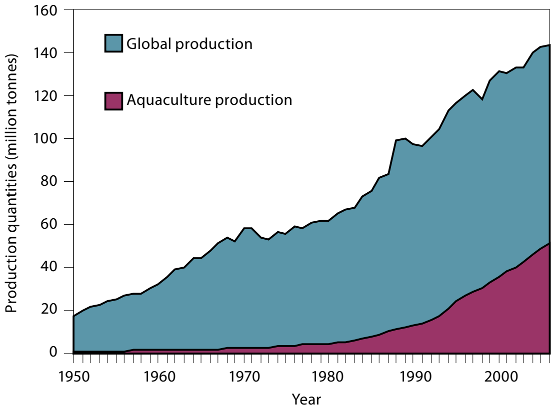

Figure 3. Production of aquatic animals from 1950 to 2006. In 2006 the fishery and aquaculture production together made 143.6 million tonnes. The aquaculture production alone made 51.7 million tonnes.

this period, per capita supply of aquatic animals from aquaculture increased from 0.7 kg to 7.8 kg, with an average annual growth rate of 6.9 percent. Aquaculture now accounted for nearly half (47 percent) of the world's aquatic food supply.

China[6] is still the dominating aquaculture producer. In 2006, the country accounted for 67 percent of the world's supply of cultured aquatic animals (Figure 4) and 72 percent of its supply of aquatic plants.

While the capture fishery production ceased to grow around the mid-1980s, the aquaculture

6. Unless otherwise stated, data for China do not include Taiwan Province of China, Hong Kong Special Administrative Region and Macao Special Administrative Region.

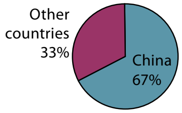

Figure 4. Aquaculture production in 2006, aquatic animals. The global aquaculture production in 2006 was 51.7 million tonnes. Of this quantity 34.6 million tonnes (67 percent) was produced in China and in the rest of the world 17.1 million tonnes (33 percent).

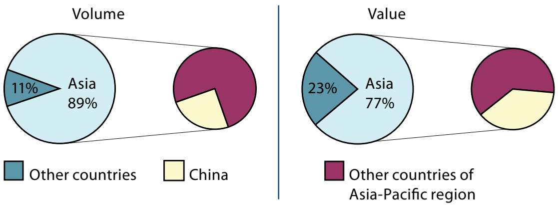

Figure 5. World aquaculture production. The global aquaculture production in 2006 was 51.7 million tonnes. The Asia-Pacific region alone produced 46 million tonnes (89 percent) and the rest of the world 5.7 million tonnes (11 percent). Of the 46 million tonnes China produced 34.6 million tonnes.

The value of Asian-Pacific countries production in 2006 including China was USD 56.3 billion (77 percent) with China alone USD 38.2 billion. The value of the other countries production was USD 22.5 billion (23 percent).

sector, since 1970, has maintained an average annual rate of growth of 8.7 percent worldwide, and 6.5 percent per year when excluding China. Annual growth rates of world aquaculture production between 2004 and 2006 were 6.1 percent in volume and 11.0 percent in value, respectively.

Asia continues to dominate aquaculture production. In 2006, the Asia-Pacific region accounted for 89 percent of the production volume and 77 percent of the value, of which China produced 75 percent by volume and 63 percent by value (Figure 5).

Aquaculture did not grow evenly around the world. Latin America and the Caribbean showed the highest average annual growth of 22.0 percent during the last three decades. Although the volume of production is small, Africa also registered a 12.7 percent growth rate during the same period. China's aquaculture grew at an average annual rate of 11.2 percent over the same period. However, China's growth rate after 2000 declined to 5.8 percent from 17.3 percent in the 1980s and 14.3 percent during the 1990s. The aquaculture growth in Europe and North America has also slowed down substantially and since 2000; the rate is around one percent per year by volume.

The top ten aquaculture producing countries for cultured aquatic animals in 2006 are listed in Table 2. Whilst the first five countries in the list remained the same as in 2004, the Philippines entered the word's top ten aquaculture producers list in 2006.

Table 2. Top ten aquaculture producing countries in 2006.

Quantity		Value	
Country	Million tonnes	Country	USD million
China	34 429	China	38 422 710
India	3 123	Chile	4 428 298
Vietnam	1 657	India	3 431 010
Thailand	1 385	Vietnam	3 316 141
Indonesia	1 309	Japan	3 098 904
Bangladesh	892	Norway	2 715 593
Chile	802	Indonesia	2 457 152
Japan	733	Thailand	2 220 012
Norway	708	Myanmar	1 785 120
Philippines	623	Korea, Republic of Korea	1 418 592

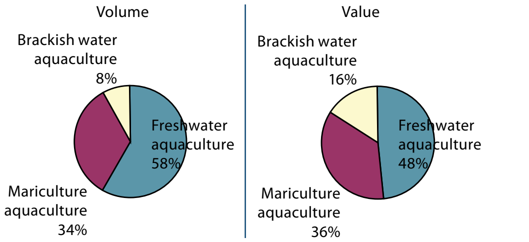

Figure 6. The global aquaculture production by environment in 2006: 30 million tonnes or 58 percent was produced in freshwater, 17.6 million tonnes or 34 percent in marine waters and 4.1 million tonnes or eight percent in brackish water environment.

The value of global aquaculture production in various environments in 2006 was USD 78.8 billion. In freshwater the value amounted to USD 37.8 billion (48 percent), in marine waters to USD 28.4 billion (36 percent) and in brackish water to USD 12.6 billion (6 %).

Freshwater aquaculture contributed 58 percent by volume and 48 percent by value in 2006, while mariculture contributed 34 percent by volume and 36 percent of the total value of production (Figure 6). Brackish water aquaculture, consisting of high value crustaceans and fish, contributed only eight percent by volume to global production but a value of 16 percent of the global total. As a result of ever-increasing production of white leg prawn, *Penaeus vannamei* in Asia, the production from brackish waters showed the highest annual growth rate of 11.6 percent by volume since 2000 (Figure 7). With the unit price of *P. vannamei* declining in the world market due to increased supply, the increase of value was 5.9 percent. Since 2000, the average annual increases in the production of aquatic products coming from freshwater and marine water environments were 6.5 percent and 5.4 percent in volume and 7.8 percent and 8.3 percent in value, respectively.

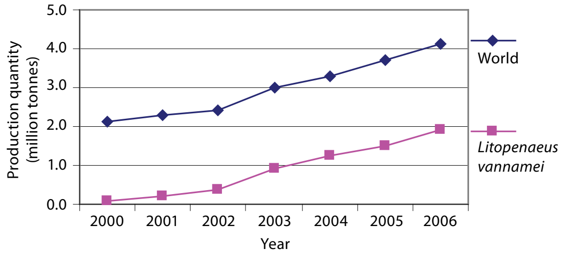

Figure 7. Global brackish aquaculture production of tropical shrimp species from 2000 to 2006. The global aquaculture production of tropical shrimp and prawn species (Penaeidae) was in 2006 4.1 million tonnes of which the white leg prawn (*Litopenaeus vannamei*) made two million tonnes.

In 2006, more than half of the aquaculture production was freshwater finfish (27.8 million tonnes worth USD 29.5 billion). Molluscs accounted for 14.1 million tonnes, or 27 percent of total production, with a value of USD 11.9 billion. Although much smaller volumes of crustaceans (4.5 million tonnes) were produced, the value was around USD 18.0 billion (Figure 8).

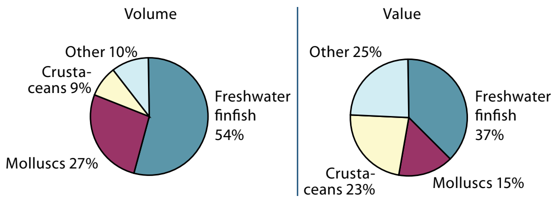

Figure 8. Global aquaculture production by environment in 2006. The total global finfish aquaculture production in freshwater was 27.8 million tonnes (54 percent) in 2006. The molluscs production was 14.1 million tonnes (27 percent), the crustacean production was 4.5 million tonnes (nine percent) and other species five million tonnes (ten percent).

The value of global production of finfish in freshwater was USD 29.5 billion (37 percent), of molluscs USD 11.9 billion (27 percent) and crustaceans USD 18.5 billion (23 percent).

Globally, a few countries still dominate production of major species groups. China produces 77 percent of all carps (cyprinids) and 82 percent of the global supply of oysters (ostreids). The top five producers of shrimps and prawns from the Asia-Pacific region, i.e. China, Thailand, Vietnam, Indonesia and India, account for 81 percent of the global production. On the other hand, Norway and Chile continues to be the world's largest producers of cultured salmon (salmonids) accounting for 33 and 31 percent, respectively (Figure 9).

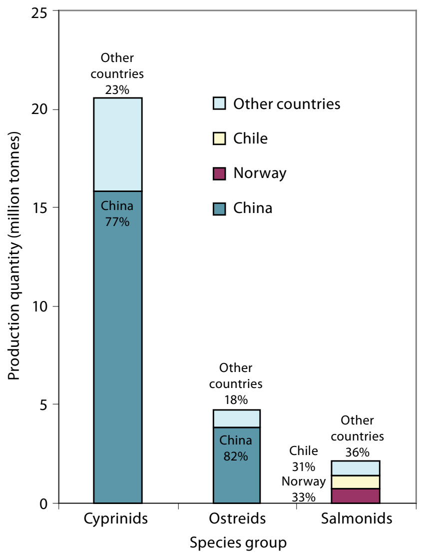

Figure 9. Aquaculture production of major species groups in 2006. In 2006 China produced 77 percent of all carps (Cyprinids), and 82 percent of all oysters (Ostreids). Most of the world production of salmonids was accounted for by Norway: 0.7 million tonnes (33 percent), and Chile: 0.7 million tonnes (31 percent). All other countries produced 0.8 million tonnes (36 percent).

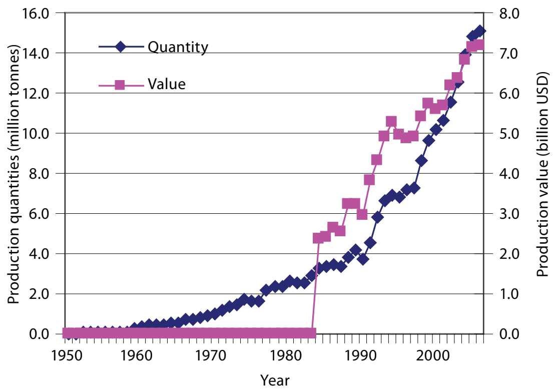

Figure 10. World aquatic plant production by aquaculture from 1950 to 2006. The world aquatic plant production in aquaculture made 15.1 million tonnes in 2006, which is 93 percent of the total production that year. The value was USD 7.2 billion.

World aquatic plant production by aquaculture in 2006 was 15.1 million tonnes valued at USD 7.2 billion. The culture of aquatic plants has increased steadily with an average annual growth rate of 8.0 percent since 1970 and in 2006, contributed 93 percent of the world's total supply of aquatic plants (Figure 10).

Food security and poverty reduction

Aquaculture plays an important role in global efforts to eliminate hunger and malnutrition and also makes significant contributions to development by improving incomes, providing employment opportunities and increasing the returns on resource use. According to FAO figures, aquaculture directly created 12 million full-time employments in Asia in 2004. The contribution to the national GDPs in many developing countries in Asia and Latin America is significant. With appropriate management, the sector appears ready to meet the expected shortfalls in fish supplies for the coming decades and to improve global food security.

The availability of sufficient and good quality food and access to this food by households and individuals and its utilization for nutritious diets and good health, are interdependent dimensions of food security. Aquaculture contributes to food availability through the supply of aquatic products from domestic farming and supply of food purchased using foreign exchange. It contributes to food quality by providing nutritious aquatic food products that are high in protein, essential fatty acids, vitamins and minerals.

Availability of food is a necessary but insufficient condition for food security. Affordability is a major aspect of food access. By providing farmers with revenues and by creating employment, aquaculture enhances households' disposable incomes. Increasing the availability of aquatic products to domestic markets can make them affordable and more accessible to local consumers. At a macro-economic level, aquaculture can also contribute to countries' economic performance and growth by generating profits and producing tax and export revenues. Good infrastructure and investments in human capital will improve the productivity of labour and increase access to capital, benefiting local businesses and enhancing the development of rural communities.

With existing resources and technological advances, food fish production from aquaculture can be further expanded in a more sustainable manner. However, this is only possible if the sector's socio-economic benefits accrue to a large social spectrum. The main challenge for policymakers and development agents is thus to create an "enabling environment" for the aquaculture sector to maintain its growth, while meeting societal needs and preserving the natural resource base. This enabling environment is multi-faceted and requires significant political will, sustained policy, public sector support and investment.

Environmental and social aspects

The environmental impact of aquaculture has received a high degree of attention in the past two decades, typically when societies were negatively affected by unregulated aquaculture development. This negative attention is likely to become more pronounced in the coming decades and will be constantly triggered by an increasing demand for products and services, in a situation of increasing competition with other sectors for land and water and the diminishing feed resources. In some regions, such a scenario could be also aggravated by climatic change.

The main concerns include: **a)** sustainability of resources used in aquaculture, **b)** impacts of aquaculture on aquatic biodiversity, **c)** sustainability of fish feed practices, **d)** use of alien species in aquaculture, **e)** escapees and their consequent effects on wild populations, **f)** release of organic matter into natural waters, **g)** discharge of antibacterial and chemical residues into the natural environment, **h)** over-fishing of wild species for aquaculture, and **i)** weakness in spatial planning and competition with other activities. The aquaculture sector has not been able to fully address these long-standing issues, which raises the question of whether the true environmental cost of certain aquaculture practices is adequately known.

Where weak or improper regulations for allocation and use of natural resources exist, there is always a tendency for conflicts to emerge between resource users. Invariably, less influential and disadvantaged stakeholders are denied access. Unregulated or improperly regulated aquaculture development also results in a high discounting rate on the use of natural resources and therefore encourages practices that exploit them beyond carrying capacity.

As a result of strong public scrutiny, significant progress has recently been achieved in addressing many of the key concerns in the environmental management of aquaculture. Public pressure and continued commercial necessity have led the aquaculture sector to make great efforts to reduce and mitigate its environmental impact, and governments increasingly recognize that aquaculture, when well planned and well managed, can yield broad societal benefits without concomitant environmental degradation.

Indeed, it is now increasingly recognized that aquaculture can make a positive contribution (e.g. mitigation) to the environment by helping reduce the negative impacts of other industries and activities. There are aquaculture systems that contribute to environmental rehabilitation or which mitigate the impacts of effluents from agricultural and even industrial operations. Integrated farming systems, such as rice-fish farming and fish farming in irrigated systems, and the rehabilitation of endangered populations through stocking, are well known examples of the benefits of aquaculture to the environment. The use of mollusc culture to improve carbon sequestering, and seaweed culture in coastal areas to reduce aquatic nutrients loading are also good examples of where aquaculture practices can serve as environmental sentinels and at the same time contributors to socio-economic development.

Despite recent progress, there is no room for complacency. Continuing improvements are required to ensure a higher degree of environmental sustainability and economic viability in the sector An ecosystem approach to aquaculture development can help reconcile the human and environmental objectives of sustainable development.

Although aquaculture does not take place in isolation and in most cases is not the only human activity in any given ecosystem, possibly this food production sector leads to a smaller impact on water bodies than other human activities (e.g. agriculture and industry). While aquaculture has been attracting much attention regarding its potential environmental impact, we often forget that most terrestrial food-producing systems have been achieved after drastically transforming landscapes. However, society grew used to these changes through a long history of agricultural development, while aquaculture is rather new.

Because producing food for human needs (especially intensive production) always has an environmental cost, this cost must be internalized in the accountings of the production process. It is also important to consider that fish derived from aquaculture could be less costly than other protein products. This is mainly due to the comparatively lower cost of energy in aquaculture production. Considering the increasing energy cost (increasing cost of fossil fuels), increasing use of grains for producing biofuel, and the possible overall increase in production costs in the coming years, a comparative evaluation of environmental costs could be useful to policy when making decisions on development options and improving management.

Aquaculture needs an enabling policy environment to grow in a sustainable manner and to be integrated into other agro-ecosystems (when appropriate) or with other coastal zone uses in order to minimize conflict occurrence. The interaction between aquaculture and the larger system – in particular, the influence of the surrounding natural and social environment on aquaculture practices and results – must also be taken into consideration. An ecosystem approach for aquaculture is a strategic approach to the development and management of the sector that aims toward its integration into the wider ecosystem, such that aquaculture development is equitable and promotes the sustainability of interlinked social-ecological systems. Therefore ecological, social and economic issues must be addressed at the various scales, i.e. the farm, the watershed (e.g. containing clusters of aquaculture farms in interaction with other sectors) and the global market. These last two often require policies and agreements beyond single political boundaries (countries, regions etc.).

Globalization and markets

As high-value species are increasingly exported (intra- or inter-regionally) and low-value products are often imported (a particular trend in Asia, where, for example, shrimp are exported and canned pilchards imported), there is a clear need to improve the quality and safety of aquaculture products in order to gain wider access to regional and international markets. However, with the more stringent requirements of export markets, small-scale farmers are facing difficulties in producing for export. As they strive to meet export requirements, they may become uncompetitive, which could drive them out of the sector. Empowering small farmers to become competitive in global trade is becoming urgent, and is, perhaps, a significant corporate social responsibility.

Through trade and market access, globalization is increasingly playing an important role in aquaculture development. Its requirements are two-fold: **a)** strengthening of national (including domestic), regional and international biosecurity and food safety measures; and **b)** enhancing the ability, through training, legislation, codes of practice, certification and traceability schemes, of governments and producers to comply with trade and market access requirements for safe and quality products. Emerging market-driven requirements (i.e. the requirements of consumers and retailers) are creating a considerable incentive for importing and exporting countries to collectively harmonize standards and protocols, as well as to address the issue of certification of products and processors.

Certification in aquaculture can have positive effects by spurring new competitive advantages and investments, but it can also disguise underlying intentions to protect domestic industries and restrict market access. Compliance with certification requirements may be costly and difficult for small farmers. As certification programmes proliferate, questions will be raised about which programmes best serve consumer protection, the environment, the public and the producers. This requires harmonization and equivalence in certification schemes and simplified compliance procedures.

As a consequence, there is a need for policy-makers to emphasize these aspects when improving governance of the sector. Policies can be much more effective if producers participate in the decision-making and regulation processes. Such recognition has already led many governments to build national capacities to assist producers and processors in complying with mandatory food safety regulations, while empowering farmers and their associations for greater self-regulation. This move is contributing to improved management of the sector at the farm level, typically through the promotion of "better management practices" (BMPs) and "codes of practice" by well-organized associated producers.

Major challenges ahead

The main challenges are for policy-makers and development agents to create an enabling environment to meet the demand for increased production and trade in aquaculture products. The major enabling factors that have been identified include:

- National and international market development and access to markets;
- Changes in population and demography, seafood consumption habits and patterns, and consumer preferences and purchasing power;
- Technology development and improvement in management systems;
- Public sector enabling environment for farmers and investors and improvement in governance of the sector;
- Access to services, finance and capital investment;
- Adoption of environmental management practices for the protection and sustainable use of aquatic resources;
- Access to quality input in sufficient quantity;
- Adequate physical infrastructure;
- Secure access to land and water resources;
- Maintaining food safety;
- Skills development and capacity enhancement; and
- Efficient communication and knowledge transfer.

National and international market development and access

Responding to market demand and gaining access to international markets are essential for increased aquaculture production and sectoral development. Market development is essential to expand markets for aquaculture products. Market demand, development and access are thus critical enabling factors for industrial scale, small and medium producers in all regions. However, there are significant regional differences.

Strategies for aquaculture development must be based on an understanding of market demand and access. Over the last decades, international fishtrade has been progressively liberalized, and current import duties for exports to developed countries are very low for most species, although for some species such as shrimp they may still be considerable. Further liberalization of fish trade through new multilateral and bilateral agreements, and continued import tariff reduction will provide new opportunities for expansion of the aquaculture sector. Developing countries frequently maintain high import tariffs on fish and fishery products, thereby impeding increased regional south-south trade in aquaculture products.

With the lowering of tariffs, non-tariff barriers have emerged as the main obstacle to increased trade and to market access. Technical and non-technical barriers to trade have the potential to dramatically impact trade in aquatic products, especially as they relate to import requirements for quality and safety. Increased trade will also influence the structure of the aquaculture industry. There is now real concern that many small-scale producers may find it increasingly difficult to compete in the future. Enabling small-scale producers to achieve market access should be a priority for policy-makers.

Aquaculture of established commodities, such as shrimp, salmon, tilapia and catfish, will be enabled through further market development, value addition, niche markets and promotion (including via domestic markets). Molluscs will also contribute significantly to local and regional market development. Market access will be enabled through certification systems for food safety and quality. Development of niche markets will also enable aquaculture for both established and novel commodities. Production and marketing based on environmental criteria with relevant certification schemes and labels will play a larger part in the future (e.g. organic production, aquaculture eco-labels). Due to the importance of the small-scale sector in Asian aquaculture, it is critically important to develop market access arrangements for small-scale producers.

Changing demography and consumption patterns; increasing purchasing power

Changing populations and demographic effects have the potential to create substantial new markets. Shifting cultural attitudes, as experienced over the past decade, are expected to have a significant influence on consumption of aquatic products. Large young populations in some countries in Asia (particularly in India) with improved living standards, rising purchasing power and disposable income have the potential to influence eating and purchasing habits.

In the short term, this will benefit the aquaculture sector, especially for internationally traded commodities such as shrimp, salmon, catfish, tilapia and marine finfish. In the long term, these population and demographic changes will have an influence on the marketing of a wide range of aquaculture commodities. Marketing and awareness campaigns, as well as development of specialized products, will be required to access these new and emerging market segments.

Increasingly, consumers are demanding fish that provides higher nutritional benefits. Omega-3 fatty acids have many health benefits. Recent research indicates that when carnivorous fish are fed with feeds containing lowered amounts of fish oil and fishmeal, the total omega-3 fatty acid content in their flesh is reduced. This raises an important question – how far can we reduce reliance on fishmeal and fish oil in compound feeds for carnivorous fish without impairing the exceptional nutritional value of these fish?

Technology development and improvement in management systems

Further improvements in technology and management systems will be essential to enable the future development of aquaculture. New technologies will be required to make more efficient use of natural resources (e.g. water, land, energy, feed ingredients) and improve the overall economic efficiency of aquaculture farms.

Improvements in aquatic animal health management and disease control will enable aquaculture development in all regions and across all scales of enterprise from small to industrial scale. Development of vaccines for the industrial-scale salmon industry in Europe and Latin America and more generally, for freshwater and marine fish culture, is also needed.

Technology development will also give improvements in the environmental performance of aquaculture systems, improve the safety and quality of aquaculture products and combined with effective education and information, lead to a more positive public perception of the sector. Nutritional research will lead to improved quality and cost-effectiveness of aquaculture feeds that will utilize new protein and fat sources as feed ingredients, eventually reducing reliance on marine protein sources. Significant improvements in weight gains in salmonids have been achieved through genetic research. Further genetic improvement, by selection against disease and for improved growth and other desirable traits, will further aquaculture development from industrial to small-scale level. Seed production for new marine species will also become a critical factor enabling aquaculture over the next decade.

Development of new and improved farming systems, particularly cages and innovative enclosure systems for fish culture in offshore and high energy coastal and ocean environments will be paramount. For an example, the Norwegian salmon industry now produce over 1,100 tonnes of salmon in 60,000 m^3 cages, a biomass corresponding to 2,200 cattle. The environmental impact of such systems will have to be estimated, minimized or even eliminated, to receive broad public acceptance. Involvement of the public and private sectors will be essential in technology development. Public-private partnership in planning, funding and implementing research will facilitate efficient R&D efforts. R&D in the private sector should be enabled through appropriate incentives.

Globalization and the increased flow of new technologies between countries will minimize differences between established and newly emerging industries. Investment by the private sector will most likely be oriented towards larger scale industrial aquaculture or towards aquaculture commodities with significant value. The R&D basis for the small-scale sector may need more targeted government interventions to ensure a balance with industrial-scale development. However, this R&D effort will only provide sustainable solutions to poverty and livelihood improvement if it leads to competitive small-scale aquaculture.

Public sector enabling environment and improvement in governance

Creating an enabling public sector environment is essential for better governance at all levels of aquaculture development. There have been many problems in the aquaculture sector, in particular in shrimp farming in some countries. Poorly regulated development of the sector has outstripped the carrying capacity of the environment in some locations, causing significant production losses mainly due to disease and sometimes resulting in abandonment of farms. Significant improvements have been made in mitigating such catastrophic problems, and the negative environmental and social impacts of shrimp farming throughout the world have been significantly reduced. The use of wild-caught postlarvae in shrimp culture, which has a significant effect on aquatic biodiversity, has almost disappeared.

Political stability has a major influence on aquaculture development at all levels. The costs of doing business influence the ability to attract investment to the sector and competitiveness. Macro-economic policies such as fiscal policy, access to manpower and skills, and technology are all important for future development of aquaculture.

Developing a legal framework is necessary, but effective enforcement is also essential. The credibility of governance arrangements will become increasingly important. Newly emerging aquaculture countries will require substantial investment in building institutions and governance arrangements for aquaculture, particularly when seeking to promote industrial, export-oriented aquaculture products. Participation of stakeholders is important; more emphasis on strengthening farmers' associations and self-regulation by industry will ensure greater sustainability. Intersectoral (i.e. between different food-producing sectors) communication is vital for better planning and for efficient production.

Ensuring access to services

Aquaculture enterprises of all scales require access to specialized services such as analytical services, disease testing, residue testing, technical information, extension services, financial services, etc. Governments will need to pay special attention to ensure the ready access of small and medium-scale aquaculture enterprises to these services, especially in newly emerging industries or aquaculture countries. Without this framework, aquaculture development cannot be sustained and farmers will be subject to unacceptable risk.

There are opportunities for industrial-scale aquaculture and large servicing industries and producer groups to provide services for small and medium-scale enterprises. Examples from India and Thailand (e.g. for shrimp) and the Philippines (for milkfish) show promise for further development. Food safety and certification assurance systems need substantial investment and may prove a barrier to newly emerging aquaculture industries/states. Operational expenses also require ongoing investment and skilled people for their effective use and sustainability. Creating a sound environment that will attract investment and assistance from financial services is critical for long-term viability of commercial aquaculture.

Environmental protection and sustainable use of aquatic resources

Protection of the environment is a cross-cutting issue and a matter of increasing public concern. The public image of aquaculture will be improved if the industry addresses and is very clearly seen to improve environmental performance. Risks to aquaculture from other sectors must be considered. Improving environmental management of aquaculture at industry and government levels will be essential.

International standards for environmental management of aquaculture can also assist effective management of the sector and provide some harmonization among the increasing number and diversity of aquaculture standards. Improved communication on the relationship between aquaculture and the environment will be essential to convey to the public the environmental benefits of aquaculture. The sector should become more pro-active with respect to conservation of biodiversity and assume greater responsibility for the negative impacts of translocation of species.

Valuation of aquatic resources and industry payments for use of resources will drive more efficient use of resources. Resource values and environmental costs may become a more significant factor when considering competitive advantage.

Access to quality inputs

Access to a sufficient quantity of quality inputs, including seed, feed, water, land and other inputs is essential for newly emerging industries, regardless of scale. International movements of aquatic animals may become more significant, but need to be backed by increased awareness and international agreements on risk analysis to minimize the spread of disease and genetic/ecological impact. Ornamental fish movements need more attention to minimize disease risks.

Newly emerging industries/states lacking critical inputs need to give careful consideration of importing inputs, particularly with respect to disease and genetic issues. Certification systems and standards for feed quality and other major inputs need to be further developed.

Marine resources and aquafeed

Some types of aquaculture rely on wild-caught seed and/or broodstock. Although the use of wild-caught shrimp seed is phasing out, there is still a heavy reliance on wild-caught seed for the culture of some marine and freshwater fish species in some countries. This is a concern, both in terms of availability of adequate seed to supply the sector's growth and because of possible effects on wild stocks.

There is a concern that the available marine resources (e.g. fishmeal and fish oil) may not be sufficient to meet the demands of projected aquaculture production. About 23.13 million tonnes of compounded aquafeeds were produced in 2005, of which approximately 42 percent was consumed by aquaculture. It used approximately 3.06 million tonnes (56 percent) of the world fishmeal production and 0.78 million tonnes (87 percent) of the total fish oil production in 2006, with over 50 percent of fish oil going into salmonid diets. The amount of fishmeal and fish oil used in aquafeeds grew over three-fold between 1992 and 2006. This increase was possible because the poultry sector gradually reduced its reliance on fishmeal.

Approximately five to six million tonnes of low-value/trash fish are used as direct feed in aquaculture worldwide. A recent estimate places the Asian use of trash fish as fish feed at about 1.6–2.8 million tonnes per year, while the low and high predictions for use in year 2010 are 2.2 and 3.9 million tonnes, respectively. In addition, unquantified large amounts of these ingredients are used by the pet food industry and the fur animal production sector. Fishmeal and fish oil production has remained stagnant over the last decade, and a significant increase is not anticipated in the foreseeable future. There is evidence that fishmeal use by the animal production sector, particularly in poultry farming, will continue to decrease in the coming years. The proportion of fishmeal and fish oil used in aquafeed is also expected to be substantially reduced by the increased use of vegetable-based protein and oil, as well as by more efficent feeding through better feed management.

However, world prices of fishmeal, fish oil and other feed ingredients are increasing. The price of fishmeal increased from around USD 500 per tonne in 2000 to around USD 1,200 per tonne in 2008. The price of fish oil also increased from USD 300 per tonne in 2000 to USD 1,800 per tonne in 2008. The average price of other feed ingredients, particularly cereal grains and soya bean, also rose by 30–130 percent during 2007.

These price increases are bound to affect aquaculture production. As the proportion of dietary fishmeal and fish oil used is relatively low in tilapia and catfish farming, varying between two and seven percent for fishmeal and one percent for fish oil, it may not be affected by prices increases in fishmeal and fish oil. However, increased prices on other ingredients will have a major impact. It is important to note that over the past four years the price of compound salmon feeds has only increased by around 15 percent. This is because the sector is highly organized and has benefited from continued research on salmonid physiology that has helped to develop substitutes for fishmeal and fish oil that have kept feed prices down while maintaining feed quality. In Asia, the scenario for catfish and tilapia appears to be different. As the feed cost for these species (particularly catfish) is around 75 percent of the total cost of production, most of the catfish and tilapia farming in Asian countries is unlikely to be able to absorb the increase in price of feed ingredients.

Increasing prices of fishmeal, fish oil, grains and other feed ingredients, and also fuel and energy, will certainly affect the cost of aquaculture production. With such a scenario, can aquaculture farms be economically viable? Scarcity will have the immediate effect of raising the price of fish, so that in the short term, farmers may gain financially until a new equilibrium is reached (i.e. until supply catches up with demand), and it will again be a question of who can produce more efficiently. Sustainability remains a concern, however, even more so when the demand for aquaculture products is outstripping the supply and prices soar so that even inefficient farms might make money. Under these scenarios, it is unlikely that the supply of fishmeal and fish oil will be a major limiting factor.

Adequate physical infrastructure

Transportation infrastructure and connectivity is essential for access to markets and services. Access to energy is also an essential prerequisite for all scales of commercial aquaculture. Other infrastructure such as water supply and drainage systems are also necessary, although there are differences among practices and systems. Aquaculture of all types will benefit from improvements in rural infrastructure. Industrial-scale aquaculture can also create demand for energy and infrastructure that benefits rural communities and contribute to improvement of community services (e.g. potable water, schools). Increasing energy costs may require exploring alternative energy sources.

There are special concerns for small and medium-scale enterprises. Cluster development and public investment in common infrastructure will enable the small and medium-scale sectors to develop, be competitive and contribute effectively to rural development. Small and medium-scale aquaculture clusters can be further supported through common marketing and processing facilities, although there may be commodity-specific differences.

While public investment in physical infrastructure can develop aquaculture, a balance must be struck between the use of public goods and services for private enterprise and cost recovery systems that require the aquaculture industry to pay for use of these services. Newly emerging aquaculture countries, or countries without aquaculture development, can benefit from the lessons learned from well established aquaculture industries.

Access to land and water resources

Land and water are essential for aquaculture. Access to these resources will become increasingly competitive. A stable and clear policy and legal framework is required for equitable allocation and use of land and water resources, including aquaculture in the context of integrated coastal management planning (e.g. as in China).

Land and water legislation must be based on environmental impact. In particular, to avoid problems of exceeding carrying the capacity, it will be essential to balance aquaculture development with the availability of water resources and distribution capacity. Small-scale enterprises are especially vulnerable when resources are limited, emphasizing the need of a legal framework for equitable use of resources. To "cluster" and organize small-scale enterprises is important. Increasing land prices in many coastal areas around the world are becoming an increasing constraint to aquaculture, requiring significant improvements in the efficiency of land use. Technological development of offshore/ocean farming systems may overcome this constraint.

In many land-based aquaculture operations, access to water might be restricted. In many countries, at least those in the industrialized world, farmers are obliged to pay for water. Water resources for coastal aquaculture are also limited. Increasingly, aquaculture will have to rely on systems and practices where water is efficiently used and conserved. In order to reduce effluents and resulting environmental impact, water treatment and recycling activities are necessary, although these may contribute to increased capital and operational costs of production. Due to sub-optimal water quality in some coastal zones, water purification plants may be necessary to establish mussel and oyster farms The technology is available, and once cost-effective operations are designed, water use efficiency in aquaculture can be significantly improved.

Maintaining food safety

Traceability and food safety assurance systems are a necessity for many domestic as well as international markets, and an important enabling factor in all regions of the world. To some degree these are being applied in countries that produce salmon and shrimp. Effective food safety and quality management systems require private and public sector coordination and partnership.

With respect to antibacterial residue levels in aquatic food products, the "zero tolerance concept" may be difficult to achieve and has been arbitrarily applied. The problems that have been encountered indicate the need to work more aggressively through the Codex Alementarius and other relevant international bodies to facilitate internationally acceptable standards for food safety and trading standards for aquaculture products. Additional resources need to be directed towards setting the international standards for production and trade in aquaculture products. The sector has been sorely neglected in comparison with capture fisheries and agriculture, despite its economic importance. The increasing trade problems faced by many producing countries argue for urgent attention to this important issue.

On the request by its membership, FAO is currently developing technical guidelines for aquaculture certification for international agreement. These guidelines will provide guidance for credible aquaculture certification schemes. The guidelines will cover the range of issues including: **a)** animal health and welfare, **b)** food safety and quality, **c)** environmental integrity and **d)** social responsibility.

There are extensive national and international legal frameworks in place for various aspects of aquaculture and its value chain that cover such issues as aquatic animal disease control, food safety and conservation of biodiversity. Legislation is particularly strong for processing and the export and import of aquatic products. National competent authorities are typically empowered to verify compliance with mandatory national and international legislation. Other aspects, such as environmental sustainability and social responsibility, may not be covered in such a binding manner, and this situation raises the opportunity for voluntary certification as a means to demonstrate that a particular aquaculture system is managed responsibly.

Standardized and universally accepted certification programmes will enable market access and improve public acceptance of aquaculture products. As the application of certification schemes may be difficult for smaller producers, small-scale enterprises may improved services to access markets requiring product certification.

Skills development and capacity enhancement

Skilled people are necessary for sustainable management of aquaculture. Enhancement of human capacity must be an integral part of the overall development of the aquaculture sector. The increasing intensity and complexity of aquaculture requires more skilled people to ensure sector sustainability. Education and technical capacity building programmes can be made more effective through the involvement of the users. A needs-based approach should be used to develop skills appropriate to the industry. Longer-term formal and informal educational programmes supporting all parts of the sector should be developed rather than short-term inputs such as study tours and training.

Building the capacity of producer associations and policy-makers deserves special attention. This can be acheived through increased networking among educational providers and researchers to make efficient use of educational resources, including those of other disciplines (e.g. health, nutrition and engineering). Involvement of the private sector in educational programmes is essential. Capacity enhancement is very critical in new and emerging industries. In new and newly emerging countries, networking with other countries and regions can facilitate skills development. The development of indigenous capacity is essential to provide a basis for long-term development of the sector. Certification of trained people and accreditation schemes for aquaculture education providers would facilitate development of the skills base for aquaculture.

Efficient communication and knowledge transfer

Effective and efficient communication is essential for transferring knowledge and learning from lessons of success and failure. Increasingly efficient communication, including web-based knowledge transfer will bridge the South-South and North-South gap in knowledge on aquaculture and provide a platform for dialogue between farmers and other stakeholders. Effective communication will allow dialogue between stakeholders and help harmonize policies, legislation, and practices etc., that govern sectoral growth.

In recent years, the demand for reliable and timely information on the status and trends of aquaculture has greatly increased. This stems from the need of sound policies and development plans, and to respond to the reporting requirements of international agreements and to public demands for transparency and accountability. There have been many attempts to improve the information base on aquaculture globally. In Asia, the improvement of information was made possible through more formalized networking among countries and institutions. There is a thrust and a dire need to establish more networks in other parts of the world. As globalization proceeds, with increasing flows of products, services and investment, the need for improved communication between regions will also increase. New technologies will enhance and facilitate such progress.

Many networks of producer associations and groups assisted by the private sector and by donor and development agencies exist, and these have contributed significantly to sectoral development. From aquaculture self-help groups, including women's groups in poor villages in Asia, to the more formal regional and international associations with their headquarters in Europe and the United States, producer groups increasingly play a major role in global aquaculture development. The challenge is to establish and empower more producer groups so that the aquaculture sector can be better managed by the true owners themselves.

Unexplored opportunities for future aquaculture

The aquaculture sector may benefit by tapping some unexplored opportunities:

- Open water and offshore mariculture is one of the key unexplored opportunities for producing aquatic food. This would need to be supported by appropriate policy and planning, including open-water zoning and legal and management frameworks.
- "Designer feeds" could be developed to improve resource use efficiency in the aquafeed sector. Vegetable proteins may be increasingly used to replace fishmeal and fish oil. Feeds suited to the specific dietary requirements of individual species (particularly marine finfish) that are economical to use in semi-industrial or commercial farming will be developed.
- Increased attention to recreational fisheries, ecotourism and ornamental fish production would widen the horizon of aquaculture's contribution to society.
- Non-food uses of aquaculture products, including the development of innovative re-use technologies for by-products and waste material from aquaculture (e.g. salmon skin, seaweed washings, etc.) show potential for future investment.
- Marine bioactive compounds, nutraceuticals, natural products etc. from marine organisms (algae in particular) are expected to play an increasingly significant role in the pharmaceutical industry.
- Large amounts of wild-caught fish are presently used for pet food, but commitments have

been made by the industry to eliminate the use of such marine resources. Aquaculture by-products could provide an alternative source, opening a significant new market.

The future

The aquaculture sector is expected to contribute more effectively to global food security, nutritional well-being, poverty reduction and economic development by producing – with minimal impact on the environment and maximal benefit to society – 85 million tonnes of aquatic food by 2030, an increase of 37 million tonnes over the 2005 level.

Identifiable trends in development of the aquaculture sector include:

- continued intensification of aquaculture production;
- continued diversification of species used;
- continued diversification of production systems and practices;
- increased influence of markets, trade and consumers;
- enhanced regulation and improved governance of the sector; and
- increased attention to better management of the sector.

These trends do not apply equally to all the regions due to differences in development, but do reflect the behaviour of the sector in those countries where aquaculture is well established. Possibly in some regions and countries mariculture will develop at a faster rate, as freshwater aquaculture may encounter more restrictions due to increasing competition for water resources, especially in a global warming scenario. Offshore mariculture also appears as an option to avoid conflicting uses of coastal areas and the pollution of coastal environments. However, offshore farming poses great challenges with regard to technological and economic investments, which may restrict or slow down the development in some regions and countries, at least initially.

Even with expected increases in aquaculture production, the question remains whether the industry can grow fast and sustainably enough to meet the projected levels necessary to maintain fish supply, while preserving the natural resource base it needs to thrive. Assuming sustained demand for fish (i.e. that the world is prepared to pay for fish as a desirable food product); there are plenty of unexplored opportunities that could allow aquaculture to significantly contribute to countries' sustainable development. These include: **a)** innovative capacity enhancement for producers; **b)** new production systems and technologies; **c)** new aquatic products and markets and **d)** the integration of aquaculture into eco-tourism, agriculture and fisheries. Although some of these areas have already been partially explored, considerable support is required to realize their full potential.

Although there are indications that aquaculture can cover the gap between expected demand and supply of food fish from capture fisheries, there are constraints that could dampen or even stall production increases.

Efforts to find solutions to soaring global energy costs have evidently contributed to an unprecedented increase in global food prices. The cost of grains has increased tremendously as a result of their alternate use in biofuel production. This trend will inevitably affect the aquaculture production sector.

One of the greatest constraints could be the impact of climate change. Climate change presents yet not quantifiable threats of changing temperatures, weather, water quality and supply. A recent report prepared by FAO examines general predictive models and suggests important differences between regions regarding the magnitude and types of impact on aquaculture. The report only opens the door to the relevant research needed on this topic and emphasizes the ability to adapt as a major advantage. There is a need for the aquaculture sector to join other economic sectors in preparing to address the potential impact of the planet's warming. One of the aquaculture sector's practical responses could be to strengthen the adaptive capacity and resilience, particularly that of small farmers and aquatic resources users. Increased resilience is a desirable feature of any sector, as it can mitigate the future impact of unforeseen events (e.g. economic change, disease epidemics, tsunamis, etc.), including those related to climate change. There is some knowledge and experience from aquaculture itself and from the broader area of agriculture and natural resources management that could provide relevant insights. Aquaculture and particularly mariculture could provide adaptive opportunities to produce good quality protein when freshwater becomes scarce. On the other hand, freshwater aquaculture can produce protein with less water than other animal production sectors.

Science can be useful to understand and reduce risks, uncertainties and vulnerabilities, but unwavering government commitment is essential to enhance aquaculture development. The level of commitment will inevitably vary within and among regions according to the importance of aquaculture in national economies. However, in countries where aquaculture contributes or has the potential to contribute substantially to food security, nutritional well-being, poverty reduction and economic growth, it is expected that the commitment will hold and the level of support increase.

Further reading

FAO 2007. The state of world fisheries and aquaculture 2006. FAO Fisheries Department, Food and Agriculture Organization of the United Nations. FAO, Rome. *http://www.fao.org/docrep/009/A0699e/A0699e00.htm*.

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FEED – THE KEY TO SUSTAINABLE FISH FARMING

Anders Kiessling

Summary

This chapter discusses fish farming in terms of feed, feed resources and nutrition physiology. Feed is both the single largest cost to the farmer but also the major factor affecting the environmental impact of fish farming, including production and transport of the feed as well as effluence from the farm during production. However, the same arguments apply to all intensive animal production. On the one hand, fish are certainly our most efficiently farmed animal in the sense of nutrient utilisation and farming space required. On the other, intensive fish farming offers challenges not faced by terrestrial animal farming in minimising the environmental impact. After a short definition of fish farming, this presentation deals first with fish versus terrestrial farmed animals and secondly the farming of carnivorous cold water versus omnivorous/herbivorous warm water fish species. The fact that the carrying capacity of all ecological systems is limited is gaining acceptance also outside the world of natural science, as is the insight that most plant- or animal-based feed sources suitable for farmed animals, including fish, are also suitable for human consumption. This insight leads to the realisation that the only sustainable alternatives are scenarios in which farmed animals become net contributors by a transfer of "non-human" food resources into human ones in an ecologically sound way. The final part of this section is therefore dedicated to feed sources with the potential of transformation of "non-human" or "low human interest" food sources into high-quality human food via farmed fish.

Fish farming systems

Using feed as the denominator, most researchers tend to define fish-farming systems in terms of the type of energy fed into the system. Early fish farming was based on photosynthesis in phytoplankton living in the same water as the fish. CO_2 and water were transformed into nutrients and tissues like protein, fat and bones via glucose. Compounds such as nitrogen, phosphorus, calcium and sulphur all occurred naturally in the system as a result of plant decomposition and minerals eroding from the soil. Herbivorous and omnivorous species, like those found in the families of tilapia (*Oreochromis* spp and *Tilapia zillii*, Africa) and carp (order *Cyprinidae* which includes many families, Asia), have naturally adapted to such aquatic food webs, feeding from different tropic levels as phytoplankton, zooplankton and their predators. A mix of species of these two large families of fish that utilise different niches in such food webs are still commonly used in so-called "polycultures". Such systems, termed *"extensive" systems*, tend to be most productive in warm climates, while fish farmed in temperate regions obtain nearly 100 percent of their energy from external, modified and refined sources and are therefore termed *"intensive" fish farming* and are exclusively based on monocultures. The sun is the ultimate source of the external energy in both cases, but the difference lies in where this energy is trapped in the ecosystem.

We also classify fish farming, from a climate or feed perspective, as either *tropical* or *coldwater farming*, sometimes also termed *omnivorous/herbivorous* versus *carnivorous* fish nutrition. Historically, these terms also referred to extensive and intensive farming systems, described above, since cold-water farming, in contrast to warm-water farming, is dominated by carnivorous fish species exclusively dependent on external food sources. Improved productivity in the tropical freshwater systems was originally achieved by adding nutrients to the system. Such systems, normally termed semi-intensive, could in their simplest form be achieved by ruminants grazing on the land surrounding the ponds, later advancing to utilise faeces from monogastric animals (pig, poultry, man) living close to the pond or effluents from agricultural or human societies including more complicated systems with animal or human housings literally built over ponds, in order to allow the droppings to function as food for the fish and fertiliser for the endogenous food web of the pond. Today it is more and more common to use low quality feed, ranging from raw plant components, such as peas, directly into the pond, or in more advance cases simple grained and pelleted products with low protein content. Such semi-intensive systems often include some mechanical improvements in order to aid gas transfer between air and water. Also the opposite, i.e. the effluent of the fish farm, is often utilised as fertilisers of plant or invertebrates (filtering) in low intensive systems.

The productivity of such systems meets local consumption including nearby cities. The modern global food market has, however, put a completely different pressure on logistics and profitability, in terms of generating a surplus cash flow, which becomes possible only by an intensified production. Today we see a rapid transformation of production strategies in these traditional extensive warm water systems towards an intensity and technology well known from modern salmonid cold water farming, including fabricated high protein/energy and highly digestible feeds, selective breeding and even genetic modification of the fish (FAO 2009).

An alternative tropical system hopefully capable to match the "salmonid cage and tank" technology is now evolving. It combines the technique of the traditional extensive pond system with the use of industrial feeds and modern technology, including breeding programmes. These systems are often referred to as *"green water" farming*,

Figure 1. Modern "green water" freshwater pond farming of tilapia (*Oreochromis* spp.) in Southern China.
The photo at top right shows mobile green houses necessary to maintain high water temperatures during the cold season. Bottom right photo shows a tilapia from the 16th generation of Genomar's breeding program. Photos provided by Dr. Sergio Zimmerman, Akvaforsk Genetics AS, Norway.

distinguishing them from tank and free floating cages, which are referred to as *"clear water" farming*. Tilapia, but also shrimps, are currently the preferred species for these systems. Figure 1 shows a typical "green water" set-up using solar-powered greenhouses. The reference to the colour green naturally refers to the occurrence of phytoplankton in the water. These systems, handled correctly, have a high production potential with two distinct advantages over the "clear water" systems. *First*, all the food introduced but not eaten by the fish will be incorporated into the "natural" food web of the pond and thereby offering the fish a second chance. In fact, it has been well demonstrated that green water systems offer the possibility of efficiently using feed, with a high level of plant sources with poorly degradable complex carbohydrates not otherwise available to higher organisms and a low protein content (< 30 percent DW[1]).[2] Not only is uneaten feed circulated by the micro-flora and fauna to the fish, but also nutrients with low digestibility are released to the micro-organisms through the faeces of the fish. The *second* advantage of "green water" over

1. DW = dry weight.
2. S. Zimmerman, personal communication.

"clear water" systems is a "pro-biotic" effect of the micro-organisms in the water. It seems likely that pathogenic micro-organisms are at a disadvantage if the correct pond environment is maintained (Pulz and Gross 2004). Drugs as antibiotics are less used in "green water" systems.[3] Diseases and pharmaceuticals are negative for fish growth, environment as well as for the farmer's finances. The drawback of the "green water" system is the need for warm water, e.g. tilapia thrive at temperatures above 29°C. Solar-powered green houses have recently extended the economic production range further to the north and south as far as southern China and Brazil, respectively.[4]

Another, but less well-known, difference between cold water and traditional tropical systems concerns the product quality in the form of healthy "fish fat", normally termed n-3 (omega-3) HUFA.[5] What is commonly called "fish fat" is only to a small proportion produced by the fish. In fact the health-promoting, long-chain fatty acids of the n-3 type normally associated with fish (EPA and DHA)[6] are mainly synthesized by marine and cold fresh water phytoplankton and then transported up the food chain. In the tropical zone phytoplankton in freshwater, and thereby also the fish, is dominated by the same type of fats as found in plant oil, namely of the n-6 (omega-6) family. If high content of marine fat is desired in the flesh of any farmed fish, it has to be added to the diet. Table 1 shows the fatty acid composition in flesh of different species of farmed and wild fish. At present "fish fat" is added to the diet in the form of marine oils. However, this involves sustainability issues, as fish oil is partly obtained through non-sustainable fisheries. New sustainable sources of marine fats are therefore urgently needed (see also Figure 4), and are focal points for the feed industry. Marine oil from artificially reared micro-algae is already in use, but the technology is costly. Another potential source is genetically modified plants (GMO), which are currently being tested on a laboratory scale with some success. Already GMO rape seed contains high levels of EPA while introduction of genes stimulating synthesis of DHA seems to require further research. Another approach towards enriching the fish flesh with these fatty acids, healthy to man, is to stimulate the endogen capacity of the fish itself to produce EPA and DHA from other fatty acids readily available in some plant oils. Trattner *et al.* (2008) demonstrated close to a doubling of DHA in rainbow trout flesh after feeding a mixture of sesame and rapeseed oil, a result noted with interest by the industry.

Development of fabricated diets

In the early days of salmonid farming, the feed normally consisted of raw animal liver, chopped fish, squid and other animal protein and fat sources, such as egg yolk.[7] Feeding then gradually evolved to include offal, different fish products and dry meals to form moist (water content > 70 per-

3, 4. S. Zimmerman, personal communication.

5. HUFA= highly unsaturated fatty acids with carbon chains from 20 carbons and upwards, not including n3 from plant oils.

6. Eicosapentaenoic acid, EPA, and Docosahexaenoic acid, DHA, are fatty acids with 20 and 22 carbons and 5 and 6 double bounds, respectively, of the n3 family and is grossly described important, respectively, in the hormone and nervous tissue formation of humans.

7. Eva Bergström, personal communication. Eva Bergström also made major contributions to the development of dry feeds for young stages of salmon at her work at the Salmon Research Institute, Älvkarleby, Sweden.

cent) and semimoist (water content > 30–40 percent) pellets. Moist pellets in fact dominated the feeding of adult stages of salmonids as late as in the 1980s, while dry pellets (water content < 10 percent) were developed for start-feeding and young stages[8] long before it became the dominating feed type for adult fish. Salmonids have large eggs and thereby larvae with a well-developed digestive apparatus already at start feeding, which facilitates the use of fabricated diets throughout the

Table 1. Examples of fat content and relative level of the omega 3 fatty acids EPA and DHA in a consumer portion[a)] of a few selected farmed and wild fish.

Species	Fat content g/100g)	EPA % of lipid	DHA % of lipid	EPA (g/100g)	DHA (g/100g)
Farmed salmon[b)]	10–23	8.5	15	0.8–1.6	1.4–2.3
Farmed salmon, given 50:50 % fish:plant oil	10–20	4.2	7.5	0.4–0.8	0.7–1.1
Wild Atlantic salmon	8–12	4.4	11	0.3–0.5	0.8–1.3
Wild Chinook *(O. tsawytscha)*	11	3	8	0.3	0.8
Wild Sockeye *(O. nerka)*	8	4	8	0.3	0.6
Wild Coho *(O. kisutch)*	6	4	11	0.3	0.6
Wild Pink *(O. gorbuscha)*	5	5	13	0.3	0.8
Wild Chum *(O. keta)*	4	3	8	0.15	0.4
Farmed Raibow trout, portion sized (300–800 g)	4	6	18	0.2	0.7
Farmed Rainbow trout, large (3–5 kg)	10	4.5	13	0.4	1.1
Farmed Arctic charr[c)]	12–16	11	15	1.0–1.7	1.7–2.3
Farmed cod	1–1.5	12	35	0.1	0.5
Wild cod	0.5–1	16	35	0.05–0.1	0.1–0.2
Carp	5	4	2	0.2	0.1
Tilapia	<1	16	35	0.005–0.1	0.1–0.2

The underlying rational for the marked variations in lipid content, also within a species, is a combination of factors as diet energy, life stage, fish size, strain and other less defined factors in the environment of the fish. Diet composition[d)] and tissue fat content[e)] are without rivalry the two most important factors setting the total content of EPA and DHA (as well as the majority of all other lipid soluble components) in the fillet of fish. Another important error factor to consider when comparing data from different studies is trimming/skinning (trimmings contain high levels of adipose tissue and the skin is attached to the fat rich red muscle). A 50-percent reduction in fillet fat content is reported after skinning of Pacific salmon[e)]. The tabulated data are based on a mix of our own work[f)] and of others[e), g)].

a) Excludes extra muscular adipose tissue and includes red and white muscle.
b) Scottish and Irish farmed Atlantic salmon tend to be found in the lower range, while farmed Norwegian and Canadian West coast Atlantic salmon are found in the upper range. Farmed Pacific salmon are found in the lower upper range.
c) In non skinned Arctic charr fillets, from fish fed high lipid diets (> 25 percent, DW) fillet fat content can exceed 20 g/100g.
d) Waagbø, R. *et al.* 2001.
e) Ikonomou, M.G. *et al.* 2007.
f) Johansson, L. *et al.* 1995. Johansson, L. *et al.* 2000. Jonsäll, A. 1995. Kiessling, A. *et al.* 2001. Kiessling, A. *et al.* 2004.
g) Mørkøre, T. *et al.* 2001. Jana Pickova, Magny Thomassen, Lars Ove Eriksson, personal communications. Information in official data bases (Swedish National Food Administration, Norwegian National Institute of Nutrition and Seafood Research, USDA, Nutrition Data Laboratory and Canadian Nutrient file).

8. Eva Bergström, personal communication.

entire life cycle. Control of the complete life cycle, including diets, was a new invention in the history of fish farming. Salmonids thereby became the first fish species, in which man had full control of all aspects of the entire life cycle, a prerequisite for optimizing both production and the organism as such, including specific breeding programmes. The development of salmonid farming led the way in the now rapidly escalating transformation of fish farming from an activity that either utilized “on growth” of wild fish or passively mimicked the natural conditions of wild fish, into an activity fully commanded and controlled by man. Fish farming hereby parallels the process of domestication seen in all terrestrial farmed animals, in which the development of formulated diets has been a prerequisite. In the field of ”aquafeeds” this development is characterized by the transition from a diet using the same nutrients source as the wild fish, to an adequate diet independent of nutrient source, be it of animal, plant, micro-organism or synthetic origin.

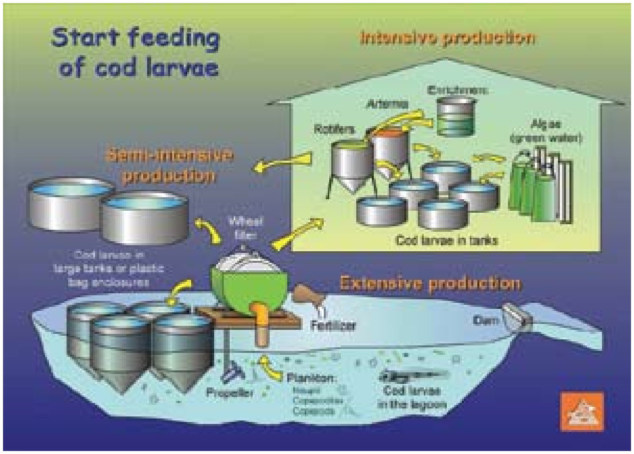

Figure 2. A schematic picture showing different types of cod larvae production ranging from extensive (bottom right), allowing the larvae to feed only on natural production, to intensive fully controlled systems with artificially enhanced live feed (top). (Van der Meeren, T. and Naas, K.E. 1997. *Reviews in Fisheries Science* 5: 367–390.)

During the 1970s, feed manufacturers started large-scale production of salmonid feeds. At first, this was a very diverse industry but it gradually became completely dominated by a few multinational companies. The same process took place at the turn of the century for Mediterranean farmed species, and is currently repeating itself in the intensification of tropical fish-farming systems. The use of moist diets is still common for many marine species, consisting of chopped fish and squid, but major environmental concerns have been expressed against this practise. During the past thirty years, the research in nutrition of marine fish has, in parity to the early development of salmonid nutrition, focused on fabricated diets to be used in intensive systems already from start-feeding. In Figure 2 the technical evolution of Norwegian cod farming is shown, illustrating both the transformation from an extensive to an intensive system and the problem of start-feeding in species with small larvae, typical of many marine and freshwater species. The development of start-feed programs, together with artificial reproduction has formed the basis for the explosion we now see in the intensive farming of several marine and freshwater species characterised by small larvae with complex nutritional needs during their early life stages. However, a labour intensive and economically costly start-feeding period with live feeds of rotifers and copepods and/or enriched artemia (Figure 2) is still necessary for most of these fish species.

The advantage and disadvantage of farming in water compared to on land

When we consider feeds for farmed fish, independent of whether it is a warm water herbivore or a cold water carnivorous fish, there are a few physiological facts that we need to be aware of. As already pointed out, fish are without comparison the most efficient protein-transforming higher animals ever farmed by man. This is as true for modern salmon farming as it is for traditional poly-culture of tropical fish. A very gross comparison between energy and protein efficiency in mammal, fowl and fish is shown in Table 2.

A second interesting fact is that fish assimilate protein without methane production, as the digestive system of fish is low in micro-organisms in comparison with most terrestrial animals, where ruminants represent the most extreme case. This high metabolic efficiency and the absence of a well-developed micro-flora is simply a result of evolution in water. The main advantages in rearing fish compared to land living animals can be summed up as follows:

Firstly, water has high conductivity. By always adapting the temperature of their body to that of the water, fish do not need to create enormous layers of fat for insulation as marine mammals do. Nor do fish need to use energy specifically for heat production when the waste heat of digestion, metabolism or muscle contraction is not sufficient to maintain a steady body temperature. In fact an

Table 2. Comparison between different types of fish and terrestrial production animals in diet carbo-hydrate content, energy and protein retention.[9, 10]

	Fish					Fowl		Pig	
	Salmon	Rainbow trout	Chanel catfish	Common carp	Indian carp	Broiler	Hen	Slaughter	Sow/Wild
Carbohydrate of diet (% DW)	10	15	25	30–40	20–30	50–60	60–70	55–65	70–80
Proportion of total energy requirement used to maintenance in actively producing animals (%)			8			61	67	41	67
Retention gross energy in edible part (%, meat or milk)	30–35			15–25*		12	–	16	< 16
Retention gross protein in edible part (%)	30–40			20–30*		18	–	13	< 13

*Due to lower slaughter yield compared to salmonids (≈ 20–30 percent and 60 percent respectively).

9. Waagbø, R. *et al.* 2001.
10. Austreng. E. 1994. Birger Svihus, personal communication. Svihus, B. 2007. Thodesen, J. *et al.* 1999. Grisdale-Helland, B. and Helland, S.J. 1997. McDonald, P. *et al.* 2002. T. Åsgård, Nofima Marine, Norway, personal communication.

outdoor-raised pig can spend up to 40 percent of ingested energy on heat production alone, while a decrease of 1°C in the indoor temperature of a broiler barn increases food consumption by up to 10 percent (McDonald *et al*. 2002).

Secondly, most fish produce an abundance of eggs which naturally reduce the resources allocated to keep a large parental generation.

Thirdly, water has unitary density. This makes excessive fat accumulation impossible (fat tissue has a density of 0.8, the so-called "cork effect") and favours energy deposition in the form of protein, i.e. muscle. Not only has muscle a density close to water and is therefore weightless, but it also has the advantage that it provides its own means of mobility. In other words it is no disadvantage to accumulate excessive energy depots in the form of protein if you live in water, while large fat depots, as seen in mammals, would be detrimental in fish, which have a very thin and light bone structure adding very little to the weight (density) of the fish. In contrast to fat, protein stored as muscle consists of water at a ratio of 1:4; i.e. one gram of protein is accompanied by at least four grams of water, increasing body weight roughly five to six times as much, as if the same dietary energy had been stored as fat. Size, a strong survival value also in the aquatic environment, can thus be achieved without the negative consequences of gravity. Consequently, fish are the only vertebrates that can afford life-long muscle growth by cell proliferation. In all terrestrial animals muscle proliferation (formation of new cells) ceases at birth and muscle growth thereafter consists only of enlarging existing muscle fibres, i.e. the number of muscle fibres present at birth is an important factor limiting maximum growth of land animals. All farmed species of fish, in fact nearly every species of fish, have the ability to form new muscle fibres throughout life, an ability that bodybuilders can only dream of, i.e. unlimited muscle growth. This contrasts sharply with animals living on land, where every gram of body weight has to be carried against the constant force of gravity, an obvious fact when we examine examples of human efforts to increase muscle growth in terrestrial animals, as is best illustrated by the extreme of the extremes, the Belgian Blue strain of cattle. Naturally, fat tissue, with its high energy value per unit weight and absence of associated water, has been favoured during terrestrial evolution in animals in need of endogenous energy stores, while protein has been favoured in the aquatic environment.

Finally, living in water offers an easy route to dispose of nitrogen, the by-product of protein and to some extent also purine catabolism. When amino acids are deaminated, the amino group is released as a water-soluble ammonium ion (NH_4^+). The ammonium ion is in equilibrium with ammonia (NH_3), a very toxic compound. Fish can easily reduce the level of ammonia by excreting ammonium ions via the gills and thereby avoiding the risk of toxic endogenous levels, while terrestrial animals reduce the amount by transferring the nitrogen from protein to urea or uric acid (poultry) and then excreting it via the urine or faeces (poultry), an energy-intensive process.

From an environmental point of view, fish are hereby at a disadvantage to terrestrial animals, as it is nearly impossible to collect these eutrophicating substances, nitrogen and phosphorus, as soon as they are dissolved in a larger water volume, while on land we can separate the urine/faeces and even chemically catch dissolved phosphorus and thereby recycle them back into plants, at least in theory. The route to decreasing nitrogen and phosphorus loss during fish farming can be separated into three levels:

Firstly, reduction of feed waste, which is accomplished through improved feeding protocols (where, when and how), more appetising diets and techniques to measure appetite and thereby know when to stop feeding (e.g. by video) or recycling or collection of uneaten feed.

Secondly, increasing digestibility and durability of the digesta and faecal matter, respectively, and thereby increasing uptake of nutrients during digestion and facilitating removal of faecal matter by filtration before the effluent water enters the surrounding water. Increased faecal matter durability will also increase the fraction eaten by organisms in the ecosystem surrounding the farm and thereby enhance growth in the local food web, allowing recapture of the nutrients in clear water systems by harvesting of e.g. wild fish, farmed/wild mussels and plants. In green water systems the farmed fish will recapture the nutrients directly by eating the organisms as feed.

Finally, by affecting the metabolic efficiency of the nutrients both by feed source, feed composition, by selecting favourable farming locations and by genetic selection, where individuals with high protein retention would be the target. One could include a fourth method, biological purification, which at present only is feasible in closed (recirculation) or low intensity systems. In these systems the effluent water passes a biological filter of nutrient binding micro-organisms after mechanical filtration. Such a biological filter can be organised in several ways, for example, as a free floating suspension, where the micro-organisms (algae/plants) later are trapped by filtering organisms (e.g. bivalves), as a bed of micro-organisms attached to a solid substrate, where they later can be mechanically harvested, or so that the effluent water can be used to irrigate plants.

Reduction of nitrogen loss by nutrition

The reduction in loss of nutrients from commercial cold water fish farming over the last thirty years, by improvement in feed regimes and feed composition is illustrated in Figure 3. Changes in feed composition for salmon during the same time period is illustrated in Figure 4. In the wild, salmonids prey on organisms higher in protein than fat. Naturally, early fabricated diets mimicked this. With increasing quality of fishmeal and thereby biological value (see below), protein was gradually replaced in salmonid feed by fat (oil), yielding energy rich and "low" protein diets (Figure 4). This fat and protein was originally from pure fish oil and fishmeal, but due to reduced availability of these commodities, followed by increases in price, 40–50 percent of both fish oil and fishmeal is now replaced by plant oil and plant protein in diets to adult salmonids. Of course, such a switch in feed sources is associated with its own problems, but an amino acid from plant is identical to the same amino acid from fishmeal. However, the amount of the different amino acids (normally termed amino acid profile of a protein) and other plant specific substances (see below for more details) are the problems that demand specific focus by the feed manufacturer, in order to assure proper function of the diet independent of nutrient source. Replacement of marine fat or oil in the diet is much less complicated because the need of the fish for the special fatty acids (EPA and DHA) of marine fats is much lower than the amounts added in modern salmon diet. A large portion of the dietary fat may therefore be replaced by any fat with a high enough melting point to

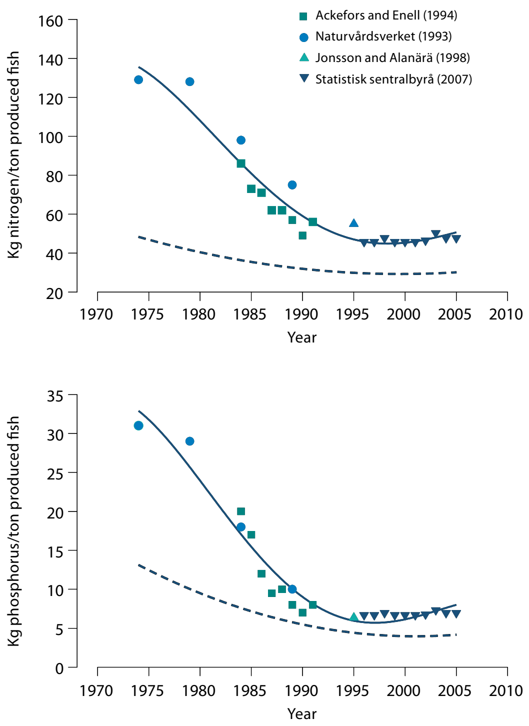

Figure 3 Historical changes in calculated and theoretical nitrogen and phosphorus effluents from Swedish fish farms. The solid line is based on official reports of feed sold and fish produced. The dotted line represents the theoretical effluent based on calculated feed conversion (kg of feed used per kg of produced fish).[11] The decrease in the reported data is mainly an effect of improved feed conversion, while the decrease in the dotted curve most likely represents in the case of nitrogen an improved retention and in the case of phosphorus a decrease in phosphorus content of the feed.[12]

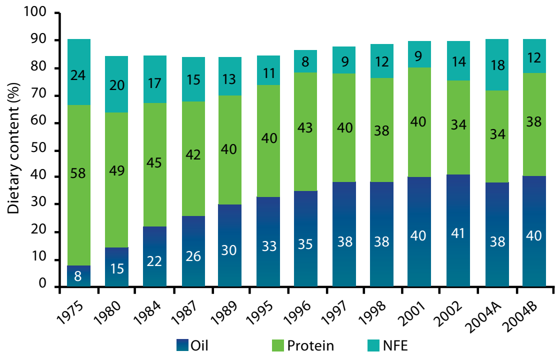

Figure 4. Changes in nutrient composition of fabricated salmon feed over the last 30 years. The over all trend is a replacement of protein by oil. Originally only fishmeal and fish oil were used as a source, but today 40–50 percent of both protein and oil originates from plant sources. The 2004A and 2004B diet exemplify the two strategies adopted from this time on with high versus low nutrient concentration, tailoring the diet to the fish potential and environmental conditions of a specific farm. The development since 2004 has mainly focused digestibility of energy and nutrients in order to always guarantee an efficient blend independent of feed source. Later increase in NFE is mainly an effect of increasing use of plant ingredience. See text for more details concerning non marine feed ingredients in modern aquafeeds. NFE = Nitrogen Free Extract (mainly digestible and non digestible carbohydrates). Figure provided by Marie Hillestad, BioMar AS, Norway. Early data are based on the work of Erland Austreng, Akvaforsk AS, Norway.

11. Alanärä, A. 2000.
12. The graph is assimilated by Anders Alanärä at SLU, Sweden based on Ackefors, H. and Enell, M. 1994. *J. Appl. Ichthyol.* 10: 225–241. Naturvårdsverket. 1993. Jonsson, B. and Alanärä, A. 1998. Statistisk sentralbyrå. 2007.

stay soft also in cold water. The only consequence, known at present, is that the meat loses its healthy fatty acid profile as human food.

Twenty to thirty years ago, adult salmonids given a high protein and low energy diet (18 MJ gross energy) used an average of 2.5 kg of feed (≈ 10 percent water) (Wagbø *et al.* 2001) per kilogram of wet weight growth (≈ 70 percent water). Fifteen years ago, only 1.5 kg (Wagbø *et al.* 2001) of feed was needed to produce one kilogram of fish, while the figure today is 0.95–1.1 kg of low protein and high energy diet. As pointed out above the modern salmon diet contains more energy than it did twenty years ago (at present 20–23 MJ/kg, DW), and at the same time the protein fraction of the diet has been reduced from 50–60 percent to 35–45 percent DW (Figure 4). Farmers have thus achieved a significant improvement in efficiency, of close to 50 percent in energy and 70 percent on a protein basis, and thereby not only gained in economical terms, but also reduced emissions to the environment over the last 30 years. The early improvements (15–30 years ago) in feed conversion of intensive farming can mainly be ascribed to "educating the farmer", i.e. unnecessary pollution was caused by overfeeding. Today, feed accounts for such a large proportion of production costs that no farmer who wastes food can be profitable, and a number of various methods to register or recirculate uneaten feed are employed to minimise any waste. The more recent improvement (last decade) therefore represents advances in feed composition, feed production technology and domestication of the animal through selection programmes.

In fact, laboratory studies indicate even further scope for improvement in feed utilization. If the same salmon/trout/charr that need 0.95–1.1 kg of feed per kilogram growth is moved to a more protected environment, it only needs 0.8–0.9 kg on average, while some individuals will only need 0.5–0.6 kg (Kiessling *et al.* 1995, Grise-Helland and Helland 1998, Wagbø *et al.* 2001), i.e. in its extreme, less than half the average of today's practical situation, and less than 25 percent of the requirement 20 years ago. On an energy or protein basis, these findings indicate that close to 80 percent retention of protein and 70 percent of the energy is not only possible in theory, but also in the commercial system, provided that we can understand the factors causing the difference between the commercial and laboratory situation and use the right genetic material. When evaluating fish production, one needs to remember that, compared to other farmed animals, fish farming protocols and level of domestication are still very rudimentary and there is most likely room for significant improvements.

Reduction of the part of dietary protein used for energy in farmed fish has so far been achieved through improvement of the biological value of the protein (see also above). A good value implicates a protein with high digestibility and the correct amino acid profile for growth. This means, the better the biological value, the less protein has to be added to the diet, in order to support the same growth. In terrestrial farmed animals such a reduction of protein in the feed is compensated by an increase in carbohydrates, replacing the part of protein that would otherwise be used by the animal for energy. In fish, and in particular carnivorous fish, fat instead of carbohydrates has such "protein-saving" effect which is the underlying rational for the replacement of protein by fat in salmon diets shown in Figure 4. Carbohydrate, due to its low price and high availability on the global feed market, has even so repeatedly been tested in carnivorous fish diets with varying, but most often low success, this as dietary starch (the component of carbohydrates digestible to animals) has low digestibility in all fish and in particular in salmon. However, in most salmonides a 5 to 15-percent dietary inclusion (DW) of gelatinised (preheated) starch seems to have a small protein-saving effect and no negative influence on the uptake of other nutrients. Adding carbohydrates in salmonid diets is likely to reduce the need to convert glycogenic amino acids (protein) into glucose (carbohydrates) necessary to fuel the energy need of brain, kidney and blood cells. Hexokinase, the first rate-limiting enzyme in glucose metabolism, can be induced in all salmonids and omnivorous/herbivorous fish, indicating an optimum of 10 and 20–30 percent inclusion of digestible carbohydrates in the diet, respectively (Waagbø *et al*. 2001). In comparison, fat to a level of 30–40 percent of DW promotes growth and allows protein to be reduced to as little as 35–40 percent (DW, Figure 4) in salmon, depending on the life stage of the fish (small fish need higher level of protein).

Carbohydrates in aquafeeds, a comparison between different fish species

Even between the salmonids, but especially between omnivore/herbivore species, there are wide differences in carbohydrate tolerance. However, to get the proportions right, we call a fish herbivorous (plant eaters) if they can handle a carbohydrate inclusion up to 40 percent by weight, while a human or pig diet often contains 60–70 percent digestible carbohydrates (starch) by weight and 55–60 percent on energy basis. Rainbow trout is the salmonid that seems to have the best tolerance for carbohydrates, and their diets often contain 15–20 percent digestible carbohydrates, in addition to high levels of fat, allowing protein to be reduced to 30–35 percent of the diet. A level close to that seen in adult carp and tilapia (25–30 percent protein in the diet). However, in very intensive rainbow trout farming, protein is rarely lower than 35–40 percent (DW), i.e. fast growth demands a higher protein level. Most carp and tilapia diets contain levels of 30 or even 40 percent digestible carbohydrates by DW, and a general rule is that the higher the ability to digest carbohydrates, the lower the preference for lipids.

It has therefore often been argued that it is better to farm omnivorous/herbivorous fish like carp and tilapia from an environmental and global resource point of view as their feed contains less protein and marine oils and is higher in carbohydrate than that of carnivorous fish. However, this takes the argument out of its context, as a number of other factors, like energy (tilapia and carp need water temperatures from 25–32°C to be productive), transport, food safety, content of n3 HUFA (Table 1) and rural development need to be considered, if carnivorous cold water farming should be replaced by farming of tropical species.

Given the large differences between species in the ability to digest carbohydrates, the surprising fact is that no fish species seems to have any essential need for carbohydrates in the diet. All fish studied to date have the necessary capacity for endogenous glucose production based on glucogenic amino acids. That apparently no carbohydrates are needed, could be a reflection of the aquatic food web which, unlike the terrestrial one, is universally low in digestible carbohydrates and rich in protein, fat and minerals such as calcium and silicon. The main source of carbohydrates for most fish is the tissue glycogen of their prey, rarely surpassing one percent of wet weight, while algae and plant feeders may find high levels of starch in their natural diet. Some fish, such as tilapia (*Oreochromis* spp.) and silver carp (*Hypophthalmichthys molitrix*), which are normally considered to feed at a low trophic level, do in fact filter a mixture of plant and animal planktons that often is low in digestible carbohydrates. This lack of complex carbohydrates in the diet of fish, compared to farmed terrestrial animals, may be the underlying rationale for the absence of major microbial activity in their gut, but it is definitely the underlying rationale for the universally low ability of all major farmed fish species to metabolise as high levels of digestible carbohydrates as terrestrial animals. In fact, if most fish species, including tilapia and carp, are fed high levels of soluble and short-chain carbohydrates, like salmonids they will also be at risk of metabolic disorders that can provoke pathological liver changes and extreme obesity. Furthermore, juvenile fish of families such as tilapia and carp need a high level of highly digestible protein for energy and tissue formation, i.e. protein of animal origin. Chitin, the structural component of crustacean shell, is probably the second most common carbohydrate on this planet, second only to cellulose, and is often suggested as a possible carbohydrate source of fish. However, like cellulose, chitin seems to be indigestible without the enzymatic support of micro-organisms.

To conclude, the major difference in the ability to handle dietary carbohydrates between different types of fish seems to be confined to adult stages and differences found in the digestive tract. The major differences between different types of fish in terms of feed formulation are thus found at the level of refinement of the nutrient source, which is needed in order to make the nutrients accessible during digestion. Fish like tilapia and carp have a long digestive tract that is adapted to utilising protein and fat presented in combination with complex carbohydrates. In carnivorous fish with a shorter digestive tract, there is not enough time before the food reaches the end of the alimentary canal. Thus, high levels of complex/low digestible carbohydrates will reduce digestibility of the feed in fish with a short digestive tract (common carp, *Cyprinus carpio*, is an intermediate case between the carnivorous and omnivorous/herbivorous types).

It may therefore be a misconception that different fish have different requirements for protein to sustain growth. In fact, the differences could well be explained by differences in amount of protein utilised in energy metabolism, giving an appearance of differences in protein requirements. Such differences can be the result of evolving in a protein rich (carnivore) or protein poor (omnivore/herbivore) feed environment. Future research will show whether genetic selection, in combination with further development of feed sources and feed technology, will be able to further improve the ability to utilise non-protein nutrients in the energy metabolism of coldwater carnivore fish, reaching levels currently seen in that of omnivorous/herbivorous fish.

Plant and other feed sources as an alternative to fishmeal and fish oil in aquafeeds

The superior ability of omnivorous/herbivorous fish to "handle" low-density protein and fat extraction in the digestive tract, in spite of the presence of high levels of complex carbohydrates, has resulted in two feed manufacturing strategies. The low intensive strategy utilises low-grade local grains in a small-scale production. The mill is often simple and locally owned, and the feed is low in protein, rich in complex and poorly digestible carbohydrates and yields low growth rate in the fish. The high intensity strategy follows that seen in intensive fish farming of coldwater fish, using concentrated diets manufactured with advanced and expensive technology. The feed is often produced for a wider geographical area, and the mill is owned by a major corporation producing feed for several species of farmed fish. This type of feed is state-of-the-art, includes less non-digestible carbohydrates, is high in energy, and is used in more intensified production systems and yields high growth rates.[13]

Most plant protein sources need to be refined to reach the protein digestibility and density levels necessary for carnivorous fish diets, while the raw form of the plant source is often acceptable in the diet of omnivorous/herbivorous fish. Due to the market price of highly refined plant protein, these have not until recently, with increasing prices of fishmeal, been of interest as a feed ingredient for carnivorous fish. Soy, with its naturally high protein content, is an exception; it has been one of the favourite plant sources for salmon diets. However, a number of new technologies now allow economically viable refinement of several other plant sources such as peas, corn gluten, sunflower, lupines, etc.

However, both soy and most other plant sources contain a number of other substances that are produced by the plant, either as protection against grazing or as hormones. We call these substances "antinutrients", because they have marked physiological effects on the animal, often reducing feed utilisation. These effects are species-specific and counteractions in terms of processing methods and refinements will vary according to the fish being targeted. Salmon is especially sensitive to a number of substances in whole soy, causing everything from reduced protein and mineral digestion to severe inflammation of the hindgut, resulting in diarrhoea and possibly compromised welfare (Baeverfjord and Krogdahl 1996). The

13. S. Zimmerman, personal communication.

salmon feed industry has therefore reduced the use of soy, and is now directing its interest at other potential and less problematic plant sources. On the other hand, cod and especially the omnivore/herbivore warm water species seem to have a much higher tolerance for these substances, most likely as a result of being exposed to a more varied feed base through evolution. Replacement of fish meal with plant protein sources is today so efficient that a modern salmon diet yields close to more fish protein than goes into the diet (break even level is 25 percent fishmeal).

Most people find this 1:1 yield in marine protein acceptable, but the main criticism now focusses fish oil. Salmon is presently using more than 55 percent of globally available fish oil from wild fish resources (Figure 5) in spite that nearly 50 percent of the oil in salmon diet is of plant origin. On average seven percent (wet weight) of wild prey fish consists of lipids. However, one third

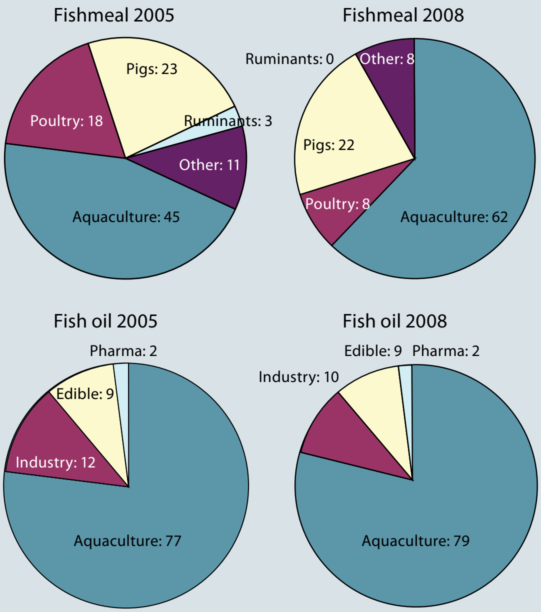

Figure 5. Changes in relative use of fishmeal and fish oil between commodity and animal species from 2005 to end 2008. Based on data from IFFO and FIN (Fishmeal Information Network) (2005 and 2009), Oil World (2009), and Tacon and Metian (2008).

Availability of marine fish oil has been a major bottleneck for increased salmon farming. Salmon feed demands 55 percent of globally produced fish oil (FAO 2009). However, Oil World (2009) predicts this to be reduced due to the practice of replacing nearly half of fish oil with plant oil in salmon diets. This may be the rational for the relative small change from 2005 to 2008, in spite an increase in global salmon production. Price of fish oil is at present mainly driven by the increase in direct human consumption (Oil world 2009). However, with technical progress human consumption may in the future be based on slaughter products from farmed fish rather than from wild fish oil (Oil world 2009). Pharmaceutical use is at present the only area with a profit margin for fish oil produced by micro algae.

Use of fishmeal, on the other hand, did already 2008 surpass growth predictions made for 2010, by the International Fishmeal and Fish Oil Organisation (IFFO) in 2005, with nearly 20 percent. This is likely an effect of an unexpected rapid increase in intensive tropical and marine aquaculture. Considering the present reduction in commercial catches of meal fish (IFFO 2009) predictions of future availability of fishmeal are presently ambiguous.

remains in the meal fraction, giving a yield of 4.5 percent pure oil. A salmon diet, if accepting a 1:1 yield (dry feed: wet weight fish), with a 38 percent fat and 25 percent fishmeal inclusion, demands on average 7.4 kg of wild fish for one kilogram of growth and 3.7 kg of wild fish if 50 percent plant oil replacement is used. Some would argue that this is an unfair comparison because in the 50 percent oil replacement scenario, more than half a kilogram of fish meal will be left over and may be used for producing e.g. fish with a low fat diet or even poultry. This is because each kilogram of prey fish yields 20 percent of its weight in fishmeal, compared to the 4.5 percent (after deducting the lipid in fishmeal) of oil (calculation based on personal communication; T. Åsgård, Nofima Marine).

Besides plants, many researchers advocate alternative marine sources like krill, by-catches or offal, as the ultimate way to supply dietary protein and lipids (marine type) to a steadily growing aquaculture industry (Shepherd *et al*. 2005, Tacon *et al*. 2006), but others have strong reservations, including both the realisation that human life ultimately depends on an environment in ecological balance and that maintaining such a balance sets limits on our use of biological resources, especially at higher trophic levels. Also most plant or animal-based sources suitable to fish are also suitable for human consumption. The interest in utilising these resources as human food may not be acute today, but no one doubts that a competitive situation for high-quality food resources will arise between humans and farmed animals in the future. The only sustainable alternative must therefore be scenarios in which the farmed animal becomes a net contributor, i.e. transforms "non-human" or "low-human interest" food resources into human ones in an ecologically sound way. A historic parallel is the grazing animal kept on "non-arable" land, where the animal, because of its rumen, is able to transfer complex carbohydrates, indigestible by the human stomach, into highly digestible protein, sugar and fat in the form of meat and milk.

Converting waste to food by fermentation

Micro-organisms are the most effective producers of organic material in nature, and often exceed 50 percent of dry weight in protein content, i.e. similar to meat/fish meal. Bacteria such as *E. coli* are capable of doubling their own biomass in as little as 20 minutes, given optimum conditions. Not only is a flora of different species from the main groups; bacteria, fungi/yeast and micro algae, capable of producing both protein and fat of the desired quality, but it will do so utilising carbon sources as diverse as human organic waste, CO_2, non-digestible carbohydrates such as cellulose, pentoses or even methane, to mention a few but important examples. It is not difficult to understand that micro-organisms are a prerequisite in a sustainable society, especially when one realises that many micro-organisms as a side-reaction can be "tricked" into reducing their main aim; that of producing new biomass (i.e. protein, fat and carbohydrates as building blocks for new micro-organisms), in favour of products such as biogas or ethanol, and to do so in compact bio-reactors under the complete control of man.

In order to obtain such high bio-production, very high levels of nucleotides are needed (DNA and RNA > 12 percent of DW are common), resulting in diseases, such as kidney stones and gout, if these organisms are eaten directly by man in large volumes. Farmed fish on the other hand has the metabolic capacity to utilise high levels of micro-organisms in their diet *(s*ee Skrede *et al*. 1998). Utilising micro-organisms would allow production of aquafeed together with such diverse commodities as waste treatment, bio-fuels and whisky production – to mention a few examples. In parity with plants, fish having been exposed to a variety of feed sources through evolution, seem to accept a wider range of micro-organisms in the feed more readily. Micro-organisms also contain a number of bio-active substances as well as a cell wall of varying digestibility. However, species and strains of micro-organisms have already been found that seem to be well suited as feed also to carnivorous fish. Therefore many believe that this is mainly a matter of matching the right organism or right process condition to the right fish species. The variety of micro-organisms is immense and even more importantly, they can easily be manipulated to change their metabolism and thereby their composition, by altered production conditions.

Refinement of low quality fish products

There is little or no prospect of increased volumes of fish meal in the foreseeable future. On the contrary; with more sustainable fishing practises, a recovery of large predator fish populations is expected and thereby an increased predation on prey fish (see Figure 5). The current growth of aquaculture, and the thereby increasing need for fishmeal and fish oil, has so far been based on an allocation to aquaculture from other farmed animals (Figure 5). Interestingly, this shift is signified by an increase in the quality of the meal itself. Traditionally, fish meal has been based on poorly treated raw material, often not even iced on the boat. This, in combination with high process temperatures, produced a protein of low biological value with high emissions of nitrogen during digestion. Such a low quality is accepted in terrestrial farmed animal feed, but not in fish feed. The introduction of high quality fishmeal with low bone content in aquafeeds during the late twentieth century resulted in a marked reduction in both nitrogen and phosphorus effluents per kilogram produced fish (Figure 3).

A positive side of fishing is that it removes biomass and thereby recovers nutrients from the water. Controlled fishing might also be instrumental in rectifying an artificial imbalance between predator and prey fish, in many cases caused by fisheries itself. The Baltic Sea is a prime example, suffering from eutrophication and an imbalanced ecosystem. However, fish in many waters, again with the Baltic Sea as a major example, is unfit for human consumption due to a high load of environmental contaminants. However, by modern cleaning procedure with active carbon, this biomass can be decontaminated and used in animal feed as fish meal instead of destructed. The contaminated fish will thereby be transformed back into high-quality food via fish farming. Other fish resources often mentioned are fish offal and by-catches/discards, either in the form of non-food species or catches too small to be commercially viable. Hydrolysation is one technique of great interest, in order to turn such by-catches profitable and to recover these nutrients via feed to farmed fish.

Mussels as animal feed

As in all animal production, feeding farmed fish with wild fish has been criticised from a resource point of view, because instead it should be used directly by humans. Ten percent of the food is normally considered to be retained from one trophic level to next (from prey to predator). As pointed out above, farmed fish are much more efficient than this, retaining well above 30 percent of the food in practice and 80 percent in theory. However, such high conversion rates are based on external energy inputs in the form of petroleum to catch/farm, concentrate, dry and transport feed and its ingredients. But the harvesting, processing and distribution of wild fish for food are also petroleum based. The high conversion efficiency of farmed fish has therefore been used as an argument that it is more efficient to catch feed/prey fish and feed them to farmed fish instead of leaving them in the ocean to be prey to a cascade of different predator fish. However, such arguments are difficult to support since the natural food web, quite apart from being petroleum-free, may have unknown positive spin-off effects. An alternative route is to use feed sources low in the natural marine food web. Wild blue mussel, a plankton feeder, was already twenty years ago tested as feed for farmed fish. However, the concept was at that time found to be unviable due to the high cost of de-shelling (Berge and Austreng 1989), as mussels otherwise had unacceptably high ash[14] content. Blue mussels are very effective plankton assimilators and from a human nutrition point of view, they have an excellent protein and fat (EPA and DHA) composition, even though their fat content is only a few percent of wet weight. By farming mussels for human consumption in eutrophic waters, an additional positive effect is achieved as nutrients are taken out of the water at harvest. Thereby farming functions as a trap for nutrients otherwise lost through leakage from other human activities as agriculture. Lindahl and Kollberg (2009) named this "Agro-Aqua recycling pathway". In Sweden blue mussel farming is even accepted as an alternative to expansion of the nutrient purification steps at sewage plants.[15] Bivalve farming is also a major human nutrient net provider in tropical regions (FAO 2009).

A problem not often mentioned is that the ropes used to attract the free-floating mussel spat become overloaded during the growth cycle so that a number of small mussels fall to the bottom, creating local eutrophication that may have detrimental effects on the ecosystem directly beneath the farm. Some mussels are also still too small for the market at harvest and create an economic loss and disposal problem to the farmer. Both these "drop-off" and undersized mussels are po-

14. Ash is the remaining mineral content of organic tissue after combustion at 450°C for one hour.
15. The Lysekil experiment.

tential "waste", to be utilised as feed for farmed animals. The harvest waste of small mussels was recently tested as an alternative to fish meal for fish (Duinker *et al*. 2005) and ecological poultry production.[16] The fish study concluded that the cost in Norway of producing de-shelled mussel meal was not economically viable below a fish meal price of NOK 20/kg. However, a slightly better profit margin could be obtained if the remaining shell was sold as fertiliser. If used for laying hens, a better cost margin was obtained as they can use the shell for egg production and only partially de-shelled mussel meal could be used. On the other hand, the fish meal normally used for poultry is of lower quality and thus obtains a lower price than meal used for salmonid feed. A positive factor is that neither poultry nor salmonids seem to be sensitive to algae toxins that cause losses when blue mussels are farmed for human consumption, and thereby offers further possibilities for economising by providing an alternative market for mussels if their level of toxins is too high for the human consumer. Furthermore, blue mussels farmed in waters like the Baltic, high in xenobiotics, do not accumulate lipid soluble substances as dioxin and PCB, in contrast to fatty fish; partly due to low lipid content, partly due to low levels in the micro-organisms constituting their feed. Therefore they offer a possible route for recycling nitrogen and in part also phosphorus back into the human food system in contaminated waters like the Baltic.

Bivalve farming, allowing a quantifiable measure of nutrients removed from the water, has the potential to be included in an exchange system of effluent certificates, especially if the geographic distance between the effluent source and the mussel trap could be reduced (Lindahl and Kollberg 2009). At present the majority of bivalve farming is located in a marine environment while freshwater is dominant for fish farming. Neither freshwater mussels nor blue mussels grown in low salinity will reach a size suitable for the human food market. However, including the environmental gain, low salinity or even freshwater mussel production for animal feed may very well be profitable, especially if the meal is used to produce high-value ecological fish and poultry products (Goedkoop *et al*. 2007, Lindahl and Kollberg 2009).

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RECIRCULATING LAND BASED AQUACULTURE SYSTEMS

Mikael Cullberg

There is an urgent need to make the growing aquaculture sector more sustainable, i.e. less polluting and less dependent on fish meal from capture fisheries. To bring this about, new cultivation methods are being developed, for example recirculating aquaculture systems in land based fish tanks.

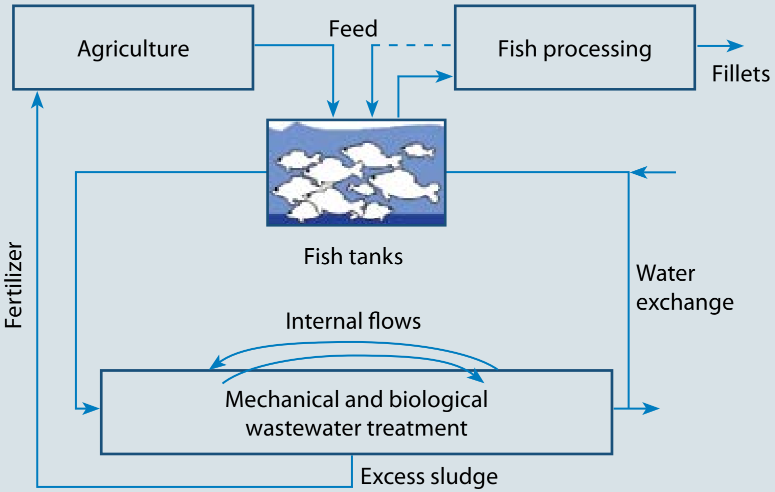
Such a system, based on a new technology, was recently developed at Chalmers University of Technology in Göteborg, Sweden, and successfully tested at semi-commercial scale with different fish species, primarily Pangasius spp. and Clarias spp. The system implies a new possibility for sustainable – including climate neutral – fish production thanks to its, in principle, full water recirculation (<1% diurnal water exchange, close to zero efflux). Such recirculation is made possible by an efficient biological purification of the fish tank effluents. The high efficiency is achieved by a computerized, very accurate control and configuration of the purification process. Therefore, the release of eutrophicating pollutants may be reduced to extremely low levels. When farming herbivore and omnivore species no fish meal is required in the feed. Omnivore species can make use of return offal, provided that it is not from the same species (Wik *et al*. 2009).

Traditionally, there are two main problems associated with recirculating aquaculture systems. The system presented here offers solutions to both of them. The first is system instability which has been solved by the technical design; *inter alia* the sophisticated control and regulation mechanism. The second is profitability and energy consumption which are closely interrelated. The system has a potential for profitable and climate neutral production. The profitability can be substantially augmented by cultivation of fast growing and protein efficient herbivore and omnivore species, originating in tropical and subtropical areas, at temperatures optimal for growth all-year round. The energy cost, which risks to be considerable in temperate regions, can be substantially reduced by, *inter alia*, insulated buildings, heat exchangers and conservation of heat generated from pumps, aeration, fish activity etc. Another great advantage from an energy perspective is that semi-moist fish feed can be used thanks to the efficient purification process. The production of such feed requires much less energy than the production of dry feed. The digestibility of semi-moist feed is also higher. Integration with agriculture, e.g. by use of fish farm sludge as organic fertilizer and thereby replacing chemical fertilizers, may contribute further to the profitability and energy budget (Wik *et al*. 2009, Gröönros *et al*. 2006, Pelletier *et al*. 2007).

Other advantages from a sustainability perspective, compared to traditional fish farming, include:

- The risk of escapes is eliminated.
- Control of in- and outgoing pathogens can be secured.
- The content of toxic substances in the fish meat can be controlled (Wik *et al*. 2009).

The illustration (from Wik *et al*. 2009) shows the layout of a recirculating aquaculture system for herbivore and omnivore species integrated with agriculture, where cereals constitute a main component of the feed and excess sludge is used as fertilizer.



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SEAFOOD IN HUMAN NUTRITION

Leif Hambræus

Abstract

Seafood contains a number of valuable components from the nutritional point of view, which make them potential members of the functional food family. However, seafood also contains some components, essentially from environmental pollution, which may entail some health risks. Their role in a healthy diet is consequently complicated from a public health perspective.

It is obvious that seafood may help to increase the nutrient density in most diets as its energy density is relatively low and its content of protein and essential nutrients is high. An increased consumption of seafood is recommended in most countries. There are still relatively few estimates on quantitative benefits and risks with a high seafood consumption in populations, although it is well known that seafood is a good source of valuable protein and n-3 fatty acids as well as of vitamins, especially vitamin D and B_{12}, and minerals, especially selenium. In societies where seafood since long is established as staple food, e.g. Indonesia, the nutrition transition as a result of changes in life style, has not affected consumption of seafood negatively. In affluent societies, however, the consumption of seafood seems to have changed from fresh fish to convenience products, such as fast food and fish fingers.

A general recommendation in Europe is a consumption of two servings per week, but this should include variation in the type of seafood consumed, and fat fish should be consumed at least once a week. This recommendation takes into account the beneficial nutritive value of seafood, as well as the potential risks due to toxicological factors secondary to pollutants.

In most of the countries, however, it is recommended that pregnant and lactating women, as well as children, should restrict their intake of certain fishes especially from fresh and brackish waters, and the intake of seafood in general due to environmental pollution.

The contribution of seafood to nutrition

From the nutritional point of view, seafood represents a valuable source of essential nutrients, e.g. protein, lipids, vitamins, minerals and trace elements. In addition, some of the nutrients are considered to be especially health promoting, e.g. vitamin D and polyunsaturated fatty acids. This has led to an increased interest in their potential to decrease the incidences of cardiovascular, cancer and inflammatory diseases. However, some of the seafood items may contain potentially hazardous compounds and be carriers of various exogenous toxicants from environmental pollution of various origins, e.g. chlorinated hydrocarbons as DDT, PCB, dioxins and methyl mercury. This has lead to some confusion for the public: on one hand increased consumption of seafood is recommended, on the other hand certain groups of the population, e.g. infants and women of fertile age, should restrict their intake of certain fishes.

It is consequently essential to better understand the potential role of seafood in human nutrition and what can be expected from a public health point of view from variations in the consumption of seafood in different parts of the world. In this perspective the role of nutrients and potential toxicants, as well as how they occur in various species in relation to environmental conditions, are of interest.

An increase in seafood consumption is well in accordance with dietary advice in most countries. Seafood is not only considered a valuable source of animal protein, but also believed to result in a decreased incidence of cardiovascular disease in the population in affluent societies.

The concept "seafood" comprises both wild and farmed fish and shellfish of marine and freshwater origin. Any analysis of their potential positive and negative role in a public health perspective consequently calls for a more structured analysis of the different species. Not only should the differences in nutrient content be analysed, but also risk factors such as natural toxicants, e.g. biogenic amines, as well as microbial or viral contamination or pollution. In addition, the development of aquaculture, in both affluent and not least low-income countries, offers new perspectives for the role of seafood in the diet, including both health-promoting effects and risk factors related to environmental problems.

In this chapter I base the discussion on the nutritional perspectives on various fish and shellfish on the FAO classification, as mentioned in Ackefors (this volume).

Energy density
The amount of energy per weight or volume. The energy density of fat-rich items is higher (38 kJ/g), not only as fat has a higher energy value than carbohydrate and protein (both 17 kJ/g), but also because fat-rich food items have lower water content.

Nutrient density
The amount of essential nutrients, i.e. protein, vitamins, minerals, per energy unit (joule or kcal). Food items with high protein content usually have a high nutrient density.

Energy percent (E%)
The relative amount of energy derived from the macronutrients protein, fat and carbohydrate, in relation to total energy content. Recommended distribution between the macronutrients is: 10–15 E% protein; < 30 E% fat; 55–60 E% carbohydrate.

From the public health perspective, the content of energy of various food items, expressed as *energy density*, and their *nutrient density*, i.e. amount of nutrients per energy unit, is central. Consumption of energy dense food items will increase the risk for obesity. A high nutrient density is especially beneficial for low-energy consumers to avoid risk of nutrient deficiencies. As will be illustrated in this review, seafood items are beneficial from the public health perspective as they, with few exceptions, have a relatively low energy density and high nutrient density.

Energy

The energy distribution between the macronutrients is illustrated in Table 1. Milk, meat, bread and potatoes, four representatives of staple food items of animal and vegetable origin in the diet, are used for comparison.

The table illustrates two major characteristics of seafood:

- The high protein energy percent in seafood, even when compared to other animal food protein sources;
- The comparatively low energy density of seafood, even in fat fish species (e.g. salmon).

Seafood shows values below those in meat from terrestrial products. Shellfish is characterized by an extremely low energy density, 80–90 kcal per 100 g with few exceptions. This makes seafood well adapted for low-energy consumers and those on a weight reducing or fat reduced diet.

Protein

As seen in Table 1, seafood is characterized by a very high protein content with a protein energy percent well above 60 E%, much higher than in most animal products. This especially characterizes shellfish. Only the most fat-rich fishes have a protein energy percent equivalent to that in meat and milk.

Consequently those interested in high protein and low fat intakes often consume large amounts of shellfish. The intake of 1,000 g shrimps per day, which is not uncommon for bodybuilders, gives 180 g protein or 2.3 g per kg bodyweight in an 80-kg man, to be compared with a recommended protein requirement of 0.8 g per kg bodyweight in adults.

The protein in seafood, like all animal proteins, has a good combination of amino acids, characterized by a relatively high and well balanced content of essential amino acids. It is particularly high in lysine and sulphur amino acids (i.e. methionine and cystine), which makes it suitable as a supplement to cereal based diets. Table 2 illustrates the amino acid contents in salmon and shrimp, representing fish and shellfish, respectively, compared to that in meat and the requirements of adults.

Fat

The fat content and quality is another matter of public health interest (Table 3). From the nutritional point of view, the various fish species can be divided into three groups with respect to their fat content. It is often said, rightly or wrongly,

Table 1. Macronutrient content in various seafood (values refer to g per 100 g).

Species		Energy kJ (kcal)*	Protein (g)	E %	Fat (g)	E %	Water (%)
Fishes							
B-11	Carp	531 (127)	18	*57*	6	*43*	76
B-12	Cyclides						
B-22	Eel	770 (184)	18	*39*	12	*58*	68
B-23	Salmon	594 (142)	20	*56*	6	*38*	68
	Trout	620 (148)	21	*57*	7	*43*	71
B-31	Flounder	381 (91)	19	*84*	1	*12*	79
B-32	Cod	343 (82)	18	*88*	1	*11*	81
B-33	Seabass	406 (97)	18	*76*	2	*19*	78
	Grouper	385 (92)	19	*85*	1	*10*	79
B-34							
B-35	Herring	661 (158)	18	*46*	9	*52*	72
	Anchovy	548 (131)	20	*61*	5	*35*	73
B-36	Tuna	603 (144)	23	*64*	5	*32*	68
	Mackerel	858 (205)	19	*37*	14	*62*	64
B-38	Shark	544 (130)	21	*65*	5	*35*	74
Reference							
Meat		1038(248)	19	*31*	18	*65*	63
Milk (3 %)		251 (60)	3.4	*23*	3	*45*	89
Bread	(ryewheat)	1170 (281)	6.4	*9*	3.1	*10*	34
Potato		360 (87)	1.9	*9*	0.5	*5*	78
Shellfish							
B-42	Crab	364 (87)	18	*83*	1	*10*	79
B-43	Lobsters	377 (90)	19	*84*	1	*10*	77
B-45	Shrimp	444 (106)	20	*75*	2	*17*	76
B-52	Abalone	440 (105)	17	*65*	1	*9*	75
B-53	Oyster	285 (68)	7	*41*	2	*26*	85
B-54	Mussels	360 (86)	12	*56*	2	*21*	81
B-55	Scallop	368 (88)	17	*77*	1	*10*	79
B-56	Clam	310 (74)	13	*70*	1	*12*	82
B-57	Squid	385 (92)	16	*70*	1	*10*	79
Octopus		343 (82)	15	*73*	1	*11*	80

* Units of energy.

Units of energy

Today Joule, the SI unit, is used in most scientific papers dealing with energy.

The old unit in energy studies was the calorie, which referred to the energy needed to raise the temperature 1 degree Celsius (from 14.5 to 15.5) in 1 g of water. This unit is still used in nutritional science, especially kcal (= 1,000 calories) in biological systems, sometimes referred to as Calorie (with capital C).

To convert between calories and joule: 1 kcal = 4.186 kJ; 1 kJ = 0.239 kcal.

Table 2. Amino acid pattern in some animal proteins.*

Amino acid	Salmon	Shrimp	Meat	Requirement in adults**
Essential				
Isoleucine	46	48	48	30
Leucine	81	79	81	59
Lysine	92	87	89	45
Methionine + Cystine	40	39	40	22
Phenylalanine + Tyrosine	73	75	80	38
Tryptophan	11	14	12	6
Threonine	44	40	46	23
Valine	52	47	50	39
Histidine	29	20	34	15

* Mg amino acid per g protein.
** WHO/FAO/UNU 2007.

that "even the fattest fish is leaner than low-fat cured meat".

- *Low fat content* (around 1 percent fat or <12 energy percent) – cod, perch, flounder.
- *Medium fat content* (5 percent fat or 30–35 energy percent) – tuna, shark, anchovy.
- *High fat content* (>6 percent fat or >40 energy percent) – salmon, trout, herring, eel, mackerel.

Interestingly, the fat content shows seasonal variations related to breeding periods, and water temperature. With respect to fat quality, there is also an interesting difference between fish in cold water and in tropical waters. This is rarely discussed or indicated in conventional food tables.

All seafood has a high content of polyunsaturated fatty acids, which contribute significantly to covering the essential fatty acid requirements of humans. The saturated fat content is low, but the cholesterol content high, which has intensified the debate on the use for individuals with disturbed fat metabolism and increased risk for cardiovascular diseases. On the other hand, the content of omega-3 fatty acids is relatively high which is considered beneficial.

The classical description of the role of polyunsaturated fatty acids of Inuits by Dyerberg and colleagues in the 1970's, started an increased interest for the role

Table 3. Fatty acid composition in various seafood (values per 100 g).

Species	Total	Saturated	Mono-unsat	Poly-unsat	Omega-3	Omega-6	Cholesterol
Fishes							
Carp	5.5	1.1	2.3	1.4	0.7	0.5	66
Eel	12	2.4	7.2	0.9	0.7	0.2	126
Salmon	6	1.0	2.1	2.5	2.0	0.2	55
Flounder	1	0.3	0.2	0.3	0.2	0.008	48
Cod	1	0.1	0.1	0.2	0.2	0.005	43
Grouper	1	0.2	0.2	0.3	0.3	0.01	37
Herring	9	2.0	3.7	2.1	1.7	0.1	60
Tuna	5	1.3	1.6	1.4	1.3	0.05	38
Mackerel	14	3.3	5.5	3.3	2.7	0.2	70
Shark	5	0.9	1.8	1.2	1.0	0.08	51
Reference							
Meat	3	2.0	0.8	0.1	tr		
Milk (3 %)	18	4.5	4.5	0.5	0.06		
Shellfish							
Crab	1.1	0.2	0.2	0.4	0.3	0.01	78
Lobster	0.9	0.2	0.3	0.2	?	?	95
Shrimp	1.7	0.3	0.3	0.7	0.5	0.03	152
Abalone	0.8	0.1	0.1	0.1	0.09	0.007	85
Oyster	2.5	0.8	0.3	1.0	0.7	0.06	53
Mussel	2.2	0.4	0.5	0.6	0.5	0.02	28
Scallop	0.8	0.1	0	0.3	0.2	0.004	33
Clam	1.0	0.1	0.1	0.3	0.2	0.02	34
Squid	1.4	0.4	0.1	0.5	0.5	0.02	233
Octopus	1.0	0.2	0.2	0.2	0.2	0.009	48

of omega-3 fatty acids in public health during the latter decades of the 20th century.

Long-chain n-3 fatty acids are also required for a normal development of children during foetal life and early infancy. A number of studies indicate an effect on the cognitive function in children of n-3 fatty acid supplements in greater amounts than can be achieved via the diet.

Vitamins

All fatty fishes are good sources of vitamin A and D, while they contain less vitamin E. Seafood in general is also a good source of certain kinds of vitamin B, essentially niacin equivalents.

Table 4 illustrates that most seafood has a high content of B-vitamins, of special interest is the high content of vitamin B_{12}. The fact that most seafood is a good source of niacin, is probably essentially the result of its high protein content, as tryptophan content is included in the estimation of niacin equivalents. The content of fat-soluble vitamins is also high, especially in fatty fish, but also in shellfish. In addition to the well-known role as a good source of vitamin D, their role as a source of vitamin A and/or retinol equivalents and E is also of interest.

The range is wide with respect to some vitamins, e.g. folic acid, B_{12} retinol equivalents and vitamin D. Thus the highest content of niacin among fishes is found in salmon and tuna; folic acid in salmon but also in carp, eel, cod and grouper; B_{12} in herring; retinol equivalents in eel and tuna, and vitamin D in herring. Among shellfishes the highest concentrations of folic acid are found in crab and mussel; for B_{12} in clam; of retinol equivalent in clam; of vitamin D in oyster, and of potassium in abalone.

Another positive aspect of seafood is its role as a good source of vitamin D, the consumption of which is low among many people in the temperate zones. This is of special concern, not only to counteract rickets in children, but to decrease the risk of osteoporosis and fractures in the adult and elderly population, increasingly an important public health problem in affluent societies.

In Sweden seafood contributes on an average to 25 percent of the intake of vitamin D, B_{12} and selenium, about 20 percent of the total intake of n-3 fatty acids and 80 percent of the long chain n-3 fatty acids.

Table 4. Vitamin content per 10 MJ.

	B_1 mg	B_2 mg	Niacin eqv mg	B_6 mg	Folic acid µg	B_{12} µg	C mg	Retinol eqv µg	D IU	E mg	K µg
Fish	1–4	2–7	8–133	2–13	11–420	16–206	5–44	26–19000	1300–24000	11–18	2–58
Shellfish	3–6	2–10	40–74	2–12	68–1200	16–1590	45–222	55–2900	129–11200	10–91	3–522
Reference											
Milk	2	6	28	2		16	24	1		<1	
Meat	1	2	73	4		14		.2	–	–	
Recommended intake per 10 MJ*	1	1	16	1	450	2	80	800	10	9	–

* Nordic Recommendations (2004) for planning diet 6–60 years of age.

Niacin equivalent

Refers to the fact that the essential amino acid tryptophan can be converted to niacin. Consequently one must not only analyse the content of niacin in the food but also the tryptophan content as a potential niacin source. This is expressed as niacin equivalents; 60 mg tryptophan is equivalent to one niacin equivalent. In practice this means that in a protein rich diet, low niacin content can be replaced by tryptophan from the protein. This is of special interest in the case of seafood, as it is characterized by relatively high protein content.

Retinol equivalent

The concept of retinol equivalents was introduced to convert all sources of retinol and provitamin A carotenoids in the diet to the same unit, instead of the earlier concept of international units, as the efficiency of the absorption of the carotenoids was very variable. (1 IU was equivalent to 0.3 µg of all-trans retinol). There are more than 50 substances with vitamin A activity. β-carotenes occur in vegetable items, and thus vitamin A requirement can be covered also for vegetarians and vegans if they eat carotene rich items, i.e. carrots and red palm oil. The bioavailability of various forms of β-carotene differs, however. Today 1 retinol equivalent is considered to be equal to 1 µg of retinol (preformed vitamin A), 2 µg of supplemented β-carotene, 12 µg of dietary β-carotene, 24 µg of other dietary provitamin A e.g. α-carotene.

International units (IU) for vitamin D

One IU of vitamin D is defined as the activity of 0.025 microgram of cholecalciferol in bioassays with rats and chickens. Thus, the biological activity of 1 µg of vitamin D is 40 IU and the activity of 25-hydroxyvitamin D, 25OH D, is five times more potent than cholecalciferol (1 IU = 0.005 µg 25[OH] D). Actually, vitamin D is a hormone rather than a vitamin according to the definition of vitamins, as human can obtain their requirement for vitamin D through exposure to an adequate amount of sunlight. However, this light-mediated synthesis is affected by a variety of factors, e.g. skin pigmentation and clothing coverage, sun exposure (latitude and weather conditions). Requirements for vitamin D consequently are gross estimates of the need for the active hormone.

Minerals

Table 5 illustrates that seafood also represents a rich source of minerals, well above the recommended content per energy unit. Especially the high content of iron (Fe) and calcium (Ca) is of public health relevance. However, although the high selenium (Se) content is of value in populations with selenium deficient diets, the very high content might also represent a potential risk factor at high seafood consumption. Furthermore, the high potassium (K) content may be deleterious for patients with kidney disease.

Table 5. Mineral content per 10 MJ (range for various species).

	Ca mg	P mg	Fe mg	Cu mg	Mg mg	K mg	Zn mg	Se µg
Fish	130–2016	2500–7800	9–23	1–2	360–930	2900–12500	7–288	117–960
Shellfish	650–2400	4300–6300	7–450	3–158	290–1700	4200–10200	18–3200	600–2200
Reference								
Milk 3 %	4520	3520	0.4		520	6080		
Meat	60	1670	41		180	3550		
Recommended intake per 10 MJ*	1000	800	16		350	3500	11	40

* Nordic Recommendations (2004) for planning diet 6–60 years of age.

The great range between various species is due to the fact that some are extremely rich in certain minerals. Among fishes the highest values for potassium are reported in carp and cod, for selenium in cod and grouper, for zinc in eel, for calcium in salmon. Among shellfishes the highest values of calcium are found in crab, of phosphorous in crab, of iron in clam and oyster, of magnesium in scallop, of potassium in clam and octopus, of zinc and selenium in oyster.

Of special nutritional interest is the role of seafood as a source of iodine and as a prophylactic against goitre. There is nevertheless little information in food tables on the content of iodine although seafood in general is considered a good source. A good illustration of the role of seafood as a potentially important iodine source was given in an analysis of the incidence of goitre in Sweden during the 18th and 19th centuries (Sjöberg 1972). Goitre seems to have been first described in Sweden by Linné in 1746 but there were still few cases described until the beginning of the 19th century, when it was almost endemic in the county of Dalecarlia. It has been suggested that the sharp increase could be related to the sudden disappearance of herring on the west coast and the following increase in price. Earlier the consumption of herring provided the population with an important part of their iodine intake.

Iodine deficiency is considered endemic mainly in populations far from the coast, where the consumption of seafood is low. Still it is described also in marine societies, e.g. Indonesia and Bangladesh. Interestingly, in Bangladesh fish and shellfish are essentially caught in freshwater, which might explain the low iodine intake, while in Indonesia other anti-nutritional factors might occur that interfere with the iodine uptake.

In some countries the intake of selenium is a matter of concern which makes seafood a valuable dietary component.

Changes in nutrition characteristics in various forms of fish products

Table 6 illustrates the changes in macronutrient content in various fish products as a result of handling and preservation. As illustrated, there is little difference in the nutritional characteristics between frozen and fresh products in many kinds of seafood, except for molluscs and crustaceans. *Industrialized products*, such as canned and cured products, for obvious reasons show higher nutrient density and energy density than whole products, fresh or frozen. According to the trend analysis, the consumption of these types of products seems to increase in affluent societies. *Lyophilized products (freeze dried)* might be of limited interest with the exception of special food products for specific situations and groups, i.e. hiking, offshore sailors, and astronauts.

Table 6. Changes in nutrition characteristics in various forms of fish products (values refer to content per 100 g).

	Fresh	Frozen whole	Fresh fillets	Frozen fillets	Cured	Canned
Freshwater/diadrome fishes						
Energy (cal)	69	69	127	127	199	161
Protein (g)	10.9	10.9	20.3	20.3	31.3	19.8
Fat (g)	2.5	2.5	4.5	4.5	7.2	8.4
Pelagic fishes						
Energy (cal)	86	86	141	141	156	185
Protein (g)	12.6	12.6	20.2	20.2	26.4	20.8
Fat (g)	3.6	3.6	6.0	6.0	4.5	10.2
Crustaceans						
Energy (cal)	47	91			149	98
Protein (g)	9.3	18.4			25.4	19.8
Fat (g)	0.5	0.8			1.3	1.1
Cephalopods						
Energy (cal)	66	74			341	137
Protein (g)	13.5	15.1			61.6	20.8
Fat (g)	0.7	0.9			6.2	2.8
Demersal fish species						
Energy (cal)	42	42	90	90	186	173
Protein (g)	8.3	8.3	17.9	17.9	37.9	25.0
Fat (g)	0.8	0.8	1.6	1.6	1.9	6.3
Marine fishes						
Energy (cal)	64	64	115	115	169	179
Protein (g)	10.3	10.3	19	19	32.1	22.9
Fat (g)	2.2	2.2	3.8	3.8	3.2	8.2
Molluscs						
Energy (cal)	15	71			345	98
Protein (g)	2.3	10.5			49.4	14.9
Fat (g)	0.2	1.2			4.7	4.7
Aquatic animals						
Energy (cal)	30				33	
Protein (g)	4.0				5.5	
Fat (g)	0.2				0.1	

Source: Fish and Fishery Products, FAO Fisheries circular no. 821, revision 7.

Seafood products for human consumption

Table 7 shows a number of representative countries from the various continents to illustrate the per capita supply for human consumption of seafood. The data refer to FAO statistics mostly from the years after 2000. It is obvious that the highest consumption of seafood occurs in Asia, with Japan in the lead. The consumption is also high in Korea and Malaysia. Interestingly, Indonesia and Thailand, which together with Malaysia may represent countries in a nutrition transition phase, show about the same per capita consumption as Australia, Peru and Greece.

The fish consumption in Bangladesh and India is still relatively low on a per capita basis. The consumption is also low in low-income countries in Africa, here represented by Ethiopia, Malawi, Tanzania and Uganda. Only Egypt and Gambia have higher intakes of seafood. In Latin America the highest consumption is reported from Peru while it is much lower in Chile.

Table 7. Fish for direct human consumption.

Country	Production (catched) (´000 tons)	Total supply (´000 tons)	Per capita supply (kg/year)	Year
Australia	193	426	22	01
Africa				
Egypt	875	1 030	14.9	01
Ethiopia	15	15	2.3	01
Gambia	37	35	25.7	01
Malawi	41	42	3.6	01
South Africa*	416	309	7.2	03
Tanzania*	310	279	8.5	99
Uganda	245	227	8.8	03
Asia				
Bangladesh	1 170	1 128	9.5	95
India*	5 556	5 099	4.8	03
Indonesia*	5 672	4 673	21.3	03
Japan	4 804	8 390	65.7	03
Korea Rep	2 282	2 782	59	01
Malaysia	1 160	1 460	59.8	03
Philippines	2 394	2 335	28.8	03
Thailand*	2 420	1 423	23.6	98
Vietnam*	1 434	973	19.4	01/02
Europe				
Bulgaria	9.7	23.5	n/a	
Denmark*	362	124	23.2	01
Finland	103	158	30.5	01
Greece	190	241	22	03
Germany	319	673	14.9	97
Malta	2	3	6.6	
Norway*	2 028	235	52,2	01
Portugal	196	420	40.6	02
Slovakia	4	21	3.9	
Sweden*	68	51	6.0	03
United Kingdom	637	869	15.6	02
Central America				
Costa Rica*	45	23	5.8	
Guatemala	30	25	2.0	
Panama*	42	10	15.7	
Latin-American				
Bolivia	7	14	1.6	03
Chile	658		3.8	03
Peru*	7 996	564	21.4	01
North America				
Canada*	991	731	23.9	98

* Catches higher than total supply for human consumption.

As for Europe, the fish consumption in Norway and Portugal is high, in Norway of the same magnitude as in some of the Asian countries. Among the Scandinavian countries, Sweden shows a remarkably low intake, in comparison less than half of Germany's. However, these figures might be misleading, as there are no reliable statistical data regarding fish consumption during the last decade. Earlier data showed a much higher consumption of seafood.

The countries listed can be divided into three major groups with regard to per capita seafood consumption

- *Low consumers* (<10 kg per person and year) – Bangladesh, Bolivia, Chile, Costa Rica, Ethiopia, Guatemala, India, Malawi, Malta, South Africa, Sweden, Slovakia, Tanzania, Uganda.
- *Medium consumers* (10–40 kg per person and year) – Denmark, Egypt, Finland, Germany, Greece, Indonesia, Panama, Philippines, Thailand, United Kingdom, Vietnam.
- *Very high consumers* (>40 kg per person and year) – Japan, Korea, Malaysia. Norway and Portugal.

It is of some interest that Swedes and Chileans, who live in countries with long coastlines, are among the low seafood consumers, although seafood is a typical component in their traditional diets.

Table 7 also illustrates that in a few countries, indicated with an asterisk, the catches are higher than the reported total supply for human consumption. In several cases this seems to be due to an aquaculture production for export, as best illustrated in the cases of Canada, Denmark, Indonesia, Norway, Thailand and Vietnam. This means that seafood represents a cash crop for export, which at least in low-income countries represents a potential conflict for public nutrition.

The demand for fish has grown in Africa, and fish products in the diet represent about 17 percent of the total animal protein intake, in a global perspective it is second only to Asia where it is about 26 percent. Although total fish supplies have increased, they have not balanced the population resulting in a net import of fishery products. Nevertheless, in 15 African countries fish represents more than 30 percent of the animal food protein consumed according to FAO statistics of 2005 (Table 8).

Table 8. Percent of animal protein from fish (FAO 2005).

Uganda	31.6 %	Nigeria	40 %
Tanzania	32.8 %	Malawi	44.2 %
Guinea	34.9 %	Congo	45.3 %
Angola	35.7 %	Gambia	47.3 %
Côte d'Ivoire	36.0 %	Cameroon	49 %
Senegal	37.5 %	Equatorial Guinea	58.2 %
Togo	39.7 %	Ghana	58.6 %
		Sierra Leone	66.4 %

Nutrition transition and sea food consumption

In most countries, there is an ongoing change in dietary habits and food availability. In affluent societies, the transition from hunting and gathering to agriculture took thousands of years, and industrialization about two centuries. This transition now occurs in the low-income countries over a few decades.

This change in socio-economic development has also induced trend changes in dietary habits which is often characterized as "nutrition transition" (Carballo and Popkin 2002). From the nutrition point of view, this transition includes not only better availability of various food items, but also changes in the dietary pattern and life style, e.g. reduced physical activity. Some of these changes are positive, e.g. a more differentiated food pattern. However, the negative changes include an increased intake of "hidden fat" and refined sugars which increases the energy density of the diet and thereby the risk of obesity. In this perspective, seafood could stand out as a good source of essential nutrients and relatively low fat products, leading to high nutrient density and low energy density. To a certain extent there is a chance to fit convenience seafood products into the modern dietary habits, if they are marketed as healthy foods, while fresh fish consumption might have a tougher role on the modern lifestyle agenda. In societies where seafood is established as staple food, e.g. Indonesia, the nutrition transition has not affected consumption of seafood negatively.

Seafood to solve global nutrition problems?

The discussion of global nutrition problems during the decades after the Second World War was initially focused on the protein gap. The interest of using fish and seafood to a greater extent as valuable sources of animal protein was recognized early. However, with time one realized that the focus on protein was too narrow in a global perspective. Since satisfying energy need is a priority for the body, protein is used as an energy source as long as the energy need is not met. Consequently, the addition of protein rich food was less meaningful as long as energy needs were not covered. As a result, the interest in producing fish protein concentrates for human consumption faded.

In a number of low-income countries, e.g. Ethiopia, India, Uganda and Vietnam, aquaculture is stimulated as an alternative to achieving food security and poverty reduction in small scale farming. In Bangladesh, pond farming and rapid development of coastal and brackish water aquaculture has lead to a conflict leading to degradation of agricultural land. In others, e.g. Tanzania, the number of ponds is decreasing although aquaculture was introduced many years ago as a complement to subsistence farming.

Since Africa, especially sub-Saharan Africa, is one of the most problematic areas with regard to food availability and food security, the potential of aquaculture in this region is of special concern. Integrated aquaculture systems can offer substantial benefits in terms of diversifying and stabilizing farm output to ensure family food security. In addition water storage in fishponds may play a critical role for small farms through cyclical droughts. It has been estimated that 37 percent of sub-Saharan Africa is suitable for small-scale, artisanal fish farming which, if realized, could have substantial impacts on household food security (Aguilar-Majarez and Nash 1998).

In 1993, King reported that over 90 percent of African fish farmers operate one or a few earthen ponds of less than 500 m^2 in surface area with family labour. About half of the output was consumed by the family and the remaining generally sold to neighbours. In Malawi farm ponds integrated in the food producing systems produced about six times the cash generated by the typical smallholder (Brummett and Noble 1995). The constraints for growth of aquaculture on an artisanal, small and medium scale or large scale commercial basis seem to be the poor market infrastructure and weak policies, in addition to the lack of technical advice. This calls for governmental policies to facilitate alleviation of key constraints. In a recent article, Brummett and collaborators (2008) discuss the potential of African aquaculture. They comment that despite the fact that African aquaculture has demonstrated its competitiveness and that hundreds of millions of dollars have been spent on aquaculture in Africa during the last 50 years, not much has happened. The lack of aquaculture development is a mystery, according to the authors.

The interest in aquaculture seems to increase. It was initially introduced to increase the availability of high quality food and sustainable food production in low income countries with limited resources to feed their population. Today aquaculture seems to be used for cultivation of specific seafood products, such as salmon and shrimp, aimed as a cash crop for export, which does not necessarily help the nutrition situation of the population.

Health problems with seafood consumption

Allergic reactions due to a hypersensitivity reaction to a protein in shellfish or fish can be serious. It has been estimated that about four percent of the population in the world are affected by food allergy. The symptoms include cutaneous rashes, but also respiratory and/or cardiovascular symptoms. In severe cases it can lead to a life-threatening anaphylactic shock, which necessitates immediate treatment with antihistamines, adrenaline and steroids. Interestingly, the symptoms are reported to be aggravated by exercise, heat and emotion and may mimic scombroid poisoning.

The allergic reaction is provoked by naturally occurring proteins. As seafood items are protein-rich, it is no wonder that allergies to fish and crustacean shellfish, i.e. shrimps, prawns, crabs, lobsters, represent a common type of food allergy in a global perspective. Allergies to mollusc shellfish, i.e. abalones, conches, clams, oysters and squids, are also described, but seem to be less frequent. In oyster and squid, allergy has been shown to be a result of antibodies against their major muscle protein, tropomyosin. A cross reaction between mollusc and crustacean shellfish has also been described. Thus, individuals with reported allergies against molluscs are recommended to avoid all forms of shellfish. Cross reaction with fish allergies is less commonly reported. The more precise prevalence of allergies to seafood, including shellfish, is still not known. A recent review on mollusc shellfish allergy was published by Taylor in 2008.

It is quite obvious that foodstuffs have a large number of constituents, some of which not only lack nutritive value, but interfere with other constituents and reduce their nutritive value. They are often termed antinutritive factors. In one situation such substances interfere with the uptake or metabolism of certain nutrients. Toxicants produced by various micro-organisms are examples of more potent factors occurring in foods that have been contaminated in one way or another. The toxicity of a substance will also depend on the specific metabolism in individuals. Most of the natural toxins are of vegetable origin, and are concentrated along the food chain in the animal body. Consequently, the toxic problems of food components of animal origin generally occur when the animals have consumed toxic products which have not been detoxified in their liver or, if fat-soluble, have been stored in their adipose tissue.

A number of intoxications have been reported from various seafood products. They are often produced by micro-organisms, such as marine algae. It has been estimated that 40 percent of the world population live within 100 km of a coastline. This makes food poisoning from ingested seafood a serious hazard in many populations. The risk is especially obvious in tropical and temperate climates, but the outbreaks tend to be sporadic and unpredictable. A special gastronomic challenge occurs in Japan where in Asian gourmet restaurants a poisonous fish dish, Fugu, is served by specially licensed chefs who are allowed to prepare puffer fish retaining enough of the toxin tetrodoxin to produce a numbing effect but not enough to cause death (!). Nevertheless, about 50 people die every year of Fugu poisoning.

Scombroid poisoning may occur when mackerel-like fishes are consumed without adequate care and preparation. If the fish is kept at room temperature for several hours after capture, microbial action will convert the amino acid histidine in the muscle protein into a histamine-like substance, saurine. The histamine toxicity is characterized by gastrointestinal symptoms, headache, tachycardia and hypotension.

The most serious of the marine toxins on a worldwide basis is *Ciguatera*, which occurs mainly in the Pacific and the tropics. The Ciguatera poisoning is caused by a microscopic plant, *Gambierdiscus toxicus*, which lives on the surface of coral algae. It is harmless to the fish but it tends to concentrate in the food chain as it passes to larger fish, e.g. red snapper and barracuda. Ciguatera poisoning is difficult to control as it occurs sporadically, but if cases occur, the public should be warned and tests be performed. The poisons are often quite stable against heat and cooking. The symptoms may develop 2–12 hours after ingestion but much earlier in severe cases. Severe neurological disturbances, i.e. delirium, ataxia, convulsions and coma, may last for months and years. There is a need for better methods of detecting poisonous fish and perhaps detoxifying them before eating. There is no antitoxin or specific treatment available so far.

In addition there are a number of other poisonous fishes, which cause, for example, hallucinatory poisoning, sea liver poisoning, shark and ray poisoning, turtle poisoning. A number of shellfish poisonings are also described:

- *Gastrointestinal symptoms* occur after ingestion of contaminated shellfish. Hepatitis B following the consumption of oysters from contaminated production is a classical form.
- *Hepatotoxic disease* leading to acute yellow atrophy may occur after consumption of molluscs which contain a toxin.
- *Paralytic shellfish poisoning (PSP)* occurs after ingestion of a neurotoxin, saxitocin, which is concentrated in shellfish such as mussels, clams, oysters and scallops. Saxitocin is one of the most potent low molecular weight poisons known. It is concentrated in the gills and hepato-pancreas of the shellfish and survives conventional cooking. It may lead to muscular paralysis and pronounced respiratory difficulties, and in extreme cases to coma and death within 2–24 hours. The prognosis is usually good, although weakness and disability may last for several weeks. Treatment in time, including stomach emptying and artificial respiration, averts lasting effects.
- *Amnestic shellfish poisoning (ASP)* is is caused by shellfish that has been contaminated with various marine organisms. Ingestion leads to nausea, vomiting, diarrhoea and abdominal pain after three to five hours, and in extreme cases hallucinations, confusion, memory loss and seizures. An excitatory neurotransmitter, domoic acid, affects the central nervous system leading in extreme cases to temporary or permanent damage including hallucinations, confusion, memory losses, sometimes progressing to seizures and cardiac disorders.

For the following poisonings no treatment is available or necessary and the patient usually recovers within a few days:

• *Diarrhoeic shellfish poisoning (DSP)* leads to diarrhoea, nausea and vomiting and abdominal pain after 30 minutes. Chronic exposure may promote tumours in the digestive tract. Recovery usually occurs within three days.

• *Neurotoxic shellfish poisoning (NSP)* gives rise to headache, chills, diarrhoea, muscle weakness, nausea and vomiting after three to six hours. In extreme cases double vision, trouble swallowing and talking and difficulties breathing have been reported.

Man-made toxicants

There are a number of man-made toxicants that occur as a result of modern food production and food technology. These include such components as residues of biocides and fertilizers. Other examples are chemical substances that are produced during the processing of food, or various food additives and preservations. If on the other hand no preservatives are used, the microbial action in foodstuffs may result in formation of toxic substances. Components that result from the pollution of the environment and from mistakes during handling of the foodstuff or accidents could be added. Many of these situations arise with seafood, which represents a real problem for aquaculture, not least crustacean farming.

Heavy metals, i.e. arsenic, mercury, cadmium and lead, occur naturally in the environment and may enter the biosphere from land or water. Their toxic properties may change drastically as a result of an alteration of their chemical form, e.g. biological methylation. Arsenic has a complex chemistry and there is a need for more specific data, as there are large differences in toxicity of various forms of arsenic for humans. Other minerals, such as copper, zinc, chromium and vanadium are essential trace elements.

The occurrence of environmental pollutants depends on the type of fish. Thus in fish with low fat content, especially in freshwater and brackish water, methyl mercury is the dominant problem. In fatty fish persistent organic pollutants are the dominating problem, e.g. dioxins or dioxin-like PCB (polychlorinated biphenyls). Marked differences are reported in the toxicity of individual chlorobiphenyls. DDT (dichlorodiphenyltrichloroethane) also belongs to the global pollutants and is concentrated in higher organisms.

Regular consumption of especially fatty fish from freshwater or brackish water will increase the risk of increased concentration of environmental toxins. The tolerable intake levels of dioxin and dioxin-like PCBs, as well as of methyl mercury, may be surpassed. This is considered as a matter of concern for children and women in child-bearing age, although so far the consumption of such fish is still low for most individuals.

Of special concern is the effect of mercury in humans. In the middle of the 20th century pollution of mercury in water and air was observed as a result of widespread use of organic mercury compounds as fungicides in the paper industry and agriculture. Serious effects in humans were first reported in 1953–1960 when 111 people living around Minimata Bay were seriously disabled and some even died. This was shown to be due to their eating fish and shellfish which had a high mercury concentration. Studies in Sweden revealed elevated mercury concentrations in erythrocytes, plasma and hair in people who eat a lot of freshwater fish but also in those with a high consumption of sea fish (Ackefors 1971). Although the use of mercury compounds is now banned, the whole environment is still heavily contaminated. Therefore, it will take a long time before mercury concentrations have returned to acceptable levels.

It should be remembered that these toxins are accumulated in the body, usually in the adipose tissue, for a long time. It is the total body storage of these components, rather than the acute intake, that is critical. This also means that when environmental pollutants are stored, the risk for toxic reactions is increased during periods of negative energy balance, and a concomitant increased breakdown of adipose tissue, in the individual. This is of special concern for lactating mothers as these types of pollutants usually are lipid soluble and consequently excreted in the breast milk.

During the last years interest has been devoted to the increased risk of pollution from pharmaceutical products through the central sewage system. Antibiotics, hormones and other components from the breakdown of various pharmaceutical drugs, which cannot be taken care of in the normal sewage treatment, may leak into the seawater. The dimension of the problem is still under discussion, but there are some indications that it has lead to disturbances in fertility of certain fishes. To which extent it also represents a risk factor for humans is still not elucidated.

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A CATCH FOR THE FUTURE – METHODS FOR MORE SUSTAINABLE PRODUCTION OF SEAFOOD PRODUCTS

Carbon footprint, energy use, life cycle assessment and eco-labeling of seafood

Friederike Ziegler

Abstract

Global resource use and environmental impact, such as the use of energy and formation of greenhouse gases caused by food production, including seafood, have recently received increased attention. Life Cycle Assessment is a method to study these types of environmental impact along with many other categories of environmental impact. The results can be used to improve the environmental performance of production chains or to establish criteria for eco-labeling of the products. Energy use and climate impact in capture fisheries are very closely related, since the energy source used in modern industrialized fisheries is fossil fuels. When synthetic refrigerants are used in onboard cooling systems with high rates of leakage, the additional non-energy related greenhouse gas emissions can be substantial.

In aquaculture, a considerable part of the feed is crop-based. In agriculture, the connection between energy use and climate impact is less clear since a large part of the greenhouse gas emissions does not stem from energy use, but rather from the production of fertilizers and biogenic processes. For both types of seafood production, however, fishing and feed production – the initial part of the chain – are the activities that contribute most to the total impact. The only post-landing activity that has been able to outcompete the climate impact of industrial fishing is airfreight. Energy use and climate impact of capture fisheries are mainly determined by the condition of the stocks and by the fishing method used. For farmed fish the main determinants are the amount of feed used and the composition of the feed. Crop-based feed ingredients are on average more resource-efficient than animal-based inputs.

The inclusion of criteria regarding climate impact into existing eco-label programs makes them more holistic and gives the consumer the chance to choose the seafood with the lowest environmental impact.

Introduction

Historically, a substantial share of research on fisheries and their environmental impact has dealt with the direct biological impact on fish stocks as a result of the annual harvesting of a substantial part of their biomass (SOFIA 2008). Numerous studies of the more indirect effects on the surrounding marine ecosystem due to landing and discarding of fish as well as seafloor impact of fishing have also been conducted (Jennings and Kaiser 1998, Pauly *et al*. 1998, Kaiser and de Groot 2000, Myers and Worm 2003).

As regards aquaculture, the second way to produce seafood, the environmental debate has largely centered on the eutrophication effects in the immediate vicinity of fish farming facilities. Another research focus has been assessing the risks imposed by escaped farm fish on wild stocks of the same or closely related species in terms of disease and parasite transmission and genetic crossing (Krkosek *et al*. 2007).

Global environmental impact, primarily climate impact[1], has recently received increased attention worldwide. Climate impact is caused by large-scale combustion of fossil fuels resulting in carbon dioxide emissions, but also by release of dinitrous oxide and methane from agriculture. Climate impact and energy use of seafood production are the focus of the present chapter. Methods for studying these types of environmental effects and recent research findings are presented. Existing systems for eco-labeling of seafood products are reviewed, along with proposals as to how these could include more environmental aspects than is currently the case.

Energy consumption in fishing and aquaculture

Energy utilization in fishing

A number of factors affect energy consumption per kilogram of fish landed. Perhaps the most significant are fishing gear and species biology. Of course, the latter is linked to the design of fishing gear, but it should be noted that schooling pelagic (mid-water) species, such as herring, offer better potential for large-scale, energy-efficient fishing compared with seafloor (demersal) fish or shellfish, which live less densely and close to the seabed. Therefore, fishing that uses gear such as purse seines and pelagic trawls to catch pelagic species are often ranked as energy-efficient. In many cases, several fishing methods are deployed to catch a particular species, frequently resulting in major differences in terms of energy efficiency (Thrane 2006, Tyedmers 2001, 2004; Ziegler *et al*. 2003, Ziegler and Valentinsson 2008).

Examples include Pacific salmon fisheries that deploy purse seines, trolling or gillnets and Norway lobster fisheries using seafloor trawls or creels (Figure 1). Flatfish can be caught using gillnets, bottom trawls or beam trawls, the latter requiring 15 times as much fuel per kilogram flatfish landed compared to Danish seine (Thrane 2006).

Energy efficiency depends, in part, on the fishing technique. The terms "active" and "passive" fishing methods are commonly used, with active meaning that fishing gear is pulled through the water or along the seafloor (as in trawling and dredging), while passive, or fixed

1. Climate impact, greenhouse gas emissions, global warming emissions and carbon footprint are all used as synonyms in this chapter, meaning the sum of emissions contributing to climate change weighted according to IPCC 2007.

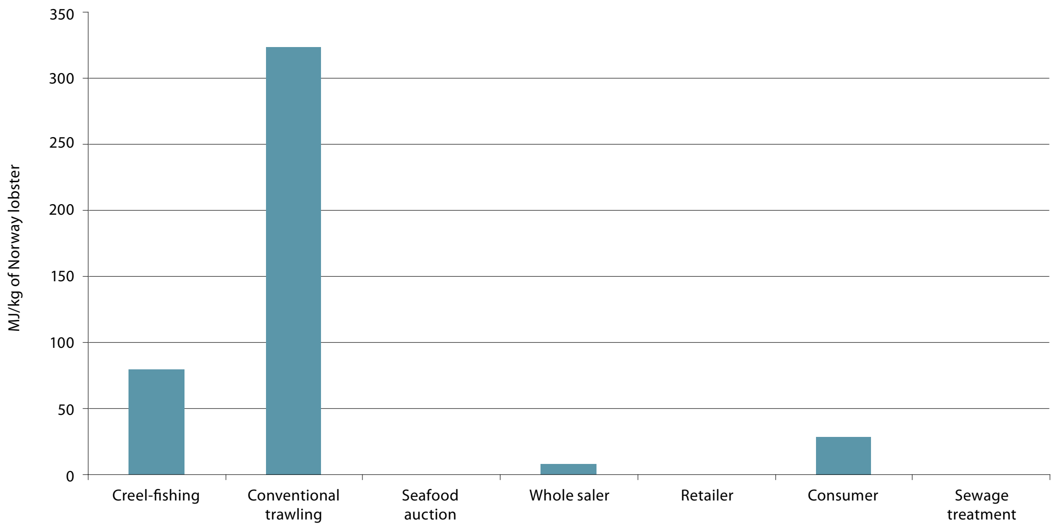

Figure 1. Energy utilized in the production of one kilogram of cooked Norway lobster (unshelled) from the catch to the consumer. Creel-fishing and conventional trawling represent alternative fishing methods. *Source*: Ziegler and Valentinsson (2008).

gear, means that the gear is laid out and then emptied one or two days later (such as gillnets, long lines, creels and pots). Occasionally, bait is used – normally from pelagic fisheries – to attract the target species to the fixed gear (such as creels, pots and long lines). Generally, fixed gear types are more energy-efficient (Thrane 2004, 2006; Ziegler and Valentinsson 2008, Ziegler *et al.* 2009), with a few exceptions (Tyedmers 2001).

Although pelagic trawling is an active fishing method, it is one of the most energy efficient, mainly because fishing is done in the water column rather than along the seafloor. The fact that many pelagic target species are schooling fish contributes to a lower fuel-per-catch ratio.

The stock situation is another key factor that can reduce fuel efficiency even with when using fixed gear. LPUE (Landings Per Unit of Effort) is a measure of the fish volume landed per unit of expended fishing time; a common unit is kilos landed per hour fished. Low-density fish stocks mean that more time is required to accumulate the same catch, compared to the same fish stock at a higher density using the same gear. It is difficult, if not impossible, to fish an over-exploited stock in an energy-efficient manner. In other words, in addition to the fishing method, the stock situation is a key factor in determining the energy efficiency of fisheries.

Figure 2 shows that, in the early 1980s, four times more cod per hour were caught in Swedish trawl fisheries in the Baltic compared to cur-

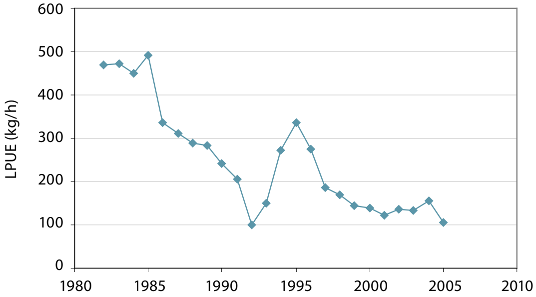

Figure 2. Cod landings per trawl hour in Swedish trawl fisheries in the Baltic Sea, 1982–2005 (data from the Swedish Board of Fisheries).

rent conditions, so it was necessary to expend only 25 percent of the time required to harvest a given catch. This of course heavily influences energy utilization per kilogram of fish landed. Tyedmers (2004) noted that energy efficiency in many fisheries worldwide has declined in recent decades, despite parallel technological progress that made it easier to localize favorable fishing grounds. This is probably due to the considerable over-exploitation of many stocks during the same period (Tyedmers 2004). The same conclusion was drawn by Schau *et al*. in a recent analysis of a number of Norwegian fisheries over time (Schau *et al*. 2009). There are indications that the steep increases in fuel prices recently have lead to higher fuel efficiency in fisheries, although this has not yet been documented.

Energy utilization in aquaculture

Energy consumption in aquaculture begins with the energy required for the production of feed and other inputs for fish farming (such as net pens, anti-fouling agents, etc.). Filtrating mussels that are farmed require no feed input, as opposed to farmed fish. Some fish (such as carp, tilapia, and pangasius) are omnivores and can survive without animal-based feed ingredients, hence they can normally be fed using agricultural products or residues. Other species (such as cod, salmon, turbot, halibut and rainbow trout) are predators that – being higher up in the food web – require some marine-based feed, i.e. a combination of fishmeal and fish oil. This marine feed derives either from by-products from fish processing or from targeted fishing for small pelagic species such as herring, sprat, sand eel, blue whiting and anchovy in various parts of the world.

It has been confirmed that energy utilization for the production of marine-based ingredients is considerably higher than for agricultural inputs (Pelletier and Tyedmers 2007). The same study also noted that feed represented more than 90 percent of the total energy utilization in the production chain from feed production to ready-to-eat salmon. Thus, the energy used directly to pumping air and water in fish farming, and in cooling and freezing equipment, plus fuel for transport, represents a smaller share of the total energy utilized in getting a salmon to the consumer's plate (Troell *et al*. 2004, Tyedmers *et al*. 2007).

Life Cycle Assessment

Life Cycle Assessment (LCA) is a method that was first used to assess the environmental impact of food products in the early 1990s and is now standardized in ISO 14040-44 (ISO 2006a, ISO 2006b). The method was initially developed to quantify the environmental impact of industrial products, but since the mid-1990s it has also been applied to the food production system. The assessment is usually divided into four phases:

1. Goal and Scope Definition
2. Inventory Analysis
3. Environmental Impact Assessment
4. Interpretation

The goal and scope phase describes the system to be studied and the boundaries set, meaning what is to be included and omitted. What is referred to as the functional unit is defined, that is, the product to be monitored during the LCA process – for food products this frequently involves a kilo or a typical packaging size.

The inventory phase involves the compilation of data on resource utilization (energy and materials) and environmental impact (emissions) of the production chain, as well as data on production, that is, the quantity of the different products emerging in the various stages. This phase is often the most time consuming, and the practitioner focuses data compilation on the core components of the system in question ("foreground system") and uses general data from LCA databases for what is referred to as the "background system" (such as the production of fuel, power, packaging materials and waste management). Dedicated LCA programs may be used or calculations can be performed using general computational software.

There are a number of strategies available to handle processes in which more than one product is manufactured (main product and by-product). One approach is to apply a procedure called allocation, which separates the environmental impact of earlier stages of the products, based either on their weight or economic value in relation to each other, or some other physical relationship between them. Another approach, recommended in the ISO standard, is to conduct what is called a system expansion, in which either the by-product is included in the functional unit, or an analysis is made of a parallel system that only produces the by-product, which can then be subtracted from the original system based on two products. Whichever is selected, the choice of method for the by-product must be clarified and justified during the goal and scope phase, as this can considerably influence the final result. Completion of the system inventory permits calculation of the initial results, which will appear as a lengthy list with hundreds of resources used and the emissions created during the production chain.

To facilitate an overview, two procedures – classification and characterization – are undertaken in the environmental impact assessment phase. All emissions to air, land and water are classified in the environmental impact categories to which they contribute. Thus, for example, carbon dioxide and methane are classified under the greenhouse effect; sulfur oxides under acidification; and freons under both the greenhouse effect and depletion of the ozone layer. Subsequently, the characterization method is used to weight the various emissions in each environmental impact category. For example, all emissions contributing to the greenhouse effect are converted into carbon dioxide equivalents based on the characterization indexes set and updated by the Intergovernmental Panel on Climate Change (IPCC 2007) of the UN. Table 1 shows the climate impact of greenhouse gases in the production of seafood, in kilograms of carbon dioxide equivalents. One kilo of freons, depending on which kind, has the same effect as 1,000 to 15,000 kilos of carbon dioxide.

Characterization results in a value for each environmental impact category (greenhouse effect, eutrophication, acidification, ozone depletion and so forth). This procedure permits the weighting of environmental impact categories to form a single indicator. However, as in the case of normalization towards average emissions per capita, this stage is voluntary according to the ISO standard.

Table 1. Climate impact of greenhouse gases that are significant in the production chain of seafood products. *Source*: IPCC (2007).

Emission	**Origin of substance**	**Climate impact (kg CO_2 equiv/kg)**
R744 (CO_2), carbon dioxide	Fossil fuel combustion and "natural" refrigerants	1
R717 (NH_3), ammonia	Natural refrigerant	< 1
CO, carbon monoxide	Fossil fuel combustion	2
CH_4, methane	Biogenic emissions from animal husbandry, landfill, composting	25
N_2O, nitrous oxide	Emissions from agriculture (commercial fertilizer, manure, and land processes)	298
R22	Synthetic refrigerant, HCFC type	1,810
R404a	Synthetic refrigerant, HFC type	4,540
R507a	Synthetic refrigerant, HFC type	4,600

This is followed by the fourth and final phase – interpretation. This phase analyzes the results, both overall and per lifecycle phase or process, and identifies the major and minor aspects as well as which data, choice of method and assumptions that are most significant for the result. Subsequently, these are varied in a sensitivity analysis and attempts are made to see how dependable the results and the conclusions are.

Finally, the ISO standard states that in the event that two products are compared using LCA and the findings are to be published, an independent review must first be undertaken.

Energy consumption = carbon footprint? Which emissions are significant?

Energy use and global warming emissions – are these synonymous, and, if not, what is the difference? In the case of fossil fuel combustion, these two are interrelated. However, the utilization of non-fossil energy sources such as hydropower and nuclear power leads to substantially lower emissions of greenhouse gases and, thus, lower climate impact. As a result, electricity utilization in Norway or Sweden hardly features in climate calculations, since it derives largely from hydro and nuclear power. The same use of electricity produced from fossil fuels gives a much higher carbon footprint per unit of energy used.

The climate impact of fisheries is dominated by carbon dioxide emissions via onboard diesel combustion, which is related solely to the amount of fuel used. The second major factor is the leakage of refrigerants from onboard cooling equipment (for cooling, freezing, and ice-making, etc) if those used have a high climate impact. As opposed to the progress made in onshore operations, fishing and shipping lag behind in the phasing out of freons with a high impact on the ozone layer. HCFCs – the most harmful types of refrigerants for the ozone layer (and which also have a substantial climate impact) – are still common on fishing vessels. This factor – combined with the fact that mobile cooling and freezing units, especially in the maritime environment, are subject to higher leakage than onshore fixed units – represents a substantial contribution of refrigerants to the overall climate impact of wild-caught fish-based products.

The phasing out of HCFCs in maritime applications is scheduled for completion by 2010, which means the global fishing fleet is faced with major changes; to adjust existing equipment to less ozone-threatening alternatives or to completely replace equipment. One problem is that while the HFCs that offer an alternative are favorable in terms of the ozone layer, they have a higher climate impact. Consequently, a transition from "synthetic" to "natural" refrigerants such as ammonia/carbon dioxide-based systems is preferable from the environmental viewpoint, and is readily feasible in terms of technology (SenterNOVEM 2003, UNEP 2000, NMR 2000). Another benefit for onboard freezing is that we can expect a reduction of 20–30 percent of the energy used for freezing (which is generated by the diesel engine), since ammonia is a more effective cooling agent than is R22.

In the case of farmed fish, diesel consumption to catch the raw material for fishmeal and fish oil is also significant. However, fish feed is based on at least 50 percent agricultural products such as wheat, maize and soybean. Generally, these have a considerably lower climate impact compared with animal-based feed components (Pelletier and Tyedmers 2007), but the ranges of marine and agricultural ingredients overlap, so that the most intensive crop derived inputs give rise to more global warming emissions than the least intensive marine inputs.

Agriculture differs to the extent that its climate impact is *not* dominated by fossil fuel combustion and the resulting carbon dioxide emissions. The dominant climate impact of agricultural products frequently emerges in the form of dinitrous oxide and methane, two highly potent greenhouse gases (Table 1), that derive from biological processes in agriculture. Dinitrous oxide is formed in the production of commercial fertilizer, as well as in manure handling and land processes during cultivation. Methane is formed in natural processes in the digestive system of ruminants, such as cattle.

Looking at the entire production chain from fisheries to fish consumption, it is the fishing phase that accounts for the greatest share of total energy utilization in the form of onboard fuel combustion during fishing (Thrane 2004, 2006; Ziegler *et al.* 2003, Ziegler and Valentinsson 2008). This applies *also* when fishing is relatively energy efficient and the product is prepared and packaged in a relatively energy-intensive manner (such as marinated herring, Christensen and Ritter 1997). But what is the effect of long-distance transport? Does the conclusion apply whether or not long-distance transport is involved?

The significance of transport of seafood

As noted above, the fish stock situation and fishing method are significant factors in determining fishery energy efficiency, which in turn accounts for the greatest energy consumption and climate impact. However, a much-discussed aspect is the significance of long-distance transport. In addition to the actual distance that the raw material or product is transported, there are several other major factors to be considered. One of these is the transport mode, whether transport is by truck, train, ship or aircraft. Other factors include vehicle size, load capacity used and cooling requirements.

Fish is a very special type of food in terms of transport. Fresh fish continues to be transported on ice in boxes and – due to odor and meltwater – it cannot be transported in combination with other food products, making its transportation inefficient from the energy viewpoint. Also, small sub-optimally loaded trucks are used. The climate impact of transporting a kilogram of fresh fish using a small fish truck (that can carry 3.5 tonnes, but only carries a load of one) between Gothenburg and Borås in Sweden (50 km) is of the same magnitude as transporting a kilo of fish in a fully loaded container vessel from Southern Africa to Sweden (10,000 km), despite the extra energy and refrigerant required to keep the product frozen.

Of course, the form of the fish product (fresh, frozen, smoked or preserved) considerably influences how transport to the consumer is undertaken. If you want fresh fish from the other side of the globe, it must be air-freighted. The use of air transport gives rise to the only known example in which transport is of greater energy significance and overshadows the fishing operation from the climate viewpoint (Seafish 2008, Ziegler 2008). Otherwise, transport typically makes up less than 20 percent of the total carbon footprint of frozen seafood.

A large share of fish catches worldwide is conveyed in frozen form to Asia (mainly China) for filleting before being transported back as finished products. Thus, the trip that fish make from the initial landing (in northern Norway, for example) via Rotterdam to Qingdao in China, and back again on the same route to a European consumer, covers 42,000 km, which is more than the circumference of the planet. Also, the fish volume transported to China is almost 50 percent more than the final fillet volume transported from the country. So those who criticize imports of fish fillets from New Zealand (24,000 km), Chile or Vietnam due to long-distance transport should remember that a sizeable portion of the fish caught in local waters is processed in Asia.

A complicating factor is that the fillet yield from filleting in China is higher than mechanical filleting of the same quality in Norway, for example. Thus, more fillets per kilo of fish are gained from the initial volume entering the processing plant. This difference means that a smaller fish volume needs to be caught to get a kilo of fillet to the consumer, which from a biological point of view is positive since the stock is saved. Of course, the optimum situation would be to avoid transportation, and fillet the fish close to the fishing operation and consumer – using manual or mechanical means to provide the maximum yield.

Eco-labeling of seafood

Eco-labeling of wild-caught seafood

A number of organizations impose criteria covering the eco-labeling of wild-caught seafood. The UK based Marine Stewardship Council (MSC) and the Swedish KRAV are two such organizations. A common feature of these bodies is that they use a third party to assess if a fishery meets the criteria. The two organizations take into account the utilization of fish stocks, the by-catch volume and the effects on other aspects of the marine ecosystem associated with the management system. In brief, they ensure that fish stocks are used in a sustainable manner or that the fisheries are progressing in this direction; that fishing does not give rise to unacceptable effects on the surrounding ecosystem; and that there is a functioning management system within which appropriate measures are taken if the stock situation deteriorates (Thrane *et al*. 2009). MSC certified fish is produced and sold around the globe, while KRAV has Sweden as its main market.

In addition to these certification systems, there are also a number of consumer guides, including those designed by WWF in Europe and by Monterey Bay Aquarium's Seafood Watch, which primarily deals with seafood on the North American market. These players assess the stock situation, ecosystem effects on by-catch species and the seafloor. Using such data, fish species are categorized using a green, amber and red rating code. While they currently do not include energy use nor climate impact, as already mentioned, these are often correlated to stock status and seafloor impact and discard levels (Thrane 2006, Ziegler 2006) and can therefore be considered being treated indirectly.

Eco-labeling of farmed seafood

A number of eco-labeling organizations provide criteria for aquaculture. In the Swedish market, for example, there is KRAV/Debio (with rules drawn up in cooperation between the Norway-based Debio and the Sweden-based KRAV) and Naturland (Germany-based Association for Organic Agriculture). MSC does not currently cover aquaculture, which the Soil Association (UK) does. However, WWF has recently started an initiative to form an Aquaculture Stewardship Council (ASC), planned to become operational in 2010.

The criteria cover requirements regarding fish farm location, water quality, fish feed origin and dosage, fish density in cages and other aspects of fish welfare, medication and other use of chemicals in operations, measures to guard against cage damage, origin of fish for stocking, keeping of records, transport, and slaughter.

The consumer guides noted in the previous section also assess farmed seafood in terms of feed composition and local eutrophication effects, for example.

Improvement potential for ecolabels

During 2008 and 2009, KRAV (the Swedish certification system for organic production) and Svenskt Sigill (a quality labeling system for Swedish agricultural produce) have developed operations-based criteria concerning climate impact for seafood products. Operations-based means that they encompass requirements governing the production method, just as in the case of KRAV's rules for organic production.

For seafood products from capture fisheries, the criteria are that the stocks are sustainably fished; that fuel consumption in fishing is less than a certain level per kilogram of fish landed; and that the refrigerant used onboard either has a very low climate impact or that leakage is minimized.

In the case of farmed fish, the rules cover the amount of feed required per volume of fish produced and feed composition. The limit on fuel consumption for designated feed fisheries is lower than the limit for fish for direct consumption. No growth-enhancing nutrient supplements for farmed fish are permitted, and land-based fish farms may be approved if they have relatively low energy consumption and use renewable energy sources. This also applies to fish processing plants. General rules are also being prepared for packaging materials and transport.

The wide-spread use of eco-labels can contribute to lowering the energy use and climate impact of seafood, and give the seafood consumer the possibility to make an active choice favouring more sustainable seafood products (Thrane *et al*. 2009). Life Cycle Assessment provides a methodology to assess both initial performance and improvement along the way.

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Tomorrows' catch? (Poster in Senegal.) Getting the boat out, Saint Louis, Senegal. *Photos*: Kajsa Garpe (courtesy of the Swedish Society for Nature Conservation)..

THE IMPORTANCE OF FISHERIES AND AQUACULTURE TO DEVELOPMENT

Cambria Finegold

Abstract

Small-scale fisheries and aquaculture make critical contributions to development in the areas of *employment*, with over 41 million people worldwide, the vast majority of whom live in developing countries, working in fish production; *food security and nutrition*, with fish constituting an important source of nutrients for the poor and often being the cheapest form of animal protein; and *trade*, with a third of fishery commodity production in developing countries destined for export.

With most capture fisheries worldwide considered fully exploited or overexploited, aquaculture will be central to meeting fish demand, which will continue to increase with population growth, rising incomes and increasing urbanisation. As aquaculture develops, however, governments will need to manage its potential ecological and social impacts. African aquaculture, which has grown much more slowly than in other regions, faces numerous challenges, including resource conflicts and difficulties in accessing credit, quality seed and feed, and information. Also key to meeting growing demand will be improvements in post-harvest processing to reduce fish losses.

Both fisheries and aquaculture are often neglected in national development policy and donor priorities, as policy makers often do not have access to data which reflect the importance of fisheries and aquaculture to development. Appropriate policies and regulation remain important, however, both in managing capture fisheries and ensuring that aquaculture development is pro-poor and sustainable.

Fisheries, aquaculture and development – introduction

Despite the significant contributions that fisheries and aquaculture make to employment, nutrition, and trade in the developing world, they are rarely included in national development policy and donor priorities. This is largely due to problems with valuation of small-scale fisheries, as policy makers often do not have access to data which reflect the importance of fisheries and aquaculture to development.

The stagnation or decline of capture fishery production in many parts of the world underscores the importance of fisheries policy, however, as the current state of stocks can be at least partially attributed to the difficulties of regulating fisheries and preventing their overexploitation. Even with improvements in regulation, however, pressures on capture fisheries will remain, due to continued population growth. Further development of sustainable aquaculture and improvements in the post-harvest sector to reduce losses could help to maintain fish supply and the contribution of fish to development.

Employment, production and trade

While data on fisheries in developing countries are often patchy[1], it is nevertheless possible to identify trends in the importance of fisheries and aquaculture for developing countries, particularly in the areas of employment, consumption, and trade.

Employment

Employment in fishing and aquaculture has grown rapidly over the past few decades, increasing more than threefold from 13 million people in 1970 to over 41 million in 2004 (Figure 1). Employment in the fisheries sector has grown more rapidly than both world population and employment in agriculture. Most of this growth is in Asia, where over 85 percent of the world's fisherfolk live, and is largely due to the expansion of aquaculture in this period (FAO 2006, FAO 1999).

While the number of people employed in fisheries and aquaculture in developing countries has been growing steadily, it has been stagnant or declining in most industrialised countries. This decline has been most pronounced in capture fisheries, while employment in aquaculture has increased in some industrialised countries.

Millions of women in developing countries are employed in fisheries and aquaculture, participating at all stages in both commercial and artisanal fisheries, though most heavily in fish processing and marketing. In capture fisheries, women are commonly involved in making and repairing nets, baskets and pots, baiting hooks, setting traps and nets, fishing from small boats

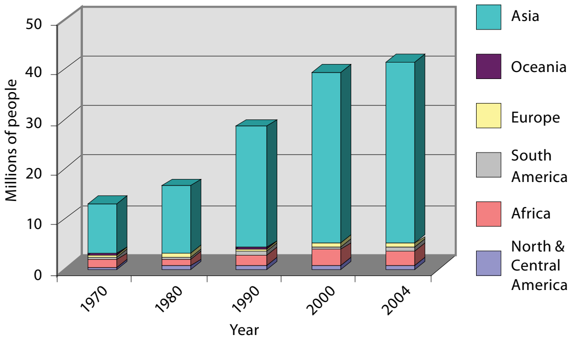

Figure 1. Employment in fisheries and aquaculture. Data for 1970, 1980 and 1990 are from FAO (1999), while data from 2000 and 2004 are from FAO (2006), and therefore may not be perfectly comparable.

1. Though many countries collect data on commercial marine fisheries and on fish exports, catches by artisanal and part-time or occasional fisherfolk often go unrecorded. The status of inland fisheries is also much more difficult to assess than marine fisheries, as fishing is often practiced in remote locations by poor small-scale fishers who target a wide range of species using several types of gear, and whose catches are rarely disaggregated by species if recorded at all. Data on fisheries in developing countries therefore often underestimate the numbers of people who depend on fisheries for their livelihoods and diets, and the actual contribution of fisheries to development is likely to be higher than is reflected in statistics.

and canoes, and collecting seaweed, bivalves, molluscs and pearls. They are rarely involved in commercial offshore and deep-water fishing. In aquaculture, women feed and harvest fish, attend to fish ponds, and collect fingerlings and prawn larvae. Women play a major role in fish processing in many parts of the world, both using traditional preservation methods and working in commercial processing plants.

In addition to affecting food supply, the status of fish stocks in capture fisheries is likely to threaten the livelihoods of small-scale fisherfolk and traditional fish processors as competition for limited resources increases. Larger-scale operators with greater access to capital and gear are already emerging in many areas, leading to changes in the structure and location of post-harvest activities and concentrating ownership and control of resources. In India, for example, fishing practices are changing with rising investment, and higher levels of mechanisation and motorisation are leading to greater centralisation of landings and competition over the catch. In the past, small-scale traders were able to purchase fish from local fishers at decentralised beach-based landings, sometimes accessing fish through husbands or taking the fish on credit and paying once they had sold it. The increasing centralisation of landings, however, has led to fierce competition at landing sites, favouring those with greater access to credit and infrastructure and marginalising traditional fish processors and petty traders (FAO 2007).

Production and consumption

Data on fisheries in developing countries often do not fully account for artisanal and subsistence production, as the magnitude of the landings of these fisheries is not generally known by the responsible fisheries administration. It seems clear, however, that capture fisheries worldwide are currently being fished at or near capacity, and that further growth in fish production will come primarily from aquaculture. FAO (2006) estimates that marine capture fisheries production will remain between 80 and 90 million tons per year, and freshwater fisheries, which face environmental degradation and competition for use of freshwater resources from other sectors such as hydropower and agriculture, are unlikely to expand significantly either.

Per capita fish supply in low-income food-deficit countries (LIFDCs) (excluding China) has increased from 5.0 to 8.3 kg since 1960, due primarily to the growth of aquaculture and to increased production from inland capture fisheries in developing countries (FAO 2007). In sub-Saharan Africa, however, per capita fish supply is declining, dropping from a peak of 9.9 kg in 1982 to 7.6 kg in 2003. This is due to rapid population growth, stagnant capture fishery production, and the slow expansion of aquaculture in the region (FAO 2006).

Demand for fish continues to increase in most of the world – in line with population growth as well as increases in consumption of animal protein associated with urbanisation and rising incomes. In developed countries, demand for high-value carnivorous species such as salmon and shrimp has also increased, largely due to income growth and urbanisation, as well as a shift

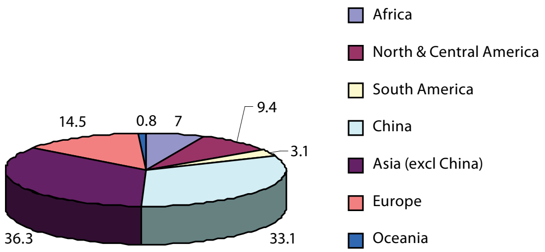

Figure 2A. Food fish supply in 2003 (million tons live weight equivalent). *Source:* FAO 2006.

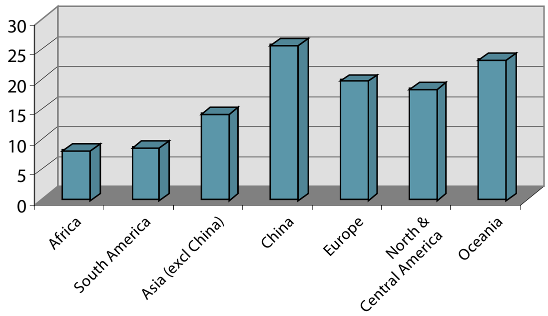

Figure 2B. Per capita fish consumption 2003 (kg/person/year). *Source:* FAO 2006.

in preferences away from red meat and towards fisheries products (Delgado, Wada, Rosegrant, Meijer and Ahmed 2003).

Trade

A large portion of fish production is destined for export, around 40 percent of global production being traded internationally, and exports from developing countries accounting for some 60 percent of this (see Ababouch, this volume). They are now net exporters of fish to developed countries, having shifted dramatically from being net importers (over 1.2 million metric tons in 1985) over the past two decades (Delgado *et al*. 2003).

Over 30 percent of fishery commodity production in developing countries is destined for export (FAO 2005a), and it is an important source of foreign exchange for many countries, including Chile, Mozambique, Senegal, and Thailand. While industrial fishing activity continues to produce a significant portion of fisheries exports in some countries, much of the recent increase in exports from developing countries has come from small-scale fisheries. Much of this is driven by rising demand for high-quality demersal fish in developed countries. The rapid growth in contribution of fish to total export earnings in Uganda (from less than one percent in 1990 to 17 percent in 2002), for example, was based largely on artisanal fishing of Nile perch in Lake Victoria (FAO 2007).

An increasing amount of trade in fish products is between developing countries, however, rather than from developing to developed countries. Demand for fish in developing countries continues to grow, due both to population growth and increased per capita consumption, while overall demand in developed countries (including the USSR) has stagnated since 1985. While there is increasing demand for higher value fish in developing countries, low-value fish continue to make up the bulk of fish consumed there, and they are projected to remain net exporters of high value finfish and importers of low-value food fish (Delgado *et al*. 2003).

International trade in fisheries products has been shown to have a positive effect on food security in many developing countries, stimulating increased production, generating foreign exchange which can be used for food imports, and enhancing the trade-based entitlements of people engaged in fishing and fish processing. Much of the discussion around the food security impact of international fish trade has focused on whether fish production for export reduces the amount of fish available for local consumption, presenting fish exports as a trade-off between foreign exchange earnings and domestic food security. Such a perspective, however, fails to take into account that foreign exchange from fish exports helps to finance imports of other foods, including fish products, and that production for export helps to raise the incomes of poor fisherfolk and people employed in fish processing, enabling them to achieve greater food security through enhanced purchasing power. In Thailand, for example, a decrease in rural poverty has been attributed to the export orientation of the fisheries sector and concomitant increase in the incomes of poor fishers. Fish processing for export can also generate employment, particularly among young women, though export-orientation in fisheries reduces the quantity of fish available to traditional fish processors (typically middle-aged women with little education), affecting their livelihoods.

Fisheries in development policy

The contribution of fisheries and aquaculture to development has consistently been underestimated both in national development and poverty reduction strategies and in international cooperation. FAO (2005b) identify two factors which influence the degree to which fisheries are included in development policy in a given country: the sector's contribution to foreign exchange earnings and its contribution to food security and nutrition (measured by dependence on fish protein). The more reliant a country is on fisheries for its foreign exchange earnings and food security, the argument goes, the more likely that policy makers will recognise their importance and that this will be reflected in development policy. As farming and terrestrial livestock often both generate more foreign exchange and are perceived to make a larger contribution to food security than other renewable resource sectors such as forestry and fisheries, they generally receive much more attention in national development strategies and donor priorities.

When faced with resource allocation decisions, many governments prioritise water use for human consumption, agriculture, hydropower, and industry over inland fisheries and aquaculture. This is largely attributable to the perceived contribution of each sector to development, but also to the prevalence of single water-use systems. Encouraging multiple uses of water, however, can increase its productivity and allow for simultaneous development of several sectors. Use of freshwater for aquaculture and agriculture, for example, is not necessarily mutually exclusive, and integrated aquaculture-agriculture (IAA) systems have been shown to increase the productivity of agricultural activities on farms which have ponds. IAA ponds also contribute to the resilience of small farms, enabling them to maintain some degree of food production during droughts (Brummett 2006).

The data problems identified in the first section also contribute to poor recognition of the contributions of fisheries to development. Since data on artisanal, subsistence and inland production, fish-based livelihoods and consumption patterns in developing countries tend to be fairly sketchy, they often under-represent the contribution of fisheries to development. Thus the perceived contribution of fish to foreign exchange earnings and food security is often lower than their actual contribution, further reducing the chances that fisheries and aquaculture will be adequately addressed in development policy.

Development aspects of health and nutrition

Even when consumed in small quantities, fish often comprises a nutritionally important part of many people's diets in developing countries. It is a vital source of protein and micronutrients, and improves the quality of protein in largely vegetable and starch-based diets by providing essential amino acids. FAO (2006) has estimated that fish accounts for approximately 20 percent of animal protein consumption in LIFDCs. In some coastal and island countries (including Bangladesh, Indonesia, Senegal, and Sri Lanka), it provides

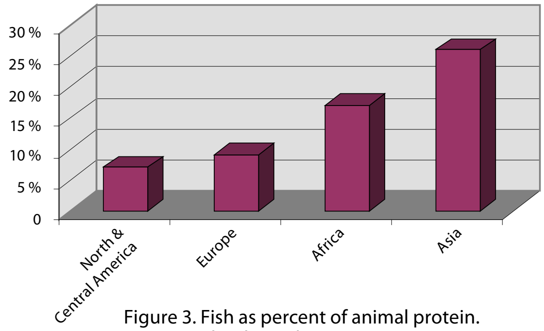

Figure 3. Fish as percent of animal protein.
Source: Delgado *et al.* 2003.

over 50 percent of animal protein, and reaches 62 percent in Gambia and 63 percent in Sierra Leone and Ghana. It is a particularly important component of the diets of the poor, as it is often the most affordable form of animal protein.

Fish is also rich in iron, zinc, magnesium, phosphorous, calcium, vitamin A and vitamin C, and marine fish is a good source of iodine. Many of these vital nutrients are found only in small amounts, if at all, in staple foods such as maize, rice and cassava which make up the bulk of people's diets in developing countries. Fish are an indispensable source of these nutrients for many people, and small low-value fish, which are largely consumed by the rural poor, provide more minerals than the same quantity of meat or large fish, as they are consumed whole, with the bones intact. Fish also contain fatty acids which are essential for the development of the brain and body, and are particularly crucial for the diets of babies, children, and pregnant and lactating women (WorldFish Center 2005a).

Consumption of omega-3 fatty acids during pregnancy reduces the risk of low birth weight, which is a key factor in both maternal and child mortality. These acids are also critical for the neurological development of infants, and are found almost exclusively in fish, making the consumption of fish during lactation and pregnancy especially important.

The nutritional benefits of fish consumption are also particularly important for people living with HIV/AIDS. Proper nutrition is essential for the effectiveness of anti-retroviral drugs, and fish has also been shown to contain combinations of nutrients which reduce susceptibility to secondary diseases.

Fish and the Millennium Development Goals

Fish, being a "rich food for poor people", is well placed to make an important contribution to the Millennium Development Goals (MDGs). While the most obvious contribution is in terms of food security and livelihoods, it also has an important nutritional role in reducing child mortality, improving maternal health, and combating HIV/AIDS and other diseases. Fish also contribute indirectly to several of the other MDGs through improved nutritional status and enhanced livelihoods, and to gender equality through women's fish-related livelihood activities (see box).

CONTRIBUTION OF FISH TO THE MILLENIUM DEVELOPMENT GOALS

Goal 1: Eradicate extreme poverty and hunger
- Over 40 million people in the developing world are engaged in fishing and fish farming.
- Fish is an important and affordable source of protein, micronutrients and fatty acids for people in developing countries.

Goal 2: Achieve universal primary education
- Indirect contribution from improved child health and income for women.

Goal 3: Promote gender equality and empower women
- Women are heavily involved in fish-based livelihoods, especially in processing and trade.
- Fish is often shared more equally within the household than other protein-rich foods.

Goal 4: Reduce child mortality
- Fish provide fatty acids critical for brain development, as well as protein and minerals.
- Reduces risk of low birth weight, a key factor in child mortality.

Goal 5: Improve maternal health
- Reduces risk of low birth weight, a key factor in maternal mortality.
- Improved nutritional status of women.

Goal 6: Combat HIV/AIDS, malaria and other diseases
- Provides proteins and micronutrients essential for effective use of anti-retroviral drugs.
- Fishing communities are among the hardest hit by HIV/AIDS.
- Income from fish can enable the poor to access health services.

Goal 7: Ensure environmental sustainability
- Good fisheries governance can contribute to sustainable aquatic resource management.

Goal 8: Develop a global partnership for development
- Fish is one of the most traded agricultural commodities and a major export for many developing countries, offering an opportunity for trade agreements which contribute to the development of poor countries.

Small-scale fish farming requires less labour than many other livelihood activities, and can be carried out by female and child-headed households and people living with HIV/AIDS, providing them with fish to eat and sell without substantially adding to their labour burden. The income obtained from the fish which are sold can enable the poor to access health care services, including HIV/AIDS treatment (WorldFish Center 2005b).

Closing the supply gap

Though further increases in capture fisheries production are unlikely, demand for fish is projected to continue increasing due to population growth and urbanisation. This trend is likely to be particularly pronounced in sub-Saharan Africa where many capture fisheries have reached their limit, and aquaculture development is failing to keep pace with population growth. Per capita fish consumption in sub-Saharan Africa is lower than any other region, and it is the only part of the world where consumption is declining (WorldFish Center 2005a).

In order to meet growing global demand for fish, the further development of sustainable aquaculture and improvement in post-harvest processing deserve special attention (see also Subasinghe, this volume). Most capture fisheries are being fished at or above their maximum sustainable yields, and are not projected to produce any further productivity gains. Therefore much of the increasing demand for fish will have to be met by increasing aquaculture production and reducing post-harvest losses.

Aquaculture is often easier to manage than capture fisheries, as aquaculture activities generally fall within national governance frameworks and do not face the same difficulties in resource management that transboundary fisheries do. Even fisheries which fall completely within national boundaries often face difficulties in managing levels of exploitation and controlling access, while property rights are much more clearly defined for aquaculture. Access to water is a key governance issue here, however, causing problems for landless wishing to farm fish in cages, for rice farmers wishing to abstract additional water for fish and for downstream users where large numbers of farmers wish to harvest rainwater for pond culture. Coastal aquaculture is often carried out in publicly-owned water bodies for which there are competing demands.

The challenges facing African aquaculture

While much growth in fish production in recent years has been driven by the rapid expansion of aquaculture in Asia, it is developing more slowly in Africa. Asia and the Pacific accounted for 91.5 percent of world aquaculture production by quantity and 80.5 percent by value in 2004, while sub-Saharan Africa accounted for only 0.16 percent by quantity and 0.36 percent by value (FAO 2006). An expansion of aquaculture production in sub-Saharan Africa could allow the region to better meet its rapidly increasing demand for fish, though there are many impediments which would have to be overcome for it to realise its full potential.

The vast majority of African aquaculture takes place at a very small scale, with over 90 percent of African aquaculture production coming from farms with one or a few earthen ponds, constructed and managed using family labour. The ponds are generally under 500 m^2 in size, yielding 300–1,000 kg/ha annually (World Bank 2006). While the ponds represent an important source of food and income for the families that have them, they have not yet been adopted on a scale capable of closing the "fish supply gap" in sub-Saharan Africa. Nonetheless, there is growing evidence of strong commercial interest in aquaculture in several countries, including Nigeria and Ghana.

Among the challenges facing aquaculture in Africa are limited access to quality seed and feed, underdeveloped credit markets, conflict over use of land and water resources, lack of access to information (both market information and information needed for the adoption of new technologies), and underdeveloped or inaccessible output markets.

Adopting an ecosystem approach to aquaculture

Like any food production system, aquaculture can have negative environmental impacts. Particularly when undertaken at a commercial scale, aquaculture places demands on land and water resources, often uses feed (including intensive formulated feeds) produced outside the immediate area, introduces alien species, may increase sedimentation or produce anoxia of local bottom sediments, and can involve the use of chemicals for disease control.

Aquaculture interacts with capture fisheries in several important ways, due both to the inputs it requires and its potential effects on the surrounding environment. Harvesting of rainwater or abstraction of river water can affect environmental flows and aquatic habitats. Fishmeal and fish oil are key components of formulated feeds used for carnivorous and omnivorous species, placing further demands on marine capture fisheries. Cage culture in coastal areas competes for space with small-scale fisherfolk, often restricting their access to the fishery, and can affect the coastal zone or lake in which it is based through the escape of farmed fish, and through sedimentation and eutrophication from uneaten feed, fertiliser, and fish waste products.

It is worth pointing out that aquaculture can also provide environmental services. For example, integrated pond-based aquaculture increases access to water for irrigation during drought periods. Seaweed, oyster and mussel farming removes anthropogenically derived nutrients released into coastal waters.

While many countries now carry out environmental impact assessments and routine environmental monitoring on aquaculture developments, these often do not take into account cumulative effects in association with other sectors such as agriculture, industrial development, tourism or hydropower. An ecosystem approach to aquaculture (EAA) could provide a more holistic approach to managing the interactions of a wide range of human activities with the natural environment. Building upon the ecosystem approach to fisheries, FAO (2006) define EAA as follows:

An ecosystem approach to aquaculture (EAA) strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems including their interactions, flows and processes and applying an integrated approach to aquaculture within ecologically and operationally meaningful boundaries. The purpose of EAA should be to plan, develop and manage the sector in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by aquatic ecosystems.

This also allows for greater consideration of the social impacts of aquaculture, which are often overlooked when using a purely environmental approach. There is still a need, however, for any environmental planning approach to take into account the demands and impacts of all sectors, rather than taking an exclusively sectoral perspective, possibly through an integration of EAA with Integrated Watershed or Coastal Zone Management.

Social impacts of aquaculture development

The expansion of aquaculture production has profound implications for labour relations, rural poverty, and class formation. While fishing is often an employment of last resort for landless poor or an activity undertaken as one component of diversified rural livelihood strategies, aquaculture requires access to capital for start-up and running costs, and thus has much higher barriers to entry than fishing in capture fisheries does. Even at a very small scale, as in the case of IAA, there is a need to buy simple tools such as shovels and buckets, as well as seed, feed, and fertiliser. Russell *et al.* (forthcoming) found that smallholder households adopting fish farming are often those who have start-up capital, raising concerns about equity. Aquaculture is also generally more profitable at higher levels of capital intensity, as larger commercial enterprises benefit from economies of scale, and compliance with often expensive environmental and documentation requirements allow greater access to lucrative export markets (Delgado *et al.* 2003). Furthermore, aquaculture is less labour intensive than, for example, rice production, and changing from rice cultivation to fish farming can affect rural labour markets and limit employment opportunities for the landless poor.

Despite the challenges, however, aquaculture holds significant potential for pro-poor rural development. Agricultural incomes of IAA households in Malawi, for example, are 60 percent higher than non-IAA households, and their income per hectare is 133 percent higher[2] (Dey, Kambewa, Prein, Jamu, Paraguas, Briones, and Pemsl 2007). Adoption of IAA by poor smallholders could therefore enable them to increase their income several times over. Aquaculture development at a larger scale could also gener-

2. While some of this is due to pre-existing inequalities (households successfully adopting fish farming tend to own more and better quality land and have greater access to family labour and resources such as water), the introduction of IAA was found to have increased the livelihood security and land productivity of adopting households.

ate increased employment opportunities for the landless poor[3], if undertaken alongside continued or expanded agricultural activities rather than as a replacement for them. Most importantly, however, aquaculture can play a major role in terms of food security. As discussed above, fish comprises a nutritionally key part of the diets of the poor in many parts of the world, providing essential micronutrients and relatively affordable animal protein. As global population continues to grow with little prospect of further growth in capture fishery production, increased aquaculture production could help to keep fish affordable for the poor. In many parts of Asia, for example, there is significant aquaculture production of low-value freshwater fish, primarily for domestic consumption.

Improvements in the post-harvest sector

The post-harvest sector also provides an opportunity for both enhancing the livelihoods of the rural poor and meeting ever-increasing food needs. Post-harvest losses due to lack of adequate infrastructure, inadequate preservation technologies, and poor market access reduce revenues of fishers and traders and the overall food fish supply. In some countries in sub-Saharan Africa, an average of 30 percent of the catch is lost to bacterial and fungal infections or eaten by pests. Use of improved processing technologies such as screens against insects, improved 'chorkor' smoking kilns and mesh trays to elevate the fish off the ground can reduce these losses significantly, resulting in greater food security for consumers and increased incomes for processors and traders.

The post-harvest sector is also important for the poor in terms of employment, with the ratio of fishers to people employed in the post-harvest sector generally estimated at approximately 1:3. Small-scale, labour-intensive processing of fish products can greatly increase the contribution of fish production to the local economy, particularly where processing and trading facilities are locally-owned and labour rights are strong. There is also a strong gender aspect to fish-based livelihood activities, with women heavily involved in post-harvest processing and marketing, making the post-harvest sector an important one for strengthening women's livelihoods.

Conclusion

Throughout the developing world, the fisheries sector provides the basis for the livelihoods and nutrition of millions of people, and constitutes a significant source of foreign exchange for many developing economies. Despite its considerable contributions to development, however, it is often not seen as a priority sector by policy makers or donor agencies, and activities such as aquaculture are frequently seen as relatively low-priority for the allocation of scarce resources such as water. This lack of attention to the sector is particularly problematic given that capture fisheries are currently being fished at capacity, and that further increases in production will have to come from

3. Particularly in Asia, as access to land is less of a constraint in much of sub-Saharan Africa.

expansion of aquaculture. There is, therefore, an important role for developing country governments to play, both in managing capture fisheries to prevent further stock depletion, and in regulating the development of aquaculture to ensure that it is both environmentally sustainable and pro-poor. Under such conditions, fisheries and aquaculture can realise their potential as an important and growing source of economic development in rural areas.

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TAKING THE CONTRIBUTION OF FISHERIES INTO ACCOUNT IN DEVELOPMENT POLICY[1]

Mustapha Kébé (extract by Mikael Cullberg)

Abstract

Integrating the fisheries sector into national policies and strategies has been a key success of SFLP initiatives across West and Central Africa. The Sustainable Fisheries Livelihood Programme (SFLP) was run by the FAO, with financing from the UK, from 2003 to 2008. Generation and distribution of strategic information on the sector, particularly data on poverty profiling in the fishing communities and contribution of the fisheries sector to the national economy, helped to increase the visibility of the sector in national strategies. In many countries the national views of the fishing sector have changed; the relevant government authorities and other stakeholders understand better the importance of the sector and its potential contribution to poverty reduction and food security in the country.

SFLP provided support to selected countries to improve the degree of inclusion of the fisheries sector in Poverty Reduction Strategies Papers (PRSPs). The generation of information on **1)** poverty profiling in the fishing communities; **2)** the economic and social role of small-scale fisheries; **3)** the importance of post-harvest issues; and **4)** the impact of Policies, Institutions and Processes (PIPs) has contributed to a better visibility of the sector in PRSPs. As opposed to the situation of the countries in 2002, the fisheries sector now (in 2008) can be considered as part of PRSPs in most of SFLP participating countries; specific strategic orientations and priority actions for the fisheries sector are included. In many countries, the perception of the fisheries sector was altered by showing that its contribution to GDP is greater than appears to be the case in national statistics.

The basis was to understand the economic contribution of the fisheries, as well as poverty within fishing communities. The visibility of the sector was increased by informing decision-makers and development partners on the importance of the sector through appropriate communication strategies and advocacy. Representatives of fishing communities and fisheries departments were involved in national strategic planning exercises. The structures responsible for national poverty reduction strategies were also involved and lobbied. It proved important to

1. Originally published in FAO Technical Paper No. 153, *Achieving poverty reduction through responsible fisheries – Lessons from West and Central Africa*, FAO, Rome, 2008 (chapter 3 "Reassessing the economic and social contribution of fisheries in developing countries", and chapter 4 "Mainstreaming fisheries in development policy").

ensure that sector plans would fit in with national strategic documents (the elaboration of sectoral poverty reduction strategies for fisheries). The result was that the fisheries sector is included in the National Poverty Reduction Strategy. This led to higher budget allocation to the fisheries sector, and to increased service provision to fishing communities. The main gains are expected to be improved resource management, increased livelihood opportunities and reduced vulnerabilities.

Introduction

The current and potential role of small-scale fisheries in poverty reduction and food security is not well documented by national statistical systems and is poorly recognized (Thorpe 2005). The subsector is consequently neglected in both fisheries and national policies (Dugan 2005, Horemans 2006).

Most of the 25 countries that participated in SFLP use PRSPs as the main strategic document for poverty related issues. However, following conventional lines of sectoral divisions, fisheries have generally been separate from these development processes. This might imply not only the possible omission of fisheries specific needs and activities in local and national development plans, but also a risk for disconnects to overall policies when fisheries sector plans are elaborated.

A key activity of SFLP has been to work with relevant government staff and other stakeholders to increase the understanding of the importance of the fisheries sector and how it needs to be included in local and national poverty reduction plans. At the same time, assistance has been provided to ensure that fisheries policies include reference to the relevant overall poverty context and objectives.

The increased visibility of the fisheries sector in these high-level policy documents is evidence of recognition of the role of the fishing sector in poverty reduction, and a chance to benefit from related funds, particularly by getting it into medium-term expenditure frameworks. It gives an account of the achievement of SFLP with regard to influencing the planning process to include the fisheries sector and to ensure a holistic approach, as well as incorporating the principles of the FAO Code of Conduct for Responsible Fisheries. Parallel efforts were made by the SFLP to get poverty-related objectives into national fisheries sector policy.

The conventional approach to evaluating the GDP of the fisheries sector is to consider it entirely part of the primary sector and hence only include value added created in primary production activities, i.e. fishing. The value of fish processing and trade activities, which are in many respects the driving forces of the fisheries sector, are counted for under other items (secondary and tertiary sectors) and hence do not appear as part of the fisheries sector GDP. More importantly, only to look at the economic contribution of the fisheries sector as measured by GDP ignores many other economic and social considerations and is likely to lead to undervaluing its economic importance. This could result in a number of disadvantages for the sector with regard to budgetary support and prioritisation in development planning.

The SFLP developed a methodology considering a wider range of economic and social impacts of the fisheries sector. Particular attention was nevertheless paid to issues related to the contribution of the fisheries sector to GDP since it is the indicator of reference for most decision-makers and donors. The approach included the whole fish value chain, i.e. from fishing through to trade and retail marketing.

Why include fisheries in PRSPs?

The PRSPs describe the overall policy and planning framework for poverty reduction. These frameworks guide the preparation of government budgets, programmes and policies. The SFLP experienced initially that in general the small-scale fisheries sector was not given enough consideration in these national economic and social development policies. Already at the preparatory analytical stage, the poverty assessments used for PRSPs did not explore systematically the main factors affecting poor people's livelihoods as proposed by the Sustainable Livelihoods Approach (SLA). This was found to be particularly true for poverty in the fishing communities where in-depth poverty profiling was lacking. The analysis tended to be superficial and the special characteristics of fisherfolk households were usually not considered in the poverty diagnosis. This led to failure to notice the entry points for relevant interventions for improving fishing communities' livelihoods by reducing poverty and vulnerability. The impression given was that the proposed strategic interventions came from a shopping list, characterized by remarkable lack of consideration for fisheries, even in the countries where fishery visibly should be accorded a certain priority.

The fisheries sector contributes significantly to the economic and social development of the West and Central African countries. The SFLP economic studies particularly demonstrated that some countries have dynamic and surplus external trade. These countries (Senegal, Mauritania and Gabon) upgrade a large portion of their export products towards one or several specific market segments. Given the high added value obtained from export products, external trade in the fisheries sector attracts a large amount of foreign currency into the economy. Moreover, the livelihoods of hundreds of millions of people depend on the fisheries sector in many of the African countries. The fisheries sector appears as the principal motor of growth in some countries of the region. For the other countries, the sector can still play an important ancillary role in enhancing African growth rates over time through exploitation of under-exploited aquatic resources – where they still exist –, development of aquaculture activities, increasing the value-added created by the sector, and integrating the sector more closely into tourism and coastal-zone management programmes (Thorpe *et al*. 2004).

Furthermore, fisheries policies were guided by a sectoral approach where emphasis was put on the resource management, forgetting that people are the centre of the decision-making process. Considering that fishing communities are characterized by a high level of poverty and vulnerability in the region, there is a need to get poverty-related objectives into national fisheries sector policy particularly by promoting responsible fishing and poverty reduction.

All these different factors served as entry points for promoting the explicit inclusion of fisheries in national planning processes, such as PRSPs, and the preparation of sustainable strategies that are well suited to poverty reduction in the small-scale fishing communities of West and Central Africa. Participation is a main guiding principle of PRSP planning and is applied to each step of the process. It is implemented through extensive discussions and consultations on priority issues and appropriate actions with various administrations, public institutions, civil society, socio-professional organisations and external partners. Participation aiming at consensus is required for mobilising the efforts needed to achieve the objectives of the poverty reduction strategy. This also implies that fishing people are – or should be – involved in the whole process.

The inclusion of fisheries in PRSPs provides an opportunity for adopting fisheries policies in a more holistic manner, reconciling sustainable resource management with the fight against poverty in fishing communities and contribution of the sector to economic growth. Within the context of SLA, this was one of the major challenges in integrating small-scale fisheries in the PRSP and by extension in improving the consistency of government policies impacting on the sector, mobilising partners to support the empowerment of communities, and providing an incentive to improve and de-compartmentalise fisheries planning.

The various poverty profiles and diagnoses conducted by the SFLP in the fishing communities gave concrete evidence substantiating the endemic nature of poverty within these populations and an argument for inclusion of the fisheries sector in the PRSPs (Thorpe 2004). The advantage of a better visibility of the fisheries sector in national strategies and policies is that this leads to increasing investment in the sector, both for specific interventions in the fisheries field and in improving access to economic and social basic services, in order to reduce vulnerability of the fishing communities and increase the livelihoods opportunities. A better understanding of the poverty in the fishing communities could help to target these interventions.

Contribution of fisheries to national economies

Following a test in Benin, the SFLP methodology was developed through case studies in 14 other SFLP participating countries. The case studies made it possible to:

1) fill in the information and data gaps on the real and potential contribution of fisheries to national economies;
2) develop a close collaboration between the Fisheries Department and National Accounts Office in each of the countries; and
3) arouse the interest of decision makers and development partners engaged in poverty reduction programmes in the fisheries sector.

The value added generated by the fish production subsector alone represents on average only

60 to 70 percent of the total value generated by the sector. The rest (30–40 percent) is derived from the secondary and tertiary sectors. It appears clearly that fisheries contribute more than what conventional national accounts show and that the contribution of fisheries to the national economy is not currently reflected in the official GDP statistics. By comparing the estimated value added by each of the fisheries subsectors using the SFLP methodology with the estimates from National Accounts data in Ghana, an apparent overall underestimation of the GDP added value created by the fisheries sector of approximately five percent was found in 2001 and in 2002. The results of the case studies assessing the contribution of the fisheries sector to national economies also showed that there is unequal development of fisheries activities from one country to another. The percentage of value added credited to the fisheries sector in national GDP ranged from 0.4 percent (Burkina Faso) to 5.7 percent (the Gambia).

The fisheries sector makes some direct, non-negligible contributions to national budgets. The major earnings from the sector are through "fishing rights" – licenses to national and foreign vessels, plus incomes from fisheries agreements. Various taxes are paid by traders and benefit usually decentralised administrative structures like the local government or community groups. It appeared that the government would generally collect between 5 and 15 percent of the value added of the fisheries sector in the form of taxes and duties.

Direct and indirect employment is an important way in which the fisheries sector contributes to national economies. There are an estimated of 10 million fishers in sub-Saharan Africa, 7 million of which are from West and Central Africa. These are mainly fishers, fish processors and fish traders, but other associated jobs should be added to his figure (FAO 2006). The analysis of the results of the case studies revealed that data on employment is the most difficult to obtain, and the most inaccurate. One of the major difficulties is the lack of clear definitions.

Both employment and revenue in the fisheries sector create multiplier effects in other sectors of the economy – highlighting fisheries' importance to national economies as a whole. A simulation exercise showed that fisheries activities have a strong multiplier effect on revenue (7.3) and therefore a strong "domino effect" on the rest of the economy. This would mean that an investment of CFA francs one million in the fishing sector generate additional revenues of CFA francs 7.3 million in the national economy. This estimate – derived from the one case study – does however seem high and would need to be confirmed by other wider analyses of the same nature. For comparison the average income multiplier effect for agriculture is between 2 and 3 (Delgado 1998).

The analysis of apparent fish availability per inhabitant highlighted the countries where the direct contribution of fish to food security is most critical. Burkina Faso, Mali and Benin have less than 10 kg/inhabitant/annum of fish. In contrast, Gabon and Ghana are the highest consumers of fish, with an availability level of 44.1 and 29.7 kilos, respectively. Interestingly, fish availability per inhabitant and the Human Development Index (HDI) showed a significant positive relationship for the 15 SFLP countries covered by the analysis.

While fish consumption per capita in Africa is less than half the global average (7.8 vs. 16.3 kilos in 2001) this figure has to be seen in the context of the generally lower total protein consumption in the diets of the African population. Fish provides 18.6 percent of animal protein in Africa – above the global average of 15.9 percent. In the case of Mali, a landlocked country benefiting from important inland fisheries, average fish consumption is higher than meat, 5.4 kg vs. 4.7 kg per capita in 2001. In countries such as Congo, Côte d'Ivoire, Gabon and Ghana, fish provide almost 50 percent of animal protein needs.

Fish exports help national economies enter into international markets, particularly in high value segments (crustaceans, cephalopods, demersal fish species). When exports mainly concern high-value fish, this does not necessarily threaten the supply of lower-value fish on local markets. In Senegal, for example, only 15 percent of cheap small pelagic catches are exported (mainly to other African countries) compared to 80, 100 and 95 percent of demersal, cephalopod and shrimp catches, respectively. Revenues from fish exports have generally exceeded the value of cereal imports (annual average of USD 275 million and USD 217 million respectively between 1995 and 2003).

When the trade balance in fisheries products is positive, as is the case in Senegal, Mauritania and Gabon, the fisheries sector is a net provider of currency to the national economy. The fisheries sector can constitute a principal motor of growth in such countries and contribute to underlying economic growth processes in a substantive manner. Between 2000 and 2003, the difference between fish imports (USD 1.2 billion) and exports (USD 3 billion) in Africa gave an average positive balance of USD 1.8 billion per year making the continent a net exporter of fish products. Overall, as a region, the exports of all the 15 countries studied generate the equivalent of USD 578 million, and imports amount to USD 320 million. The trade balance as a whole is in excess by USD 258 million.

Furthermore, it should be noted that better knowledge on the trans-boundary trade of fish products among African countries would likely show much greater volumes than those actually recorded in trade statistics. This is especially the case in inland fisheries for which data are generally poor. Lack of reliable data at the customs posts of the borders between the countries is likely to contribute to an underestimation of exports from, for example, Chad, Gabon, Ghana and Mali (see Gordon, this volume).

Beyond quantitative analysis – poverty reduction and food security

The fisheries sector contributes immensely to the livelihood aspirations of millions of people in West and Central Africa. However, an important lesson learned from SFLP work is that the ways fishing activities contribute to household's live-

Table 1. How the fisheries contribute to economy (selected examples).

Countries	GDP	Employment	Fish supply	Fish trade	Taxes
Congo	Fisheries contributes to 2.75 % of GDP and 23.6 % of the primary sector	6.8 % of the labour force is involved in fisheries 80 % to 90 % of fish traders are women	Fish consumption averages 25 kg per year per person Fish provides 46 % of animal protein	37 % of the national fish supply is provided by imports	Taxes are mainly collected from fishing licenses but their contribution is marginal
Ghana	Fisheries contributes to 4.5 % of GDP The small-scale sector alone contributes 3.4 % of GDP	The livelihood of one in ten Ghanaians depends on fisheries 300,000 people depend on Lake Volta fisheries	Fish consumption averaged 27.2 kg per person in 2003 Fish provides 45 % of animal protein	Exports amounted to USD 95 million in 2002, representing 4.74 % of total export earnings	Taxes are from fishing licenses and market tolls and represent less that 5 % of local revenue
Mali	Fisheries related activities contribute 4–5 % of GDP	Fisheries provide 285,000 jobs, of which 70,000 are fishers, and represent 7.2 % of the national labour force	Fish consumption averages 5.4 kg per person per year, compared to 4.7 kg for meat	Official exports are marginal; however, 15–20 % of the fish traded in Niger Central Delta is exported to other countries in the region	Taxes on added value represent about 10 % of the total value
Mauritania	Fisheries sector contributes to 4–5 % of GDP and 22 % of the primary sector	Small-scale fisheries represent only 10 % of fish production, but provide 80 % of the jobs	Fish consumption averages 4.3 kg/year but varies regionally – 17.1 kg/year in Nouadhibou and 9.2 in Nouakchott	Fish exports represent 70 % of total exports, half from small-scale fisheries	From 2000 to 2004, fisheries contributed to 41 % of budgetary revenues, mainly through EU fishing agreements (34 %)
Sao Tome and Principe	Fisheries contributes to 5.2 % of GDP and 19 % of the primary sector	Between 1999 and 2002, the number of fishers increased from 3,310 to 5,296 (+ 60 %)	Fish consumption averages 28 kg per person per year – well above the world average of 16.3 kg	International fish trade is insignificant	Main source of revenue is the EU fishing agreement providing 600,000 Euros per year
Senegal	Fisheries contributes to 4.1 % of GDP and 13.7 % of the primary sector	600,000 people are employed in the sector, i.e. 17 % of the national labour force	Fish consumption averaged 30.8 kg per person in 2003 Fish provides 44 % of animal protein	Fisheries are the leading export sector, representing in value 37 % of total exports	25 % of the value added goes to the state In the fishing district of Joal, the sector provides 27.5 % of the budget revenue

lihoods are complex and cannot easily be reduced to basic statistical indicators. The small-scale fisheries sector creates employment. This makes it possible for people in the poorest groups in the communities to earn income on a permanent basis, or occasionally. The fact that this trend is most common in the poorest circles suggests that it contributes directly to poverty alleviation. The number of people dependent on fisheries in developing countries is estimated at 234 million. However, there are people who are engaged in temporary fishing activities in marine areas and, more typically, inland water bodies that are not included in these estimates (FAO 2005). For them, fishing may not be a full-time occupation but an activity that complements other livelihood strategies (Béné *et al*. 2007).

Fishing is of particular importance to the protein needs of West and Central African people. Fish is the preferred and cheapest source of animal protein and represents a large proportion of the animal protein intake by the African population. Fish products contribute to food security, both directly, by providing animal protein and nutrients, and indirectly, by providing a source of income to both fishers and fish workers and the state. Many countries rely on the incomes from fish exports to generate the hard currency they desperately need to import food staples for their population. These multiple roles of the fisheries sector confirm the need to consider the relationships between fishery and national policy on food security.

Fishing and fish processing and trade are also considered as safety-net activities for the poor. It was demonstrated through the case studies that small-scale fisheries contribute to poverty reduction at the household level in West and Central African countries. However, it is recognised that at the present time the most important contribution of small-scale fisheries to poverty alleviation is probably through their role in poverty prevention.[2] It was noted that for the large majority of households involved in the fisheries sector in African countries, fishing and related activities do not generate high economic returns but instead help them to sustain their livelihoods and prevent them from falling deeper into deprivation.

The safety-net dimension of fisheries is of greater importance and relevance to poor and marginalized households – generally those with limited access to land and other resources (Béné *et al*. 2007). The relatively easy and free access to fishing grounds allows poor people to rely more heavily on the local commons' resources to obtain the goods and services they need to sustain their livelihoods, or to gain access to paid employment, in situations of economically or institutionally restricted access to other capital (e.g. financial capital such as credit) or production factors (such as private land). The fisheries sector offers a lot of opportunities for the social integration of women, in trade, processing and food-catering. These activities provide income for those groups considered as the poorest and marginalized.

Integrating fisheries: process and results

Different initiatives were developed by SFLP to push for the integration of small-scale fisheries communities into the national policies of West and Central African countries, particularly the PRSPs. The process started by exploring the ideas and work done in the past to reduce poverty in the small-scale fisheries sector of the West and

2. Poverty prevention refers to maintaining a minimum standard of living, even when this minimum standard of living is below a given poverty line, and preventing people from falling deeper into destitution. Thus small-scale fisheries can contribute to reducing risks and creating a safety-net in a general context of vulnerability. In contrast, poverty reduction is when people become measurably better off over time, due to their involvement or investment in economic activities. For small-scale fisheries this would mean when wealth is generated and capital accumulated through investments in fishery-related activities.

Central African region. During the next step, entry points were identified with a view to improving the integration of fishing communities in PRSPs by using the SLA guiding principles and by developing partnerships with Fisheries Departments through the SFLP National Coordination Units (NCU) in each SFLP participating country. This made it possible to compile the national poverty reduction papers of the different countries, as well as information on the way fisheries stakeholders had thus far been involved. A first analysis of the PRSP process in the region was made, and information was collected on the place of fisheries in national poverty reduction strategies. The PRSP process and its linkages with poverty reduction in the small-scale fisheries sector in West Africa was analysed, and the approaches were identified that the SFLP could adopt in providing support to the integration of fisheries in the PRSP.

In parallel with these interventions, an important component of capacity building was developed by the SFLP in most of the countries. Guidelines for the assessment of the contribution of artisanal fisheries to the national economies in West and Central Africa were produced. SFLP assisted the countries in obtaining information on the social and economic role of small-scale fisheries, and in the lobbying required to ensure that more consideration is given to the sector in national poverty reduction policies. SFLP's work on poverty profiling also provided key information on fishing communities in this respect. National studies and workshops were conducted to support the different stages of the process.

The example of Niger illustrates the SFLP course of action taken. The SFLP initiated a participatory study on Policies, Institutions, and Processes (PIP) which have an impact on the livelihoods of fishing communities. The result of the study served as the basis for a discussion on poverty reduction efforts in fisheries. Support was provided to the Fisheries Department to prepare a fisheries and aquaculture sub-programme within the context of the Rural Development Strategy (RDS) of the PRSP. The guidelines for the sustainable improvement of the livelihoods of fishing communities defined by the PRSP of Niger were translated into priority actions identified in the fisheries and aquaculture sub-programme. This action plan was discussed and validated by the main stakeholders including representatives of public institutions, fishing communities, civil society and development partners. The exercise in Niger was completed by the formulation of the Strategy for Fisheries Development which was integrated into the 2006–2011 Medium Term Action Plan adopted by the government. This was an opportunity to include for the first time the fisheries sector in the ongoing PRSP process in Niger. This engagement was facilitated by the importance of the support provided to the national authorities following their request to make more visible the sector. It provided a good model for similar activities to achieve better sectoral integration in other countries in the region.

The SFLP process contributed to a significant positive change in how the fisheries sector was treated in PRSPs in the region. Although not all the support needs and suggested actions have yet been addressed, the inclusion of the sector in the national development planning process was improved in most SFPL participating countries. This was particularly the case in Burkina Faso, Cameroon, Chad, Congo, Gabon, the Gambia, Guinea, Mauritania and Niger.

Lessons learned

The economic assessments and fishing community poverty profiles conducted by SFLP generated more realistic information on the importance of the fisheries sector in terms of employment, incomes, food security and safety net. This information generated renewed interest in the sector and a concomitant uplifting of its status in the PRSPs.

The development of appropriate communication strategies in some countries facilitated a wide dissemination of the results of the various studies and the mainstreaming of the fisheries sector in national policies. Advocacy work done by the SFLP and Fisheries Departments through generation and dissemination of information on the sector, resulted in more visibility of the sector and led to its integration into national PRSPs.

The creation or reinforcement of community-based organizations and national umbrella organizations, and various training received contributed widely to improving the negotiation capacities of the fishing communities. This made it possible for them to participate actively in the PRSP process, especially in the phase dedicated to incorporating their needs and aspirations in national poverty reduction policies.

Emphasis on PIPs and micro-macro linkages providing information from field level poverty profiles, and SFLP interventions to the attention of policy and decision-makers, triggered changes in favour of the small-scale fisheries sector. For example, in Guinea, the SFLP contributed to the integration of fisheries into the finalized PRSP, in particular in the field of participatory Monitoring, Control and Surveillance (MCS) in fisheries.

The increased recognition of the fisheries sector influenced and improved data collection mechanisms. Such data helped to prepare the national fishery policy and contributed to a better integration of fisheries in PRSP and to the eligibility of fisheries to PRSP related funds.

This improved visibility of the fisheries sector in national strategies led to increased capital flow for the benefit of the sector, both for specific interventions in the fisheries sector, and for the provision of basic social services to the communities. This is of vital importance in improving the fishing communities' livelihoods, by reducing the vulnerability of fishing communities, and in increasing the opportunities provided through better basic social services like water, health, education, transport, etc.

In addition to support to better integration of the fisheries sector into PRSP, SFLP developed linkages between the fisheries and various other national policies such as food security, HIV/AIDS, microfinance and literacy, ensuring that the fishing communities receive necessary attention. It appeared clearly that integration of the fisheries sector in national policies and strategies is crucial for building partnerships and establishing the necessary national awareness to catalyse integration of fisheries communities in local development and decentralisation processes. The preparation and implementation of a well adapted communication strategy, as well as the production of information and communication materials probably facilitated the lobbying exercise.

The importance of the current and potential contribution of small-scale fisheries for achieving poverty reduction and food security is the principal factor of mainstreaming the sector in development policies. The fisheries sector is dynamic and reactive to its local, national and international environment. To sustain this successful integration it is necessary to guide policy formulation by identifying the role that the fisheries sector can play in poverty reduction, food security and economic growth, and ensuring a fair representation of the fisheries sector in poverty reduction strategies at macro (national), meso (departmental/district/regional) and micro (local) levels. Particularly the impact that improved fisheries management could be expected to have on the contribution of the sector to national economy should be investigated. The elaboration and implementation of a sectoral poverty reduction strategy for the fisheries sector in each country would facilitate this task to ensure both the inclusion of fisheries specific needs and activities in local and national development plans, and the connection to overall policies.

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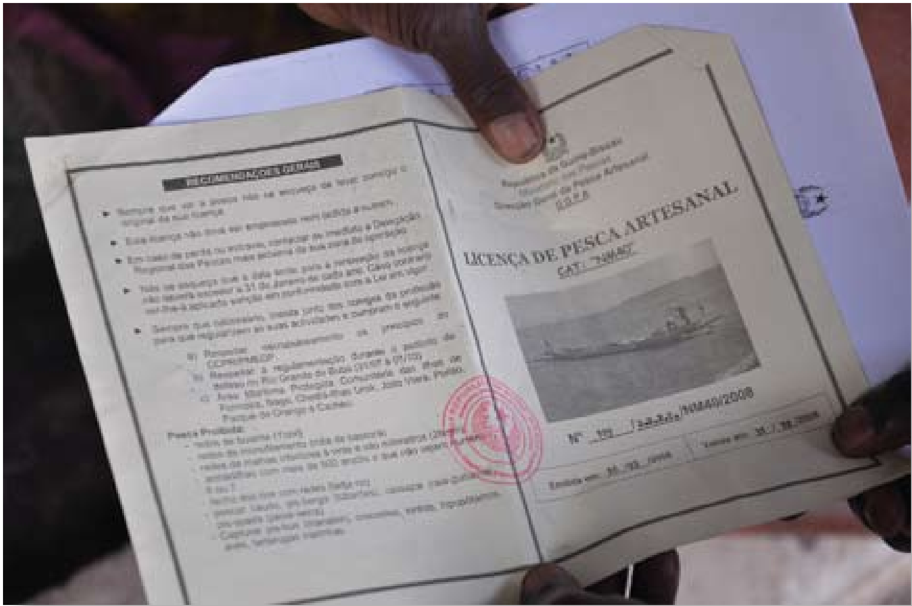

Fishing licence, Guinea-Bissau. *Photo*: Mikael Cullberg (courtesy of the Swedish Society for Nature Conservation).

FISH UTILIZATION AND TRADE

Lahsen Ababouch

Abstract

Fish and seafood are the most traded food commodity worldwide. At the same time, fisheries and aquaculture are very significant for global food security, either directly by supplying nutritious and healthy proteins and fats, or indirectly by providing opportunities for livelihoods, employment and income, in particular for coastal communities and women.

But fish and seafood are highly perishable. Optimal utilization of the harvests requires investment of capital and know-how to preserve its nutritional quality and prolong shelf life in a cost effective manner. Driven by a sustained demand for fish and seafood and the globalization of fish trade, innovations and advances in preservation, processing, packaging, transport and logistics have been achieved. Nowadays, it is not unusual to have fish caught in one country, processed in another and consumed in a third. These developments have made the value chain complex and are not always accessible or affordable. Consequently, post harvest losses still occur in many countries of the world.

Likewise, because of the increasing role of civil society, market access requirements are getting more complex, encompassing consumer protection, environmental sustainability and social equity, with many players trying to regulate the access, not always in a synergistic manner.

This chapter compiles updated global information on fish utilization and trade and analyzes the major issues that need to be addressed to promote responsible practices in this area.

Background

From very ancient times, fish and seafood have been an important source of food and also a provider of livelihoods and economic benefits for those engaged in harvesting, culturing, processing and trading of fish.

Because of their nutritional and health attributes, taste and easy digestibility, fish and seafood are much sought after by a broad cross-section of the world's population, particularly in developing countries. For example, fish contributes a high percentage (19 to 22 percent) of animal proteins in Africa and Asia, as compared to 7.6 and 11 percent respectively in North Central America and Europe, which rely on other sources of animal proteins.

Likewise, livelihoods, employment and income can be generated from culturing, harvesting, processing and marketing fish. These activities attain great significance along the coastal areas of many developing countries, where large sections of the population have limited opportunities for employment. Access to harvesting fishery resources, their processing and trade is often important, or sometimes the only option open for earning a livelihood, improving earnings and the quality of lives.

Finally, fish and seafood are commodities that have been preserved and traded since the Bronze Age. Over the last 40 years, around 32 to 40 percent of fish harvested globally entered international trade, increasing in value from a mere USD 8 billion in 1976 to an export value of USD 93.5 billion in 2007 and estimated trade value of USD 104 billion in 2008. Developing countries contribute around 50 percent of world exports of fish and fishery products and their net receipts of foreign exchange (i.e. deducting imports from the value of exports) increased from USD 1.8 billion in 1976 to USD 24.5 billion in 2007.

But fish and seafood are highly perishable. Immediately after capture, several chemical and biological changes can spoil the flesh making the fish unfit for human consumption. These fish post-harvest losses have been estimated at 10 to 12 million tonnes, representing over eight percent of global fish production, but can reach over 30 percent in some developing countries.

This chapter analyses fish and aquaculture production, processing, trade and consumption and the main issues to be addressed to promote responsible fish utilization and trade, as a way to achieve sustainable social and economic development for fishing and aquaculture communities, while preserving national and household food security, social equity and the environment.

Fish utilization and trade[1]

Production

Fisheries and aquaculture remain very significant for global food security, providing an apparent per capita supply of 17 kg (live weight equivalent LWE) in 2007, which is the highest on record (Table 1). Production averaged 131.5 million tonnes during the period 2000–2007, with a record high of 140.4 million tonnes in 2007.

While fish production from capture fisheries has stagnated over the years, the demand for fish and fishery products has continued to rise. Consumption has more than doubled since 1973. The increasing demand has been steadily met by a robust increase in aquaculture production, estimated at an average 8.3 percent yearly growth in volume during the period 1990–2007. Likewise, the contribution of aquaculture to fish food supply has increased significantly to reach 44 percent in 2007 from a mere seven percent in 1970. This trend is projected to continue, with the contribution of aquaculture to fish food supply estimated to reach 60 percent by 2020, if not before.

Fish utilization

As a highly perishable commodity, fish is often processed to conserve its nutritional properties

1. FAO 2009, pp 42–80.

Table 1. World fisheries and aquaculture production and utilization.

	2003	2004	2005	2006	2007
PRODUCTION (in million tonnes)					
Inland					
Capture	8,6	8,6	9,4	9,8	10,0
Aquaculture	23,1	25,2	26,8	28,7	31,0
Total inland	**31,7**	**33,8**	**36,2**	**38,5**	**41,0**
Marine					
Capture	79,6	83,7	82,8	80,1	80,0
Aquaculture	15,8	16,7	17,4	18,6	19,3
Total marine	**95,4**	**100,4**	**100,2**	**98,7**	**99,4**
Total					
Total capture	***88,2***	***92,3***	***92,2***	***89,9***	***90,1***
Total aquaculture	***38,9***	***41,9***	***44,3***	***47,3***	***50,3***
Total world fisheries	**127,2**	**134,2**	**136,5**	**137,2**	**140,4**
UTILIZATION (in million tonnes)					
Human consumption	102,2	104,2	107,7	111,0	113,7
Non-food uses	24,9	30,0	28,7	26,1	26,7
Population (billions)	6,4	6,4	6,5	6,6	6,7
Per capita food fish supply (kg)	16,1	16,2	16,5	16,8	17,0

Note: Fishery production data presented in the above table exclude production of marine mammals, crocodiles, corals, sponges, shells and aquatic plants.

and prolong its shelf life. It is estimated that over 1,200 fish and seafood species are exploited commercially worldwide, with a wide variation in appearance, taste, and price.[2]

Nowadays, fish is distributed in a variety of ways and product forms as either live, fresh, chilled, frozen, heat-treated, fermented, dried, smoked, salted, pickled, boiled, fried, freeze-dried, minced, powdered or canned, or as a combination of two or more of these. These many options allow for a wide range of tastes and presentations, making fish one of the most versatile food commodities. Yet, unlike many other food products, processing does not necessarily lead to greater value than that of premium fresh fish. In fact, for many finfish species, high quality fresh fish is the most highly-priced.

During the period 2000–2007, 102.2 to 113.7 million tonnes, representing on average 79.7 percent of yearly world fish production, were used for direct human consumption (Table 1). The remaining 20 percent, or 25 to 30 million tonnes, were destined for non-food products, in particular for the manufacture of fishmeal and oil.

Figure 1 shows the evolution of the utilization of world fisheries and aquaculture production over the last 45 years.

In 2007, 48.1 percent of the fish destined for human consumption was in live and fresh form. Fifty-seven percent (79.4 million tonnes) of the world's fish production underwent some form of processing by freezing, curing, canning or extraction of fishmeal/fish oil. Seventy-four percent (59 million tonnes) of this processed fish was used for direct human consumption in frozen, cured and prepared or preserved form, and the rest for non-food uses.

Figure 1 shows that the proportion of fish marketed in live/fresh form worldwide increased more significantly over the years compared with other products. Live/fresh fish quantities increased from an estimated 17.6 million tonnes in 1980, to 54.6 million tonnes in 2007, representing an increase in its share of total production from 24.4 to 38.9 percent. For longer shelf life, freezing repre-

2. OECD 1995.

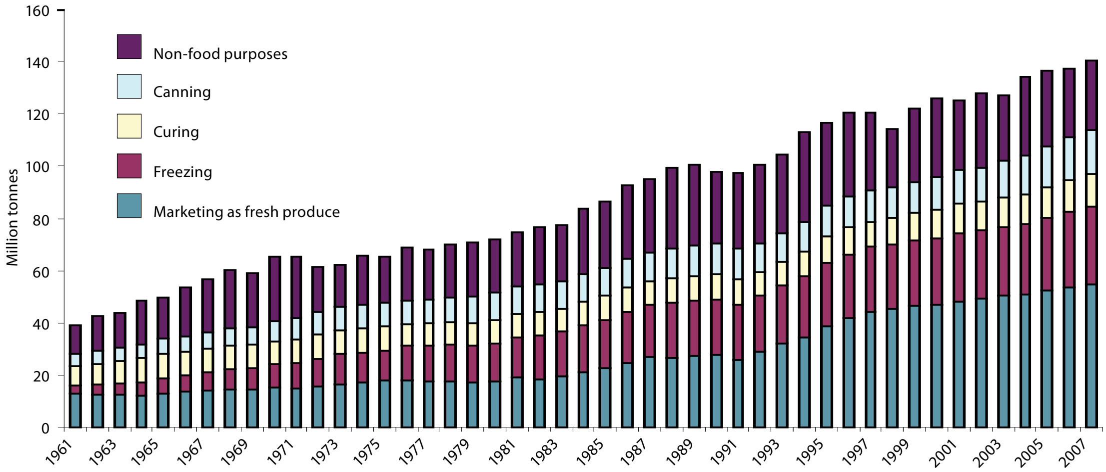

Figure 1. Utilization of world fisheries and aquaculture production (breakdown by volume) 1961–2007.

sents the main method of processing fish for food use, accounting for 50.3 percent of total fish processed for human consumption in 2007, followed by canning (28.5 percent) and curing (21 percent). In fact, the volume of fish destined for curing has changed only marginally during the last 25 years. A similar trend is seen for fish destined for canning which stagnated around 11 to 12 million tonnes for many years, albeit showing a greater increase during the period 2000–2007, going from 12.4 to 16.9 million tonnes per annum.

Fish utilization have diversified significantly in the last two decades, fuelled by changing consumer tastes and advances in technology and logistics, in particular improvements in storage and processing capacity, together with major innovations in refrigeration, ice-making, food-packaging and fish-processing equipment. Vessels incorporating improved facilities and able to stay at sea for extended periods have been built. This has permitted the distribution of more fish in live or fresh form, higher yields resulting in more fish food from the available raw material.

Across the world developing countries prepare/process a large volume, estimated at 112 million tonnes or 80 percent of the global fish production in 2007, of which 47.9 percent, representing 59.3 percent of fish food, was utilized as fresh/live, whereas developed countries used frozen fish most, 43.9 percent of total and 53.9 percent of fish food. By comparison, the share of frozen products was 15.3 percent of total (19 percent of fish food) in developing countries, although 35 percent greater than that in developed countries by volume. Fish curing and the production of fishmeal and fish oil is mostly done in developing countries,

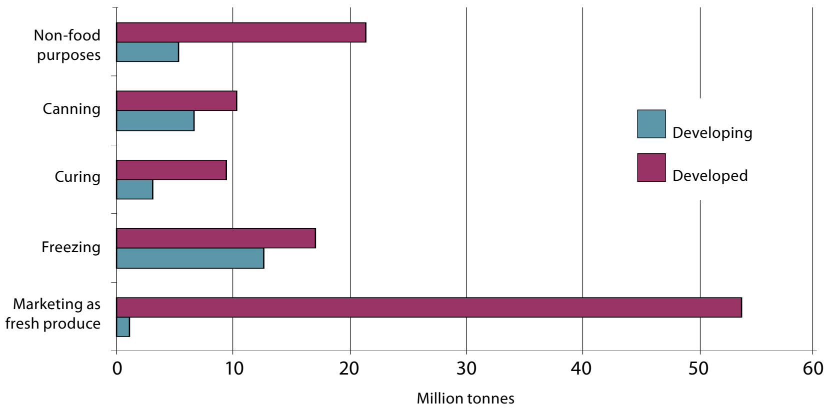

Figure 2. Utilization of world fisheries and aquaculture production (breakdown by volume) in 2007.

whereas canning is significant in both developed and developing countries, although greater volumes are canned in developing countries (Figure 2).

Likewise, utilization of fish production shows marked continental, regional and national differences. The proportion of cured fish is higher in Africa (17 percent in 2004) and Asia (11 percent) compared with other continents. In 2004, in Europe and North America, more than two-thirds of fish used for human consumption was in frozen and canned forms. In Africa and Asia, the share of fish marketed in live or fresh forms was particularly high. Unfortunately, it is not possible to determine the exact amount of fish marketed in live form from available statistics. The sale of live fish to consumers and restaurants is especially strong in Southeast Asia and the Far East.

However, in many developing countries, quality deterioration and significant post-harvest losses occur because of insufficient icing, poor access to roads and electricity, and inadequate infrastructure and services in physical markets. Market infrastructure and facilities are often limited and congested, increasing the difficulty of marketing perishable goods. This, together with well-established consumer habits, explains why fish production is utilized in such countries mainly in live/fresh form (representing 59.3 percent of fish destined for human consumption in 2007) or processed by smoking, drying or fermentation (10.4 percent in 2007). But, in the last few years, there has been an increase in the share of frozen products in developing countries (19 percent in 2007, up 7.9 percent since 1996), with a more significant rise in prepared or preserved forms (11.4 percent in 2007, up 43 percent since 1997). Given the limited cold chain in many developing countries and the large volumes distributed as fresh fish, it is likely that their quality and nutritional benefits deteriorate before consumption. Likewise, fish destined for curing are in several developing countries often made of unsold or substandard quality fresh fish, with the same negative consequences on quality and nutritional benefits. This highlights the increasing need for improved technologies to preserve better fish quality and nutritional benefits in developing countries.

In developed countries, value-added innovation is mainly focused on increased convenience foods and a wider variety of high value-added products, mainly in fresh, frozen, breaded, smoked or canned forms. These necessitate investment in sophisticated production equipment and methods. The resulting fish products are commercialized mainly as ready to eat meals.

In developing countries, processing is still focused on labour intensive processes, such as filleting, salting, canning, smoking, drying and fermentation, providing livelihood support for large numbers of people in coastal areas. These activities are likely to continue to contribute to rural development and poverty alleviation. However, there is a trend towards increased processing, ranging from simple gutting, heading or slicing to more advanced value-addition, such as breading, cooking and individual quick-freezing. Some of these developments are driven by demand in the domestic or regional markets or by a shift in cultured species, such as the introduction of *Penaeus vannamei* in Asia. But, these changes reflect mainly the increasing globalization of the fisheries value chain, with the growth of international distribution channels controlled by large retailers. More and more producers in developing countries are being linked with, and coordinated by, firms located abroad.

The practice of outsourcing processing is increasing significantly, its extent depending on the species, product form, and cost of labour and transportation. For example, whole fish from European and North American markets are sent to Asia (China in particular, but also India and Viet Nam) for filleting and packaging, and then re-imported. In Europe, smoked and marinated products are being processed in Central and Eastern Europe, in particular in Poland and in the Baltic countries. European shrimp is peeled in North Africa and tuna loins or canned tuna are prepared in many African and Latin American countries. For some commodities, an entire industry has been delocalized over the years from the developed to the developing world. For example, the preparation of salted anchovies has been moved from Southern European countries to North Africa, mainly Morocco.[3] Further outsourcing of production to developing countries is restricted specifically by sanitary and hygiene requirements that can be difficult to meet.

In aquaculture, large producers of farmed salmon, catfish and shrimp have established centralized processing plants to improve the product mix, obtain better yields and respond to evolving quality and safety requirements in importing countries.

Another emerging application of fish, crustaceans and other marine organisms is their use as a source of bioactive molecules for the pharmaceutical industry. Chitin and chitosan, from shrimp and crab shells, have wide-ranging applications in many areas such as water treatment, cosmet-

3. Ababouch and El Marrakchi 2009.

ics and toiletries, food and beverages, agrochemicals and pharmaceuticals. Biomedical products from fish wastes (e.g. skin, bones and fins) are attracting industry attention as a source of gelatine, collagen and pigments. Fish silage and fish protein hydrolysates obtained from fish viscera are finding applications in the pet feed and the fish feed industry.

Finally, around 19.7 to 22.4 percent of world fish production is used for non-food products, with the bulk (76 percent) being converted into fishmeal and fish oil. The remainder, mainly consisting of low-value fish, is largely utilized as direct feed in aquaculture and livestock. In 2007, the quantity of fish used as raw material for fishmeal was around 20.4 million tonnes, down 14 percent from 2005 but still well below the peak levels of over 30 million tonnes recorded in 1994. Most fish used for non-food purposes came from natural stocks of small pelagics.

Fish Consumption

Fish is rich in micronutrients, minerals, polyunsaturated fatty acids and proteins, and represents a valuable supplement in diets lacking these nutrients, essential vitamins and minerals. In many countries, especially developing countries, the average per capita fish consumption may be low. But, even in small quantity, fish can

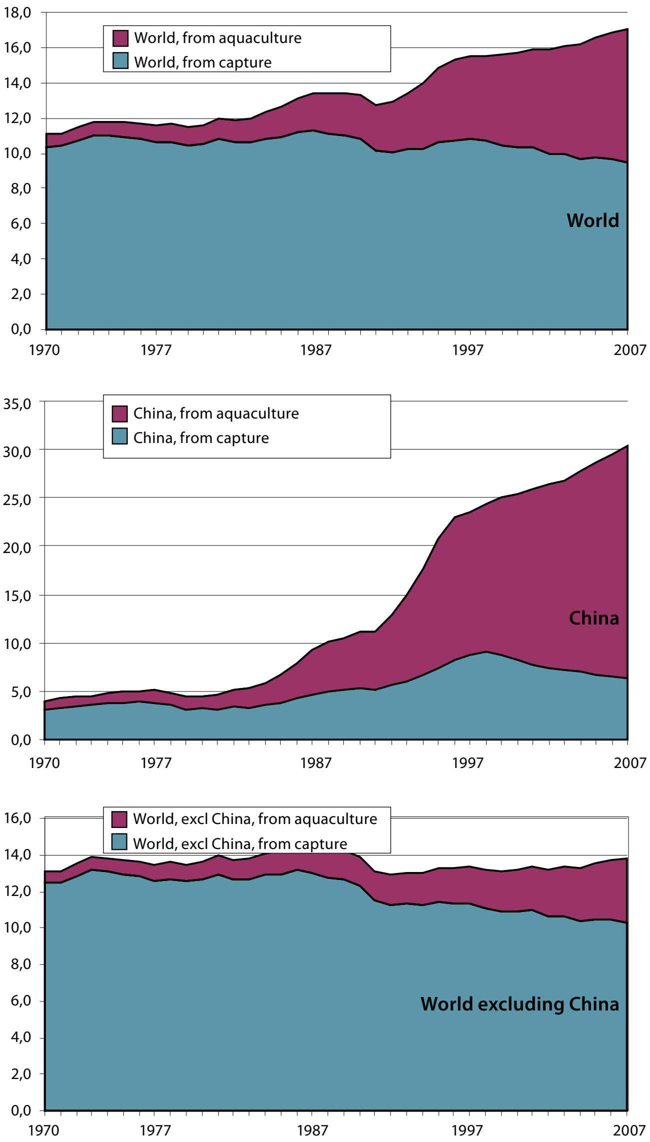

Figure 3. Fish food supply (kg/capita).

significantly improve the quality of dietary proteins by complementing the essential amino acids that are often present only in low quantities in vegetable-based diets.

In the past four decades, fish consumption has increased steadily, from a world yearly average of 9.9 kilograms per capita in the 1960s to 11.5 kg in the 1970s, 12.5 kg in the 1980s, 14.4 kg in the 1990s, reaching 17.0 kg per capita in 2007 (Figure 3). However, there are large variations across countries and regions of the world, reflecting different eating habits and traditions, availability of fish and other foods, prices, socio-economic levels, and seasons. As a consequence, fish consumption can vary from less than one kilogram per capita in one country to more than 100 kilograms in another. Differences are also evident within countries, with consumption usually higher in coastal areas.

Of the 107 million tonnes available for human consumption in 2005, consumption was lowest in Africa (7.6 million tonnes, with 8.3 kg per capita), while Asia accounted for two-thirds of total consumption, including 36.9 million tonnes consumed outside China (13.9 kg per capita), and 33.3 million tonnes in China alone (25.8 kg per capita). In Table 2 the corresponding figures are given for all regions. In North America consumption was 24.1, and in Central America and the Caribbean 9.5 per capita.

The average 2005 per capita fish supply in developing countries was 14.4 kilograms, and 13.7 kilograms in LIFDCs[4]. If China is excluded, these data become 10.6 and 8.6 kilograms, respectively. Although consumption in LIFDCs excluding China has increased in the last four decades, and especially since the mid-1990s (+1.5 percent per year since 1995), the per capita fish intake is only half that of industrialized countries. In 2005, apparent fish consumption in industrialized countries reached 27.4 million tonnes LWE, 14.2 million tonnes more than in 1961, a growth in annual per capita consumption from 20.0 to 29.2 kilograms in the same period.

Table 2 Total and per capita food fish supply by continent and economic grouping in 2005.

	Total food supply (million tonnes live weight equivalent)	Per capita food supply (kg/year)
World	106,7	16,4
World excl China	73,4	14,0
Africa	7,6	8,3
North and Central America	9,8	18,9
South America	3,1	8,4
China	33,3	25,8
Asia	70,2	17,8
Asia excl China	36,9	13,9
Europe	15,2	20,7
Oceania	0,8	24,6
Industrialized countries	27,4	29,2
Economies in transition	4,1	12,3
LIFDCs excl China	23,7	8,3
Developing countries excl LIFDCs	17,4	17,1

4. LIFDC = Low-income, food-deficit country.

Aquaculture production is playing an increasing role in supplying fish for human consumption. Its contribution to per capita fish food rose from 16 percent in 1987, to 30 percent in 1997 and to 44 percent in 2007, equivalent to a global average per capita fish supply of 7.5 kilograms, although it was 24.1 kilograms in China and only 3.5 kilograms for the world excluding China. But, the share of fish from aquaculture is increasing steadily in the world excluding China, rising from 10 percent in 1987, to 15 percent in 1997 and 26 percent in 2007. Aquaculture production is pushing the demand for and consumption of several freshwater species, such as tilapia and catfish as well as for high-value species, such as shrimps, salmon and bivalves. Since the mid-1980s, these species have shifted from being primarily wild-caught to being primarily aquaculture-produced, with a decrease in prices and a strong increase in commercialization. Aquaculture has also had a major role in terms of food security in several developing countries, particularly in Asia, with significant production of low-value freshwater species, mainly for domestic consumption.

However, fish contribution to the diets is more significant in terms of fish proteins and polyunsaturated fatty acids. Fish proteins are a crucial dietary component in many developing countries, where the total protein intake level may be low, and are significant in the diets of many other countries. For instance, fish contributes to, or exceeds 50 percent of total animal proteins in some small island developing states as well as in Bangladesh, Cambodia, Equatorial Guinea, the Gambia, Ghana, Indonesia, or Sierra Leone. Globally, fish provides more than 1.5 billion people with almost 20 percent of their average per capita intake of animal protein, and 3 billion people with 15 percent of such proteins. The contribution of fish proteins to total world animal protein supplies rose from 13.7 percent in 1961 to a peak of 16.0 percent in 1996, before declining somewhat to 15.6 percent in 2005. Corresponding figures for the world, excluding China, show an increase from 12.9 percent in 1961 to 15.2 percent in 1990, slightly declining thereafter to 14.7 percent in 2005. Figures for 2005 indicate that fish provided about 7.6 percent of animal protein in North and Central America and above 11 percent in Europe. In Africa, it supplied about 19 percent, in Asia nearly 22 percent, and in the LIFDCs about 19 percent or 20 percent, respectively including and excluding China. These figures may be higher than indicated by official statistics in view of the unrecorded contribution of subsistence fisheries.

Fish trade

World fish trade has developed rapidly during the last three decades, increasing from a mere USD eight billion in 1976 to a record export value of USD 93.5 billion in 2007, representing a 8.6 percent growth relative to 2006 and 77 percent increase since 1996.

A specific feature of the trade in fish is the wide range of product types and participants. In 2006, 194 countries reported exports of fish and fishery products, of which 99 were net exporters. Export value expanded at an average annual rate of five percent during the period 1996–2006

(Figure 4). In real terms (adjusted for inflation), fish exports increased by 32.1 percent during the period 2000–2006 and by 103.9 percent between 1986 and 2006. In terms of quantity (LWE), exports peaked at 56 million tonnes in 2005, with a growth of 28 percent since 1995 and of 104 percent since 1985. In 2006, exports decreased by four percent to 54 million tonnes because of a reduced production and trade in fishmeal. In fact, exports of fish for human consumption rose a further five percent compared with 2005 and by 57 percent since 1996. Available data for 2008 indicate further strong growth to about USD 99.5 billion, although, some weakening in demand was registered in 2008 as turmoil in the financial sector affected consumer confidence in major markets.

Table 3 shows the top ten fish exporters and importers in 1997 and 2007. Since 2002, China has been the world's largest fish exporter, a leading position that has been further consolidated during the last few years, although fish exports represented only one percent of its total merchandise exports in 2006 and 2007. This increase is the result of a growing aquaculture and the expansion of fish-processing industry, reflecting competitive labour and production costs.

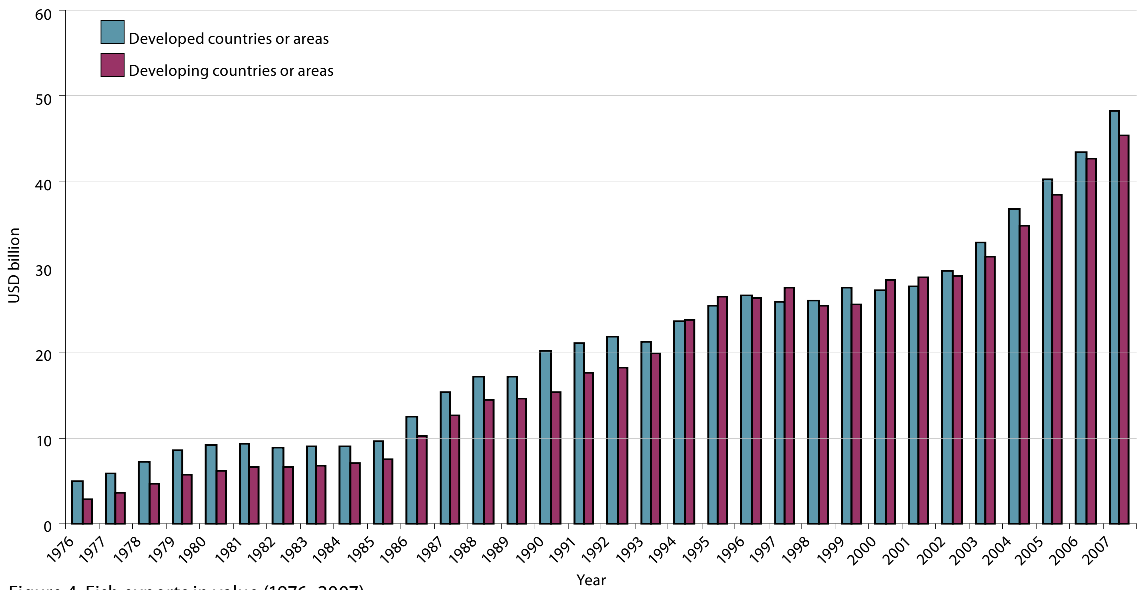

Figure 4. Fish exports in value (1976–2007).

Table 3. Top ten exporters and importers of fish and fishery products.

	1997	2007	APR
	USD million		*per-centage*
Exporters			
China	2,937	9,251	12.2
Norway	3,399	6,228	6.2
Thailand	4,330	5,709	2.8
United States of America	2,850	4,437	4.5
Denmark	2,649	4,128	4.5
Viet Nam	763	3,784	17.4
Canada	2,271	3,712	5.0
Chile	1,784	3,677	7.5
Netherlands	1,426	3,281	8.7
Spain	1,471	3,231	8.2
Top ten subtotal	**23,880**	**47,437**	**7.1**
Rest of world total	**29,622**	**46,084**	**4.5**
World total	**53,502**	**93,521**	**5.7**
Importers			
United States of America	8,139	13,632	5.3
Japan	15,540	13,184	-1.6
Spain	3,070	6,980	8.6
France	3,062	5,366	5.8
Italy	2,572	5,144	7.2
China	1,183	4,512	14.3
Germany	2,363	4,279	6.1
United Kingdom	2,142	4,140	6.8
Korea, Republic of	1,031	3,090	11.6
Denmark	1,521	2,887	6.6
Top ten subtotal	**40,622**	**63,214**	**4.5**
Rest of world total	**16,061**	**34,890**	**8.1**
World total	**56,683**	**98,105**	**5.6**

Note: APR refers to the average annual percentage growth rate for 1997–2007.

In addition to exports of domestic production, China also exports reprocessed imported raw material, adding value in the process. In 2007, it was the sixth-largest importer with USD 4.5 billion, and imports reached USD 5.2 billion in 2008. This growth has been particularly noticeable since the country's accession to the WTO in 2001, which led China to apply lower import duties, including those on fish products. The growth in imports also reflects China's growing domestic consumption of species, mainly of high value, that are not available from local sources.

In addition to China, other developing countries play a major role in fish trade. In 2007, their exports represented 48 percent (USD 45.3 billion) of world fish exports in value terms and 59 percent (31.3 million tonnes) in volume. A significant share of their exports consisted of fishmeal (33 percent by quantity, but only 3 percent by value). In fact, 72 percent in volume of world non-food fish exports originated from developing countries, and their share of fish export volumes destined for human consumption increased from 43 percent in 1996 to 54 percent in 2007. In terms of imports, several developing countries import increasing quantities of fish, mainly low value small pelagics for low income consumers and high value species for emerging middle classes, or for further processing and re-export. Fourty percent of fish imports in value by developing countries originated from developed countries in 2006.

In 2006, 75 percent of fish exports of developing countries in value were destined for developed countries. A share of these exports consisted of processed fishery products prepared using imported fish. Fishmeal was the only product for which exports from developing countries to other developing countries (58 percent of the total) were more important than exports to developed countries. This is mainly due to the significant aquaculture production in many developing countries and the resulting need for feed.

The role of fish trade varies among countries, in particular for developing nations. Trade in fish represents a significant source of foreign currency earnings, in addition to the sector's important role in employment, income generation and food security. In a few cases, fishery exports are crucial for the economy. For example, in 2004 they accounted for more or about a half of the total value of merchandise trade for St. Pierre and Miquelon, Maldives, Federal States of Micronesia, Iceland, Panama and Kiribati.

Fish net exports (i.e. the total value of exports less the total value of imports) continue to be of vital importance to the economies of many developing countries (Figure 5). They have increased significantly in recent decades, growing from USD 1.8 billion in 1976 to 7.2 billion in 1986, 16.7 billion in 1996 and reaching 24.5 billion in 2007. The LIFDCs are active fish traders. Their exports, which accounted for 10 percent of the global fish export value in 1977, has expanded to 12 percent in 1987, 17 percent in 1997 and 19 percent in 2007, worth USD 18.2 billion and a net export revenue worth 11.0 billion.

In 2007, world fish imports reached a new record high of USD 98.1 billion, an increase of 9 percent over the previous year, and of 73 percent since 1997. Preliminary data suggest that world imports of fish and fishery products totalled about USD 104 billion in 2008. All major importing markets, except Japan, further increased the value of their fish imports. The USA became the top importer in 2007, overtaking Japan for the first time in 30 years. With stagnant domestic fishery production and growing demand, developed markets rely on imports and/or on aquaculture to cover a growing domestic demand. In total, developed countries accounted for 79 percent of imports in terms of value but only 62 percent in

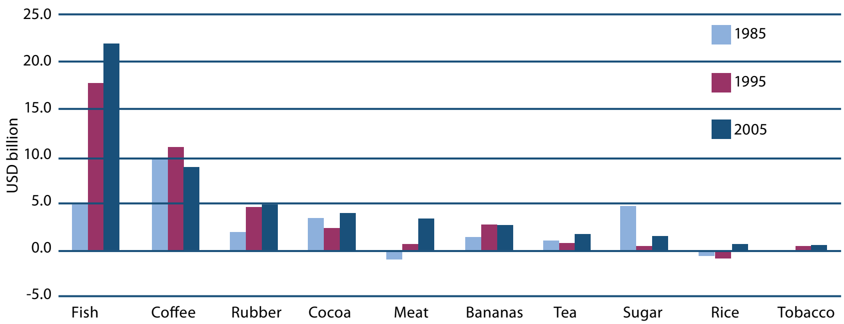

Figure 5. Net exports of selected agricultural commodities by developing countries.

terms of quantity, with Japan, the USA and the EU absorbing 66 percent of the total import value in 2007.

At present, the main obstacles to increased export from developing countries are stringent and increasing requirements for food safety, animal health, environmental and social standards. This has led to the emergence of private standards and labels imposed by retailers on suppliers, making it more difficult for small-scale fish producers to enter international markets.[5, 6]

Most developed countries trade more with other developed countries than with developing countries, despite a growing share of fish consumption being covered by imports from developing countries. In 2006, some 85 percent (in value terms) of fishery exports from developed countries were destined to other developed countries, and about 50 percent of developed-country fishery imports originated in other developed countries. Intra-EU trade is particularly significant, with more than 84 percent of EU exports going to, and about 45 percent of imports coming from, other EU countries in 2006 and 2007. Trade in fish and fishery products among the more developed economies consists mainly of demersal species, herring, mackerel and salmon but also bivalves. In general, a significant share of trade among developed countries is of farmed origin.

Trade in fish between developing countries represents only 25 percent of the value of their fishery exports. This trade should increase in the future, partly as a result of the emergence of more liberal and effectively implemented regional trade agreements, and partly driven by the demographic, social and economic trends that are transforming food markets in developing countries. However, such trade is hampered by high import tariffs applied by the majority of developing countries, mostly to generate much-needed government revenue.

Major issues for responsible fish utilization and trade

Fish trade and food security

In 1996 the Declaration of the World Food Summit defined food security as existing *"when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active healthy life"*.

Fish is an important source of both direct and indirect food security in many developing countries. Much of the concerns on issues relating to fish and food security focussed on the direct dimension of fish for consumption. Consequently, when fish exports are examined, the focus has been primarily on how it reduces fish availability for domestic consumption. Fish imports, on the other hand, are mostly seen as a means to increase local availability. In actual fact, the relationship between trade (exports and imports) and food security is more complex.

Production for exports to lucrative markets can enhance the income of poor fishers substantially and thus achieve greater food security. This is the case of non-fish-eating communities

5. Ababouch 2009.
6. WTO 2007b.

in Mauritania or vegetarian fishermen in India. On the other hand, exports may deprive a section of the domestic consumers of a variety of fish, leading to a potential loss of food security for them. This is particularly so when fish is an integral part of the culturally conditioned diet of a population. In such cases, if supply is less than effective demand by even a very small margin, the price of fish will increase sharply leading to undesirable nutritional consequences especially for the lower income households. Exports can also be based on new sources of production such as a new species at sea, or on increased aquaculture output, and consequently the direct, adverse food security implications may not necessarily arise.

Fish import for human consumption can help to stabilize or reduce fish prices for poorer fish consumers. However, this can have an adverse effect on the income of fishers in the importing country by lowering their food security. As a response they may begin to exploit the local fish stocks heavily endangering resource renewal. Alternatively, women working in fish processing may have more employment opportunities to secure income to spend on household food security. The main beneficiary may, however, be the consumer in the importing country who gets a wider choice of fish at reasonable prices. Imports may also be for re-exporting after processing. Also in this case, new employment is generated in processing facilities for fish workers from urban and rural areas. Their increased incomes will contribute to household food security. The paths towards enhanced or reduced food security will depend on specific details and must therefore be examined keeping these in mind to the extent possible.

These examples illustrate that a single answer regarding the impact of international fish trade on food security is not possible, and that it is essential to analyse very specific case studies in a variety of country contexts. Any attempt to assess the impact of trade on food security should recognize that any changes in the response of fish production and supply, consequent to the impetus for greater trade, will be dependent upon several factors. These include *inter alia* the manner in which existing policy and institutional arrangements have evolved the nature of ecosystem constraints and the level of physical and human capital. There is no standard pattern to this.

A FAO/Norway study[7] examined the impact of international fish trade on food security both at the global level and through 11 national case studies in Nicaragua, Brazil, Chile, Senegal, Ghana, Namibia, Kenya, Sri Lanka, Thailand, Philippines and Fiji. The evidence drawn from this study indicates that, globally and in eight of the 11 countries, international trade has had a positive impact on food security. This assessment was based on outcomes related to national impacts, impacts on fishers, workers, consumers and resources. International fish trade was, however, determined to have a negative impact on the fish resources for the 11 countries studied, highlighting the urgent need for more effective management regimes. Consequently, the study cautions that sustainable resource management practices are a necessary condition for sustainable international trade and that fish export promotion needs

7. Kurien 2006.

to be coupled with a sustainable resource management policy.

The study also highlights the need for free and transparent trade and market policies to ensure that the benefits from international fish trade are equitably enjoyed by all segments of society. The study underscores the FAO's Code of Conduct for Responsible Fisheries recommendation that States consult with all stakeholders, industry as well as consumer and environmental groups, in the development of laws and regulations related to fish trade.

Post-harvest losses

The generally acknowledged limits of production from capture fisheries and the widening gap between fish supply and demand reaffirms that post-harvest losses are an unacceptable waste of scarce natural resources.

Post-harvest losses of fish occur in various forms. The physical loss of material is caused by, for example, poor handling and preservation or the discarding of bycatch. Economic losses occur when spoilage of wet fish results in a value-decrease or when there is a need to reprocess cured fish, raising the cost of the finished product. In addition, inadequate handling and processing methods can reduce nutrients, leading to nutritional loss. Similarly, the lowering of large quantities of fish catches into animal feeds can be considered under certain conditions as a "loss" for human food security.

Post-harvest losses in small-scale fisheries can be very high. Fish losses caused by spoilage are estimated at 10 to 12 million tonnes per year, accounting for over eight percent of the total fish production. Improved preservation methods can significantly reduce this loss, including from glut catches.

Physical fish loss results from the discarding of by-catch. This type of loss is especially significant in shrimp trawl fisheries where the proportion of co-occurring species caught incidentally can represent up to 95 percent of the catch. By-catch contains a variety of fish sizes and species and is sometimes thrown back at sea, except in densely populated areas of many developing countries where it is largely used for local consumption. Chilled or frozen storage facilities on board the trawlers are limited and are mostly kept for the main target species. Sorting the by-catch would require additional crew time further reducing the financial incentive. It is currently estimated that around eight million tonnes of fish catch are discarded.

Likewise, about 15 to 20 percent of the global fish production is still processed into fishmeal and fish oil, using mainly small pelagic oily fish such as herrings, sardines, mackerel, anchovies, pilchards, sand eel, menhaden and offal from the processing of more valuable species (e.g. tuna). Recycling fish catches as feed for poultry or pigs can be considered a net loss because there is a need for at least three kilograms of edible fish to produce approximately one kilogram of edible chicken or pork and five kilograms of edible fish are needed to produce one kilogram of cultured fish. Therefore, while fishmeal and oil are the result of acceptable and efficient fishing strategies, they can also be considered a "loss" from a food security perspective. Ideally, reduction into fishmeal and oil should only occur when it is not economical or practical to utilize fish for direct human consumption. This may happen, for instance, when preservation technology is not available, the distribution chain is inadequate or food habits do not encourage human fish consumption.

Reducing post-harvest losses requires wiser use of resources, reducing spoilage and discards and converting low-value resources into products for direct human consumption. Reducing spoilage requires improved fish handling on board, during landing, processing, preservation, and transportation, all of which are particularly deficient in small-scale fisheries. With increasing fish scarcity, the problem of discards tends to resolve itself at least partially as new species previously deemed commercially inferior are progressively integrated into consumer feeding habits and markets. This is insufficient, however, and efforts are needed to use more appropriate technologies systematically, such as square mesh and by-catch excluder devices.

Low-value species such as small pelagic or mesopelagic species could, in theory, be used for human consumption if problems of acceptability, transformation and distribution could be resolved. Large quantities of fishmeal are often produced in upwelling countries with arid and scarcely populated coastal areas (Peru, Chile, Namibia) or countries where the consumers prefer meat (Latin America, Mauritania, USA) or have easy access to higher quality imported fish (Europe and USA). Increased awareness and targeted fish consumption promotion campaigns are needed to promote further the use of fish for human consumption. Examples of successful national experiences to promote consumption of small pelagic fish have been reported in Portugal, Spain, Tunisia and other countries.

Market access requirements

Duties, quotas and value addition

The World Trade Organization WTO classifies fish as an industrial product which carries lower import duties, as compared to agricultural products. Furthermore, the current Doha round of negotiations decided that “tariff escalation” for fish and fishery products would be reduced. This means that import duties for value-added products will be lowered thus creating new opportunities, not the least for developing countries.

In addition, stagnant domestic fishery production and growing demand in developed markets, which rely on imports and/or on aquaculture to cover a growing share of internal consumption, have reduced import duties on fish to a current average around 4.5 percent.[8] As a result, fishery products from developing countries are able to gain increased access to developed-country markets without facing prohibitive custom duties similar to those applied to agricultural products.

However, although developing countries account for approximately 50 percent of global fish exports, many have been exporting fish with limited or no processing. Over the last decade, many tariffs on processed products have been reduced.

8. Melchior 2006..

Consequently, the transfer of value addition technologies, know-how and investment capital to developing countries has increased, generating further employment and hard currency earnings from processing and value-addition. Part of this production has taken place in emerging economies, mainly in Asia, but also in Africa and Latin America.

But, despite the availability of technology, several projects in value-addition for export from developing countries have not been successful, mainly because due consideration was not given to quality assurance, marketing and distribution issues. Some operators have circumvented the problem by using the label, know-how and distribution system of the importer or retailer, giving up some benefits that accrue downstream from marketing and distribution in the value chain.

An important issue is the study of the distribution of costs and benefits to understand how and where in the fish value chain revenues accumulate, values are added, profits are generated and what are the principal barriers against adding more value to exported seafood products in the country of origin or destination. Preliminary studies indicate that the distribution of benefits is not always equitable, especially in developing countries, where upstream operators, especially small scale fishermen, receive the least benefits, which increases their vulnerability.[9, 10]

Subsidies

It is generally agreed that subsidies have an indirect effect on trade whenever they have an impact on the prices or on the volume of products moving across international frontiers. Unfortunately, not much work has been carried out on possible trade distortions caused by subsidies in the fishery sector, and only few attempted to quantify them. It has indeed proved difficult even to reach international consensus on how to define and classify a subsidy, and what some countries see as harmful and trade distorting subsidies, others may see as legitimate and indispensable assistance for regional development, fleet renewal, export trade promotion or poverty alleviation.

The question of subsidies in fisheries has received wide international attention. Studies by APEC, the World Bank, OECD, UNEP as well as FAO focus on the use of subsidies in fisheries and the possible negative consequences primarily on resources but also on trade. Subsidies to aquaculture are likely to be trade distorting as they would encourage production, whereas subsidies in the capture sector are likely to lead to overexploitation.[11, 12]

The WTO Agreement on Subsidies is relevant and applies to fisheries. It deals with two groups of subsidies: prohibited and actionable subsidies. Use of subsidies in fisheries are therefore not illegal *per se*, it depends on the category; even those subsidies that are classified as prohibited, for example export subsidies, may under certain conditions be allowed for least-developed countries.

9. Gudmundsson *et al.* 2006.
10. Nyeko 2009.
11. Schorr 2005.
12. Schorr and Caddy 2007.

In 2001, the Doha Ministerial Declaration singled out Fisheries Subsidies as a specific issue in the Doha negotiations. The aim is to clarify and improve WTO rules that apply to fisheries subsidies while preserving the basic concepts and principles of the Subsidies and Anti-dumping Agreements, taking into account the needs of developing and least-developed countries.

In November 2007[13], the Chair of the WTO group negotiating fisheries subsidies tabled a Chair's draft text which proposes a broad ban on subsidies that contribute to overfishing and overcapacity. It also proposes general exceptions to the prohibitions for all WTO members and special and differential treatment (S&DT) for developing countries. The general exceptions and S&DTs are conditional on WTO members having in place a fishery management system designed to prevent overfishing. The Chair's text proposes that WTO members who wish to grant a subsidy that would fall under the general exception or S&DT provisions must notify FAO of their management system. It is proposed that FAO then undertake a peer review of the management system prior to the granting of the subsidy.

With the renewed focus on the negative impact of subsidies in fisheries, it can be anticipated that the use of subsidies will be reduced in the future. This should reduce the impact on overexploitation of resources and cause less distortion to trade with market prices better reflecting the true cost of fish, be it caught or farmed. At the same time, we will probably see more disputes related to the use of subsidies. One reason is the growing role of aquaculture where state intervention in many cases can be documented. The other is the general decline in import tariffs which makes residual distortions in cost and price both more relevant and visible.

Safety and quality requirements

The increased globalization of fish trade has highlighted the risk of cross-border transmission of hazardous agents. Likewise, the rapid development of aquaculture has been accompanied by the emergence of food safety concerns, in particular residues of veterinary drugs. The food and feed scares of recent decades (bovine spongiform encephalopathy BSE, dioxins, avian flu, SARS, foot and mouth disease) have exacerbated the concerns necessitating the development of a food safety strategy applicable throughout the entire fish food chain – from "farm or sea to table". This strategy must be scientifically based, adaptive and responsive to changes in the food production chain. It should be articulated around the use of risk analysis to develop food safety objectives and standards and the preventative systems to manage food safety hazards.

The implementation of the food chain approach requires an enabling policy and a regulatory environment at national and international levels with clearly defined rules and standards, establishment of appropriate food control systems and programmes at national and local levels, and provision of appropriate training and capacity building. Development and implementation of

13. WTO 2007a.

Good Aquaculture Practices (GAP), Good Hygienic Practices (GHP) and HACCP[14] are required in the food chain step(s). Government institutions should develop an enabling policy and a regulatory environment, organize the control services, train personnel, upgrade the control facilities and laboratories and develop national surveillance programs for relevant hazards. The industry should adopt good practices and train personnel to implement GAP, GHP and HACCP. The support institutions (academia, trade associations, private sector, etc.) should provide scientific, technical and training support to stakeholders. Finally, civil society should promote consumer education and information, and play a counterbalancing role to ensure that safety and quality policy is not influenced negatively by political or economical considerations.[15]

Globalization and further liberalization of world fish trade, while offering many benefits and opportunities, also presents emerging safety and quality challenges. Improved scientific tools must be adopted and novel flexible approaches to safety must be sought to ensure that responsibility for consumer protection is effectively shared along the food chain and that regulations reflect the most current scientific evidence. This requires significant resources which are not always available, especially for small scale operations in developing countries.

Fish safety and quality assurance in the new millennium will require enhanced levels of international co-operation in promoting transparency, harmonisation, equivalency schemes and standards setting mechanisms based on science. The SPS/TBT agreements of the WTO and the benchmarking role of the Codex provide an international platform in this respect.

Traceability

Traceability is *the ability to trace the history, application or location of that which is under consideration* (ISO 9000:2000). When considering a product, traceability relates to the origin of materials and parts, the processing history and the distribution and location of the product after delivery.

In the case of foods, the *Codex Alimentarius* defines *traceability/product tracing as the ability to follow the movement of a food through specified stages of production, processing and distribution*.

This definition has been adapted into a regulation by the EU to signify *the ability to trace and follow a food, feed, food producing animal or substance intended to be, or expected to be incorporated in a food or feed, through all stages of production, processing and distribution* (EU 2002).

Traceability can use either paper or electronic systems, although most are a mixture of the two. Paper traceability systems are widespread and have been used for a long time throughout the supply chain. Electronic traceability uses either the bar code systems or the more recent radio frequency identification (RFID) systems. Bar code systems have been in use since the 1970s and are well established in the food industry. RFID technology uses tags that send identification codes electronically to a receiver when passing through a reading area.

14. HACCP = Hazard Analysis and Critical Control Point.
15. Valdimarsson *et al*. 2004.

Traceability can be divided into *internal* and *external* traceability. *Internal* traceability is traceability of the product and the information related to it, within the company, whereas *external* traceability is product information either received or provided to other members of the supply chain.

In fisheries and aquaculture, traceability can relate to:

- the origin of raw materials, ingredients and other inputs
- the production, handling and processing history
- the distribution and location of the product after delivery.

Interest in traceability in food production and distribution has increased in recent years, primarily because of the different crises in the food sector. Authorities have focused on traceability to assure consumer safety, to be able to re-call defective/hazardous products and to identify the source of the problem.

As the food chain has lengthened from local production, processing and consumption to more global commercial opportunities, the need to transfer information related to production, nutrition, safety, etc. and the complexity of these transfer vehicles have expanded. For example, over 1,000 fish species are marketed in the EU and over 800 in the USA. Similarly, over 120 countries export fish to EU countries. With the increase in complexity, stakeholders wish to be fully informed about fish species, place, condition of rearing or catch, handling, transformations and the distribution of the food products they consume.

In processing, traceability may be advantageous allowing different raw materials to be directed to production of different categories of product – and subsequently relating yield, quality, or safety of a particular category to a particular raw material, practice or ingredient. Furthermore, traceability systems are in some form required for a HACCP system to be implemented.

With traceability, the whole chain from vessel or farm to retailer can be managed in a more effective way, when the traceable information is used actively to enhance mutual trust and co-operation between stakeholders of the food chain. Significantly less time (and resources) can be spent on quality checks and storage, and when recalls are to be carried out, traceability is an assurance that the company limits the loss, and protect its image on the market.

Certification and labelling

Certification and labelling have become important to access international fish markets. Not only must suppliers adhere to the regulatory requirements of importing countries, but additional labels or certificates may also be required by the importer for commercial and marketing reasons. In the same way, the supplier may also choose to apply particular labels or undergo voluntary certification programmes in order to target specific segments of consumers, thereby gaining a competitive advantage in market niches.

Alternatively, producers may choose to adopt specific requirements that permit them to label their products as environmentally friendly or produced in respect of certain social values.

Examples of such labelling include: *"organic production"* labels, *"fair trade"* labels, *"dolphin-safe tuna"* labels or other eco-labels. An eco-label is a tag or label placed on a product that certifies that the production was environmentally friendly. The label provides information at the point of sale that links the product to the production process.

Increased interest in eco-labels results from the concerns about the dramatic state of the world's marine resources. The perceived failure of governments to effectively manage marine resources has led environment groups to develop alternative mechanisms for protecting marine life and promoting sustainability. These are aimed at influencing the purchasing decisions of consumers and the procurement policies of retailers. Eco-labels are one such mechanism. Organizations developing and managing an eco-label develop standards against which applicants wishing to use the label will be judged. They also manage the accreditation and certification process, and market the label to consumers to ensure recognition and demand for labelled products.[16]

These strategies can be seen in terms of a continuum from more reactive mechanisms that highlight and "shame" bad practice, to more proactive activities: encouraging consumers to purchase fish from sustainable stocks, and working with retailers to improve their procurement policies, as well as rewarding those that do with positive publicity. These developments have led buyers and retailers to impose private standards and certification back through the supply chain, especially on producers and processors.

As a consequence, there has been a proliferation of certification bodies and schemes designed to trace the origin of fish, its quality and safety, the environmental and/or social conditions prevailing during fishing, aquaculture production, processing and distribution.

But as standards, certification schemes and labels proliferate, both producers and consumers are questioning their value. Producers in particular question whether these private standards and certification schemes duplicate or complement government work and whether they really provide better protection for the consumer and the environment and/or contribute to social equity.

Many producers and exporting countries hold the view that private sanitary standards represent unjustified restrictions to trade, especially where they introduce measures which duplicate those already applied by government authorities. This raises the issue of how to define boundaries between public regulations dealing with food safety, animal health, environmental and social protection on the one hand and private market standards on the other? And who is responsible for what and accountable to whom? While governments that are seen to use standards as trade barriers can be challenged through the rules of WTO, what international mechanism, or agreement, should be invoked to challenge private companies whose standards are judged to create technical barriers to trade between countries? Several countries and industry associations have raised serious concerns about the potential for private standards to have trade limiting or trade distorting effects.[17]

16. Washington 2008.
17. WTO 2007b.

Proponents of private standards and certification schemes claim that they encourage suppliers to force the use of responsible practices in fisheries and aquaculture. Opponents of such standards see them as a private sector attempt to replace/duplicate governmental policy in fisheries and aquaculture. The key issue is how private standards and certification schemes can be reconciled with the public sector's responsibility to regulate the use of responsible practices in fisheries and aquaculture, throughout the food chain.

Resolving these issues requires a concerted international effort. A precondition for an international understanding and an approach to dealing with this issue is better knowledge. More must be known about the effects of private standards and certification schemes. Such knowledge may make it possible to propose solutions that will ensure coherence of private standards with WTO trade measures. Several initiatives are currently undertaken by FAO, OECD, WTO and others to introduce disciplines in this area.[18, 19]

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18. Ababouch 2009.
19. WTO 2007b.

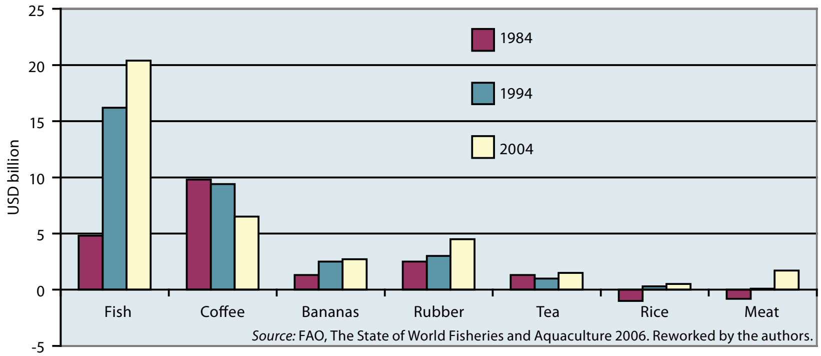
GLOBAL FISH TRADE

Malin Wilhelmsson and Ylva Mattsson

Trade in products deriving from fisheries and aquaculture is currently the most internationalized portion of the food products trade. Moreover, international trade in fish has also risen considerably during the past two decades, with trade flows moving primarily from the South to the North.

Exports of fishery products are a key source of revenue for many developing countries. Figure 1 illustrates net exports of a number of agricultural products and fish from developing countries. This highlights the importance of fish exports for the developing countries and their growing significance. In the case of developing countries, the trade surplus[1] in fish and seafood products rose from almost USD 4 billion in 1980 to some USD 20.4 billion in 2004. Exports go primarily to the developed countries.

The Law of the Sea, entailing a 200 nautical mile exclusive economic zone (EEZ), has led to a shift in international trade patterns that has favored certain developing countries, notably in Asia and Latin America. However, the opportunity to fully utilize this export potential is limited, especially for African coastal states. This is due to various trade barriers, primarily non-tariff, set by the developed countries, as well as the fact that the fishery assets of many developing countries are not exploited by the countries themselves – mainly because of insufficient domestic technical and economic resources – but are instead used by the developed



Source: FAO, The State of World Fisheries and Aquaculture 2006. Reworked by the authors.

Figure 1. Net exports of fishery products and selected agricultural products from developing countries.

1. The trade surplus is exports minus imports.

countries, who pay for fishing rights in these waters. Seafood catches by vessels under the EU's fisheries agreements with third countries are granted common origin status and are not specified in trade statistics.

Trade in seafood products is surprisingly large considering that fish and shellfish are distinctively fresh goods. The species that are primarily exported to the developed countries from the developing countries are those that command the highest price, such as tuna and shellfish.

The rising trade in fishery products is probably due to four factors:

1. Increasing demand for fish. Access to fish has declined in the developed countries due to the over-exploitation of many stocks, adding to the need to import from developing countries. The developing countries have seen rising population figures, along with increased income per capita, leading to higher demand for fish.
2. Improvements in logistics have contributed to the internationalization of trade in fishery products. This includes improved packaging and preservation techniques as well as faster and, especially, cheaper transport. Transport costs continue to decline – a factor that should not be underestimated.
3. Tariffs on seafood products both in the developed countries and developing countries in Asia have declined substantially for both raw fish and processed products, although tariffs on raw fish are generally lower.
4. Politically inspired intervention through subsidies or currency devaluation – in other words, measures that can distort trade.

Access for foreign products to a market can be curtailed in a number of ways. The most obvious method is through various types of tariffs. The applicable tariffs are set in trade agreements. International trade in fishery products is regulated by a series of agreements, both multilateral (WTO) and bilateral (two parties). There are also unilateral preference arrangements through which mainly developed countries offer benefits to developing countries.

The World Trade Organization

The WTO is the only global organization in which binding agreements provide rules governing international trade and compliance monitoring. It is a multilateral organization with 150 members, most of whom are developing countries. The WTO's goal is to dismantle all trade barriers and all forms of trade discrimination. WTO agreements have extensive scope, ranging from more conventional trade policies – such as tariff levels and subsidies – to patents and investment rules, as well as health requirements and technical stipulations for imported goods.

Within the WTO, various agreements can be negotiated separately, or alternatively a negotiation round can be initiated, during which all areas are negotiated among parties. This means that a country can request counter-performance in a totally different area than that in which it makes an offer. It is worth noting that negotiations in a round are conducted in accordance with the principle that nothing is agreed until everything is agreed – referred to as the single undertaking. This means that negotiations must be fully completed for all agreement areas before a new agreement is enacted.

A new round of negotiations commenced in September 2001 in Doha which is still ongoing. Compared to previous rounds, there is greater emphasis on the needs and growth of developing countries – hence the term "Development Round". Developing countries are to be given special and differentiated treatment. This means that all issues must take into consideration the progress of developing countries. For developing countries, this entails clearer undertakings than previously in the WTO on tariffs and the abolition of quotas for the least developed countries (LDCs). In addition, efforts are to be made to facilitate the compliance of developing countries with their WTO undertakings, through for example, longer transition periods, technical assistance and clearer rules on preferential treatment of developing countries. For most developing countries, agriculture is the single most important area of negotiation.

Doha's development agenda covers a number of issues linked to the fisheries sector, including improved market access, subsidies, eco-labeling, linkage between WTO trade regulations and environmental agreements, as well as technical support and capacity expansion in developing countries to meet the provisions covering safe food requirements. Currently, tariffs on fishery products are being negotiated within NAMA (Non-Agricultural Market Access), meaning they are being negotiated along with other industrial goods. Fisheries subsidies are currently the subject of the Rules group negotiations, within which other subsidy issues are also being negotiated. The most controversial area in fishing is the issue of fisheries subsidies. Fisheries subsidies are viewed as a trade issue, since countries that subsidize their fleet can take larger catches at a lower cost.

A key principle within the WTO is that involving the "Most Favored Nation" (MFN) principle, which means that a country must treat all other countries equally. If, for example, a country reduces the tariff on a certain good, the reduction must apply to all members. However, there are many exceptions to this principle. For example, the EU countries can introduce free trade among themselves while maintaining trade barriers vis-à-vis the rest of the world. This is because the EU is a customs union and thus regarded as a single state. Another example is that – subject to certain conditions – a country may grant special tariff reductions for developing countries.

The WTO has a dispute settlement procedure to which a country can turn if it has complaints against another country for breaching its WTO undertakings. That this is an arbitration body and not a court means, among other things, that there is no prosecutor or defending attorney; instead countries making a complaint and those who are the subject of the complaint must pursue their own case. There is no common penalty, but a country found guilty may be punished by the complaining country in the form of trade sanctions. The WTO's dispute settlement procedure is only concerned with strict literal compliance with agreements and does not take into account the real consequences of compliance.

Regional agreements

A bilateral agreement is concluded between two parties, which may be two states or two groups of states. A key WTO principle is that a tariff reduction must be available for all WTO members. However, a significant exception to this principle is regional or bilateral trade agreements. There are two main types of regional trade agreements – customs unions and free trade areas. According to WTO rules, a regional or bilateral trade agreement must encompass the majority of trade flows.

The number of regional agreements has risen sharply in recent years. As of July 2007 there were 205 agreements in progress and more have been notified. Almost all WTO member countries are part of one or more preference arrangements (which provide tariff benefits). Most of the regional agreements notified to WTO have been concluded between European states, even though the US and Asian countries have also been very active recently.[2]

EU agreements with developing countries

Trade between the developing countries and the EU is regulated primarily by the GSP system (Generalized System of Preferences), and by the Cotonou Agreement, which refers to the EU's trade preferences for countries in the ACP bloc (African, Caribbean and Pacific countries). Some developing countries also have separate trade or association agreements with the EU.

It should be noted that it is not only the EU that grants developing countries special preferences. Most countries in the West have their own GSP procedures vis-à-vis the developing countries, although the configuration of agreements and the products covered differ among countries. The presentation below deals solely with EU trade agreements with developing countries.

The GSP system

The EU's initial GSP system was deployed as early as 1971. Today, some 180 countries and territories have access to the system, which entails tariff reductions or tariff exemptions for some 7,200 goods, primarily in industry and agriculture. In practice, however, far fewer countries utilize the GSP system, since many of them have other more beneficial trade agreements with the EU.

Within GSP, products are classified as *sensitive* and *non-sensitive* products, depending on their production in the EU. Sensitive products from GSP countries receive a reduction in the MFN tariff rate of 3.5 percentage points. Non-sensitive products enjoy tariff-exemption status for export to the EU. In the case of products not covered by the GSP system, GSP countries must pay the same MFN tariff rate as developed countries. All fisheries products are included in the GSP system. All – except for live aquarium fish – are classified as sensitive products.

For certain countries, essentially all products are exempt from tariffs. Exemption applies to the LDCs, who, via the EU preference system known as EBA (Everything But Arms), are tariff exempt,

2. *http://www.wto.org*.

except for weapons and ammunition. However, in the case of bananas, rice and sugar, a stepwise reduction in tariffs is in progress. Another group of countries that enjoy extra tariff reductions are those that are classified as vulnerable and that have ratified and implemented a number of international conventions. This preference system is referred to as GSP+. In this case, exemption from tariffs is granted for almost all tariff lines – about 7,200 – included in the enclosure to the provisions.

Competitive countries or product sectors that have reached a certain development level lose preference in the EU's GSP system (graduation mechanism). The aim is that GSP preferences should accrue only to those countries that really need them and to encourage countries to diversify production.

Utilization of GSP preferences requires compliance with product origin rules. In brief, it seems that particular preference is granted to processed seafood products and not to raw fish, which must be viewed as a positive feature. However, it must be remembered that many developing countries have problems in meeting EU veterinary and hygienic requirements and thus cannot export processed goods to the EU.

The Cotonou Agreement – replaced by Economic Partnership Agreements

The Cotonou Agreement was an aid and trade agreement signed between the EU and the ACP countries – 77 countries in Africa, the West Indies and the Pacific. The EU previously had special trade agreements with former colonies in Africa, the West Indies and the Pacific. The agreement had two main components, namely trade and aid. The trade accord gave these countries certain preferences in the EU market compared with other countries. For fish, this meant that imports of fishery products were exempt from tariffs. The origin rules provided complete cumulation between ACP countries and the EU.[3]

The configuration of the Cotonou Agreement, and its predecessor, the Lomé Convention, was not WTO compatible, as they were not mutual; that is, it was only the EU that granted benefits to a limited number of countries. The GSP regime is also unilateral, but it gives preferences to all developing countries, making the system WTO compatible. The EU was granted a waiver from the WTO for the Cotonou Agreement, which extended to the end of December 2007.

The Cotonou Agreement stated that it was to be replaced by mutual partnership agreements. Negotiations covering these partnership agreements commenced in September 2002. The partnership agreements must be WTO compatible and, effective year-end 2007, replace the trade provisions of the Cotonou Agreement.

To facilitate the practical aspect of EPA negotiations, the ACP countries agreed to negotiate in six regional country groups: The Economic Community of West African States (ECOWAS), Central Africa (CEMAC), Eastern and Southern African States (ESA), the Southern Africa Development Community (SADC), and Caribbean and Pacific countries, with each group

3. Certain cumulation rules apply to South Africa, notably in the case of fishery products.

having a bilateral agreement with the EU.

Negotiations on EPA agreements have progressed very slowly and only one of the six regions – the Caribbean – has managed to complete negotiations. To prevent trade disruptions, and the consequent negative impact on the ACP countries' economies as a result of the non-completion of partnership agreements, the countries have been offered the possibility to sign interim agreements that should apply while negotiations on EPA agreements continue. These agreements allow the countries to continue to export fishery products to the EU, exempt from quotas and tariffs. Twenty ACP countries in five EPA regions have concluded interim agreements with the EU. These agreements apply until an EPA agreement is concluded.

The predecessor to the Cotonou Agreement, the Lomé Convention – signed about 30 years ago – granted the ACP countries major benefits for their exports to EU countries. However, these advantages have diminished over time, because the EU has granted an increasing number of countries various trade benefits. Regarding fish, it may be noted that the EU has gradually cut tariffs – though nevertheless they remain high – which has undermined preferences. However, future EPA agreements will continue to offer ACP countries some advantages compared with countries such as Thailand and the Philippines (major fishing nations) that do not enjoy similar preferences.

How is trade curtailed?

There are a number of ways of limiting the access of foreign products to a market. The most obvious method is via various types of tariffs. The configuration of tariffs and the levels applied in various countries have a major impact on trade flows worldwide.

The types of tariffs imposed by a country depend on whether or not it is a WTO member, as well as by the trade agreements concluded with other countries and regions, and, of course, by the trade policy that a country has opted to follow. All WTO countries have pledged to fix some of their tariff lines, which entails an undertaking not to raise tariffs above a certain level. The tariffs that WTO member states set vis-à-vis each other are referred to as Most Favored Nation tariffs (MFN tariffs). In practice, however, these are not the lowest but the highest tariffs imposed. Frequently, lower tariffs apply among countries covered by bilateral trade agreements and in trade between developed countries and developing countries via the GSP system.

Tariffs are largely value-based, levied on the basis of a certain percentage of import value. This is the most common type of tariff, although there are also specific tariffs, where a set amount is levied.

Quotas represent another instrument to regulate product imports. A quota means that a certain amount – for example, 100 tons of prawn/shrimp – may be imported subject to a reduced tariff or, occasionally, exempt from tariffs. All volumes above the quota are imported at the normal tariff rate. Occasionally the quotas are stated in various trade agreements, such as those between the EU and EFTA, but sometimes a country unilaterally decides to introduce a quota, referred to as autonomous. Such quotas, or tariffs, are frequently not country specific. The use of autonomous quotas is relatively common in the EU.

The EU also uses tariff suspensions – a reduction in tariffs on the initiative of the importing country – and, thus, not negotiated between two parties. The EU may reintroduce the suspended tariffs again without consulting the exporting countries. The factor underlying autonomous quotas and tariff suspension is usually a shortfall of a certain product on the EU market. For fishery products, autonomous tariff quotas are usually opened for products for processing – reflecting a need for cheaper raw material in the EU processing industry.

A comparison of tariffs levied on fishery products by developed countries and developing countries shows that tariffs in developing countries are frequently as high or indeed higher than those in developed countries. There are exceptions, of course; quite often the set tariffs are slightly higher than the applied tariffs.

In the developed countries, tariffs are frequently used to protect national interests and have an insignificant role for government finances. However, in poorer countries, tariffs are often a source of government revenue, too. Tariffs and trade-related surcharges are often a relatively easily managed way of financing government expenditure, as opposed to alternative revenue sources. Income distribution effects of tariffs are not solely negative; on the contrary, the share of revenue spent on imported products and services is far higher among the urban middle-class than among the rural poor. For this reason and others, there is frequently considerable political resistance to lowering tariffs.[4]

EU tariffs vis-à-vis other countries

Different countries encounter different tariffs in their trade with the EU. The tariffs applied to products exported to the EU depend on whether the country in question has a trade agreement with the EU, and whether it can benefit from the GSP system or the Cotonou Agreement. If the country does not have the potential to utilize any of the preference arrangements for developing countries or does not have a bilateral agreement with the EU, its goods are subject to MFN tariffs.

Table 1 shows EU tariffs for selected countries and goods. Bangladesh is classified as an LDC and is thus granted tariff-exemption for all fishery products, thanks to the GSP arrangement. The Ivory Coast is an ACP country and, due to the Cotonou Agreement and a forthcoming EPA, it also enjoys tariff exemption for all fishery products. China is a developing country, but not an LDC, and thus receives reduced tariffs for certain fishery products via the GSP system. Finally, the table shows the MFN tariffs, which are the highest tariffs applied by the EU. The products in the table have been chosen on the basis that they are generally key export products for developing countries.

The EU has introduced tariff quotas for some of the products presented in Table 1. Thus, there

4. de Vylder *et al*. 2001.

Table 1. EU tariffs (percentage) for a number of fishery products from selected developing countries.

Fish species	CN Code	Processing level	Bangladesh	Ivory Coast	China	3rd country (MFN tariff)
Tuna	0303 41 – 0303 49	Frozen, for further processing	0	0	0	0
		Frozen, for consumption	0	0	18.5	22
	0304 29 45	Frozen fillets	0	0	14.5	18
	16041411 – 16041490	Processed or canned tuna	0	0	20.5	24
Prawn/shrimp	0306 13 10 10	Frozen, *pandalidae*, for further processing	0	0	0	0
	0306 13 10 90	Frozen, *pandalidae*	0	0	4.2	12
	03061330	Frozen, *crangon*	0	0	14.5	18
	03061350	Frozen, *penaeus*	0	0	4.2	12
	03061380	Frozen, other	0	0	4.2	12
	160520	Processed prawn/shrimp	0	0	7	20
Pilchard	03037110	Frozen, European pilchard	0	0	19.5	23
	03037130	Frozen, S. American pilchard, sardinella	0	0	11.5	15
	16042050	Processed or canned	0	0	17.5	25

Source: Applied tariffs database. TARIC 2007-11-13.

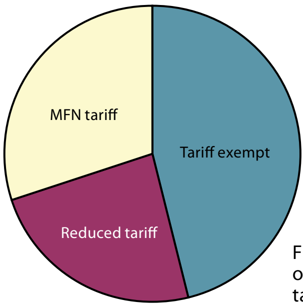
is the possibility – albeit limited – to import these products into the EU with lower tariffs than those noted in the table, or even with tariff exemption.

Figure 2 shows how large a share of EU imports of fishery products that is subject to MFN tariffs, which is about one third. Most imports are *de facto* tariff exempt – as a result of the trade agreements and preference arrangements that the EU has drawn up with various countries.

Tariff escalation

Tariff escalation is a frequent issue in the trade policy debate. This concept refers to the configuration of the tariff structure to protect the processing industry behind tariff walls, at the cost of competing processing industries in other countries outside the walls – in other words, tariffs on processed goods are higher than tariffs imposed on raw materials.

Tariff escalation may be designed either to favor the domestic processing industry against



Source: Roheim, C. 2004..

Figure 2. EU imports, based on value, distributed by tariff rate.

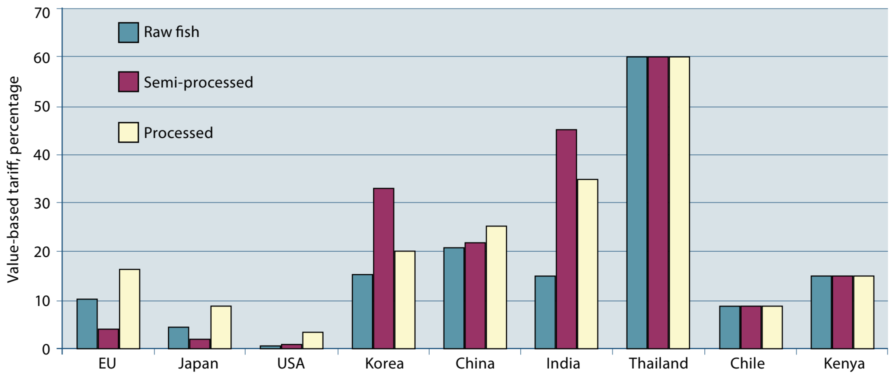
foreign competition, or to encourage the establishment of new industries inside tariff walls instead of outside. Consequently, this type of tariff structure may lead to a distortion of competition and, in turn, to resource mismanagement.

Developing countries frequently demand that the developed countries reduce or eliminate tariff escalation in their tariff structures, as this counteracts the efforts of developing countries to diversify their production and exports and, thus, emerge from their dependence on raw materials.

Figure 3 presents the average MFN tariffs on fishery products for a number of countries, distributed on the basis of the processing level (value added). Two features emerge clearly in the diagram: firstly, that tariffs imposed by developing countries are usually much higher than those of developed countries; and, secondly, that tariff escalation is more marked in the case of developed countries. Three of the developing countries – Thailand, India and Chile – have very basic tariff structures, with a similar tariff on all products. Korea's and India's tariff structures show escalation as well as de-escalation, meaning that they have peak tariffs for semi-processed products. The EU and Japan have the lowest tariffs for semi-processed products. The reason for this is that fish processing companies in the EU have substantial import requirements in terms of semi-processed products, such as frozen fillets, for further processing in the EU. Accordingly, tariffs are kept low for such products.

An explicit aim of current WTO negotiations is to reduce tariff escalation and tariff peaks.

Most developed countries offer tariff reductions to the developing countries, such as via various GSP systems, and thus the tariffs presented in Figure 3 are not always those levied on exported fishery products. In the EU, all fishery products imported from LDCs and ACP countries are tariff exempt.



Source: ICTSD (2006), with some adjustments by the authors.

Figure 3. Average MFN percentage tariffs on fishery products in selected countries.

Non-tariff trade barriers

Traditional border protection, such as tariffs, frequently has a purely protectionist purpose – the idea being to raise the price of imports or completely block them – but the picture is more complex as regards the measures covered by the concept of non-tariff trade barriers (NTB). Non-tariff trade barriers are all sorts of official actions – except tariffs – that curtail trade in one way or another. The dominant feature in this respect in the fisheries area is various types of technical trade barriers, notably different types of veterinary and quality requirements, but various environmental requirements also appear to be increasingly common.

The term "trade barriers" is really unfortunate in this case, since the primary purpose is not to exclude international trade but instead to achieve other purposes, such as food safety. Fish and shellfish, as well as fresh produce, have a higher risk of food-related infections and are therefore subject to stricter sanitary requirements than the traditional export goods of the developing countries (coffee, tea, cacao, cotton and so forth). One consequence of the rising trade in goods with significant requirements in terms of hygiene, safety and environmental considerations is that the differences in standards among countries become evident. Generally, the developing countries have more basic standards and, thus, their export potential is limited by the ever-increasing demands imposed in respect of safe food.[5]

Technical barriers vary in terms of impact. A total import ban is most effective while voluntary labeling rules have the least impact. A total import ban is used primarily to protect livestock and plants from serious diseases. For example, the EU previously imposed a temporary ban on all imports of prawn/shrimp from Bangladesh, after inspections revealed serious shortcomings in terms of hygiene at processing plants, and the authorities could not meet requirements in terms of being able to check compliance with the required standards.[6] However, an import ban is an extreme measure and is not frequently used. Instead, technical specifications are the most common forms of action. This means that imports are permitted if certain requirements are fulfilled, which involve undertaking cultivation or processing procedures, or requirements in respect of the actual product.

Labeling is one alternative. This involves mandatory labeling as well as rules related to requirements for voluntary labeling to market fishery products that are environmentally compatible.

The rules listed in Table 2 are national measures. In addition to official requirements, there are, of course, companies that impose more stringent requirements than those applying interationally, such as in respect of hygiene and environmental certification. In the case of fishery products, more stringent requirements have emerged to the effect that the fish should come from sustainable fisheries. As a result, a number of international food chains currently have stricter requirements in respect of catch documentation and traceability than those set by national legislation.

5. Swedish FAO Committee publication series no. 2/05.
6. Cato and Subasinge 2003.

Table 2. Technical trade barriers for fishery products and other food.

Import bans		Technical specifications			Information requirements	
Complete import ban	Partial import ban	Manufacturing process requirements	Product require-ment	Packaging require-ment	Labeling and product require-ments	Rules for voluntary labeling

Source: Krav på säker mat – Självklarhet eller handelshinder? (in Swedish), Swedish FAO Committee publication series no. 2/05.

Generally, requirements in these areas have tightened over the years, notably in the developed countries. Underlying factors include food scandals that have raised consumer awareness, as well as rising incomes, which have permitted food quality to become a priority.

What problems do developing countries face as a result of trade barriers?

As noted above, the food safety has gained increasing significance for the global fish trade. Import countries in the developed world – which account for some 80 percent of imports – set strict conditions for the import of seafood products. Compliance with food safety requirements frequently takes priority over price in determining the goods to be imported. Almost 50 percent of fish imports originate from developing countries that frequently have limited capacity to undertake the investments required to meet the requirements imposed by import countries.[7]

The countries in question frequently lack the administrative, technical and scientific capacity to meet requirements. Moreover, these countries often suffer from major problems in terms of infrastructure and effectively functioning authorities. And in so far as they can meet the requirements, the high costs undermine competitiveness, the profitability of their exports decline. An additional problem is that many developing countries suffer from insufficient capacity to participate in the processes in which international standards are shaped and to act within the WTO to protect their own interests. Among developing countries, there is also considerable suspicion regarding technical trade barriers; many of them feel that these are used for protectionist purposes.

Food safety is a key factor in the fish sector, since it involves a fresh food product whose quality easily deteriorates if handled inappropriately. It is unlikely that we will see less stringent food requirements in the future. What the developing countries can hope for and work towards is to promote simpler and clearer regulations, and for greater harmonization among countries.

It is important to remember that standards offer advantages to those who can meet them. Among other benefits, they can give better market access, superior prices and a reduced risk of costly import suspensions in the future. Stricter demands on the basis of hygiene and quality mean that the authorities in the particular developing countries are compelled to focus on the fisheries sector and its problems and to improve food safety. However, it must not be forgotten that the rules governing food safety apply primarily to exported fish and that the fish consumed

7. FAO 2001.

by a country's inhabitants do not always need to meet the same requirements.

In fish-producing countries, and especially in developing countries, the reduction in revenue for non-fulfillment of food safety requirements is quite substantial. The economic losses are frequently greater than direct production losses. The costs of illnesses caused by inferior food, product recalls from export markets and for the bad reputation a country gets when its products do not meet standards are frequently considerable. Fish and seafood products account for an estimated 30 percent of illnesses (mainly food poisoning) due to tainted food. Almost 10 percent of the world's total fish output is lost as a result of it becoming unfit for human consumption because of poor handling.[8]

The SPS Agreement and regulations

Non-tariff measures are regulated at the multilateral level through a number of WTO agreements. However, there is no single compilation of non-tariff measures.[9]

Within the framework of the negotiations on agriculture in the Uruguay Round, a new agreement was reached on sanitary and phytosanitary measures (the SPS Agreement), and it is this accord that is most applicable in the fisheries sector. The purpose of the SPS Agreement is to permit countries to protect themselves against trade-related risks that affect the life and health of people, animals and plants, but also to ensure that the measures adopted have the minimum negative impact on trade flows among countries. Two basic principles are that the measures taken should not discriminate among different producers and that the measures are based on scientific findings and risk analysis.

EU regulations indicate a minimum sanitary level for all production and sale of fish and shellfish in the EU. The sanitary regulations governing the fish sector are wide-ranging and require, for example, health certificates for imported fish or seafood products. Import is permitted only from countries and factories that have prior approval from the EU. Special regulations in respect of sanitary checks apply regarding the direct landing of fish from vessels from a third country.

Japan applies an extensive range of non-tariff trade restrictions. All fish, shellfish and molluscs and their processing are subject to requirements in respect of special import licenses for direct landings as part of efforts to protect endangered fish species. Fish imports are subject to requirements involving health certificates from the exporting country in a bid to avoid the introduction of infectious animal illnesses, especially into Japanese aquaculture. All seafood products – domestic and imported – are also subject to general food hygiene regulations. Certain documentation is required for the import of bluefin tuna, swordfish and whale meat, for example, as well as salmon from China, Taiwan and North Korea.

8. Abila 2003.

9. The following WTO agreements are worth noting: 1) The General Agreement on Tariffs and Trade (GATT), 2) The Application of Sanitary and Phytosanitary Measures (SPS Agreement), 3) The Agreement on Technical Barriers to Trade (TBT Agreement), 4) The Agreement on Trade Related Investment Measures (TRIMs Agreement), 5) The Agreement on Rules of Origin, 6) The Agreement on Import Licensing Procedures, 7) The Agreement on the Application of SPS protective measures, 8) The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement), and 9) The Agreement on Government Procurement (GPA Agreement).

All types of fresh, chilled or frozen fish fillets, salted, dried or smoked fish as well as shellfish and molluscs are subject to labeling requirements for public health reasons. In addition, there are mandatory standards for content, labeling, manufacturing methods, storage, distribution and sales of all seafood products for reasons of public health.

New rules have been introduced that require the labeling of all fresh seafood products in respect of origin and production method (fishery/aquaculture). Since April 2001, there are also mandatory labeling rules for processed seafood products, with a range of information regarding production, including preservation methods and the manufacturer's name. Imported products must carry the name of the importer and the country of origin.

In the ***United States*** all fish, shellfish and molluscs, as well as all processed fishery products – with the exception of live fish and fishmeal – are subject to special health and quality stipulations as well as regulations covering labeling administrated by the Food and Drug Administration (FDA) and which have been passed in the interests of public health. The regulations forbid the import of goods that are falsified, incorrectly labeled, hazardous, tainted, or manufactured in inadequate sanitary conditions. Imported products that are subject to FDA regulations are inspected in conjunction with their import. Moreover, canned fish are subject to requirements in respect of prior approval for food hygiene reasons.

Environmental requirements

In the fisheries area, there is also a series of environmental measures introduced in various countries, which in one way or another act as trade barriers. The basic idea of introducing various environmental measures was probably the desire to attain a sustainable utilization of fish resources. As such, these demands must be regarded as warranted, provided that they are non-discriminatory and contribute to attaining the goal. However, discussions regarding the protection of a certain species have sometimes been heated. Exporting developing countries often feel that they are subject to disguised trade barriers, and the term "green protectionism" has been used occasionally in this context. Some measures have also led to disputes within the WTO.

One environmental measure that has been implemented and which has affected trade is the US import ban on prawn/shrimp from countries unable to verify that their fishing methods comply with US rules for the protection of marine turtles. As early as 1987, the US commenced legislation to ban the import of prawn/shrimp caught in a manner that endangered turtles. However, legislation was not fully implemented until 1990. Only countries using fishing methods that include a turtle excluder device (TED) were permitted to export prawn/shrimp to the US. Naturally, this measure impacted on the international prawn/shrimp trade. There are other examples of environmental measures introduced in countries to protect species and which have taken the form of environmental trade measures. These measures have led to a substantial impact on exporting countries, since only certain fishing methods were approved.[10]

Another subject that continually recurs in discussions on "green" disguised trade barriers is the issue of environmental labeling. The number of eco-labeled fishery products has increased in recent years. This is particularly a consequence of the alarming reports on overfishing of marine resources. Consumers have begun to demand environmentally friendly seafood products, for which MSC labeling (Marine Stewardship Council) has probably had the greatest influence. MSC is an independent non-profit organization established by WWF and Unilever. This international organization certifies fish stocks worldwide. In addition, there have been calls for a ban on the consumption of some fish species to prevent overfishing.

Developing countries are generally skeptical to environmental labeling, since they feel this is an attempt by developed countries to further curtail trade and is thus a disguised trade barrier. However, most eco-labeling is voluntary – meaning there are no barriers to selling goods that do not meet eco-labeling requirements. Consumers frequently demand eco-labeling and there is the potential to charge higher prices for products produced in an environmentally compatible manner.

The developing countries have many fishery and aquaculture operations that could be classified as environmentally compatible. The major problem is to get product certification to function, that is, to be able to guarantee that production has been performed in a certain manner and to ensure that the right product ultimately reaches the consumer. Documentation and traceability are important for environmental labeling and it is often in this area that small scale, artisanal fishing encounters problems. Production may well be highly environmentally compatible and fishing may be pursued in a sustainable manner – but there are problems in verifying these facts.

Why is trade important and does it reduce poverty?

Generally, international trade can act as a powerful growth engine and a major source of external influence and development financing. Trade permits economies of scale, which are of key significance for the LDCs. Their domestic markets lack the capacity to provide the foundation for industrialization based solely on domestic consumption. Trade also gives greater competition, compelling companies to be more competitive. Sheltered domestic markets need external competition to raise productivity and exert downward pressure on prices, thereby favoring domestic consumers. Greater competition from imports may also be positive for producers dependent on input goods from abroad. Moreover, trade and foreign direct investment can facilitate a country's access to new technology, innovation and new ideas, working methods, networks, contacts and so forth. Finally, corporate financing may be facilitated. As a rule, companies in poor countries have little access to capital. Accordingly, foreign trade can offer opportunities for financing opportunities not available to companies focusing exclusively on the domestic market.[11]

10. Valverde 2001.
11. de Vylder *et al*. 2001 and SOU 2001:96.

The actual impact of trade on poverty is difficult to gauge. The most common measure of poverty is income per capita. However, this is a rather blunt measure of the multi-faceted nature of poverty. The advantage of this measure is that it is easily available and can thus be shown for essentially all countries over a lengthy period, making it easy to use in comparative studies. However, to gain a more accurate picture of the level of poverty in a country, it is necessary to measure such aspects as individual vulnerability to change and the potential of people to influence their situation and assets. The concept of assets includes features such as education, natural resources, and financial and material resources.

The linkage between increased trade, high growth and less poverty is weak. Currently, trade is regarded as a necessary but not sufficient factor for a country's development.[12] Even though increased trade leads to higher income for a country, there is nothing to indicate that higher income necessarily favors the poor; but neither is there any evidence that higher trade systematically disfavors the poorest in society.

In today's globalized world, the chances of protectionism leading to development are small and diminishing. However, it appears that the timing for when a country should open itself up to international trade is significant in determining whether or not trade favors the country's development. Factors that seem significant in determining whether increased trade leads to a reduction in poverty and greater development include the educational level (the greater the number educated, the better); that export potential can be utilized by many small producers and not solely by large players; and that part of the gains from increased trade are managed by the state and used for social programs and improvements in infrastructure, along with market diversification. Slightly simplified, we may conclude that trade serves to amplify a country's underlying structures. Thus, it is crucial to consider the features that will be amplified when trade increases.[13]

Effects of greater trade in fishery products for developing countries

There is no definite answer as to whether increased trade in fishery products has been positive or negative for the developing countries and the answer undoubtedly depends on the circumstances of the particular country. More fish exports provide increased revenue for the country, but higher revenue does not necessarily imply a reduction in poverty, although it may do so.

The problems noted in connection with increased trade in fishery products are linked, firstly, to food supplies – meaning that fish is exported rather than consumed by the country's inhabitants, and, secondly, there are environmental considerations – which refer to fears of overfishing or environmental destruction in connection with aquaculture.

Increased demand for fishery products has led to significant price rises; however, demand for fish has not increased solely in developed countries, but also in developing countries. The fact that fish has become relatively more expensive compared to other foods may have negative implications for

12. Stiglitz and Charlton 2007.
13. Human development report 2005 and Rodrik 2001.

the food supply, especially in countries in which the intake of animal protein derives largely from fish. Nowadays, it is an oversimplification to say that species with a high economic value are exported to the developed countries while low-value species are consumed in the developing countries. If demand for fishmeal rises due to an expansion in aquaculture, it may prove profitable to make fishmeal from low-value fish species currently consumed by the poor in developing countries. This type of development could be disastrous for the food supply in large swathes of the Third World.

Another effect of rising trade and demand is that the production of fishery products tends to rise in terms of scale. Generally, this favors those with greater access to capital and/or land but disfavors the poor who are usually landless or have a low level of education. However, income from higher fish sales may mean that those who earn money can spend it increasingly, with a multiplier (or chain) effect throughout society. In aquaculture, increased demand for land may result in the destruction of the local population's traditional lifestyle.

One of the resolutions adopted at the World Summit on Sustainable Development in Johannesburg in 2002 is to attain sustainable fishing by 2015, considering the over-exploitation of global fish stocks. However, the magnitude of the impact of trade per se on overfishing has not been clarified. There are indications that extensive trading in seafood products reduces natural resources – increased demand leads to higher pressure on fisheries, leading in turn to overfishing of stocks. It also leads to increased fish and shellfish farming, which may entail an unsustainable utilization of natural resources. The extent and nature of the negative consequences vary among countries and over time.

It should be noted that it is difficult to gauge the effects of fishing on fish stocks due to the large number of factors involved. Nevertheless, fishing is the factor that has the greatest impact on the growth of fish stocks. Other influencing factors include water temperature, marine currents, oxygen content, salt content and various forms of man-made negative environmental impacts. Other factors that control stock size are the balance between the stock and predators, and how the stock develops with varying access to food.

The fish species hardest hit by overfishing are those that are most in demand on export markets. The negative environmental effects linked to aquaculture include the destruction of mangrove, increased emission of nutrient salts and a higher incidence of disease. Increased farming of carnivore species, such as salmon, may result in higher demand for fishmeal, since this is used in farm fish feed. In current conditions, it is impossible to fully substitute fish proteins with vegetable proteins in the production of fish feed, as this would lead to rising mortality rates and a decline in the quality of farmed products. A rise in the demand for fishmeal may lead to greater utilization of marine stocks, which in turn can lead to the overfishing of stocks along with imbalance in the marine ecosystem.

This adverse impact on stocks can be counteracted by efficiently functioning fisheries administration and the application of environmental requirements to aquaculture. However, a functioning fisheries administration and compliance with environmental demands require more than legislation. It requires structures (authorities) to apply the regulations and a functioning control apparatus to ensure compliance. Environmental destruction frequently arises as a result of higher demand, combined with insufficient regulations and a lack of control in ensuring compliance.

Trade per se is neither positive nor negative for the environment or natural resources – trade acts as an amplifying factor. This means that if the underlying structures are defective or weak – for example, that subsidies make it profitable to focus on fishing – trade will amplify the effects, with the potential of negative results for the environment, food supply and so forth.

What can be done to counteract adverse effects of fish trade?

The attainment of sustainable utilization of fish resources and the counteraction of the adverse impacts, as noted above, require an effectively functioning fisheries administration. This includes rules and regulations, functioning structures and – not least – effective control systems.

In cases in which rising exports lead to an expansion in fish and shellfish farming – and thus higher environmental impact – stricter environmental rules and controls need to be observed. More stringent requirements may result in technological progress, such as improved water treatment and higher feed intake.

Greater efforts should be made to reduce tariff escalation (increases in tariff rates in line with processing levels) in the fisheries sector. This can facilitate the efforts of developing countries to export more processed products to generate higher revenue, which could contribute to a reduction in resource extraction, compared to a situation in which the country exports only raw fish and products with a low processing value.

Positive effects and how to enhance them

Trade in fishery products also gives positive effects for the exporting developing countries, primarily because they offer the potential for export revenue. Apart this, however, there are other benefits from foreign trade – technology transfer, greater competition and economies of scale. Revenue can contribute to raising living standards (in other words, less poverty) if used in the appropriate manner.

Currently, the major problem of developing countries is in meeting the developed countries' non-tariff trade barriers in the fisheries sector. The most challenging and most wide-ranging of these are the technical trade barriers (various sanitary requirements in respect of labeling, standards and packaging and so forth).

In view of the high global demand for fish, and the limited assets available, losses and illnesses that arise from inferior fishery products are sufficient reasons to take measures to improve quality and safety. In addition, consumers impose stringent requirements in terms of safe food and products that meet environmental and sustainability demands. Thus, requirements should not be reduced in an effort to "assist" developing countries. Instead, additional financial and technical support should be offered to developing countries to enable them to meet the technical requirements imposed by developed countries. Efforts should also be made in WTO negotiations to reduce the imposition of unwarranted, non-tariff trade barriers at the global level. Furthermore, the WTO must seek to improve notification of non-tariff trade barriers.

The issue of environmental labeling has been topical worldwide over a number of years. The leading organization in this field has been the FAO, which, following many years work, recently adopted guidelines for the environmental labeling of fish caught at sea. As yet, it is unclear how large an impact these guidelines will have. Uniform international standardization and harmonization of various regulatory systems are urgent matters, since such actions would reduce the need for special national rules. In this context, it is important that eco-labeling is viewed as a complement to the two basic tools, meaning resource management and food safety systems. The standards ought to be voluntary and non-discriminating.

For many developing countries, the EU, Japan and the US are key markets in terms of fishery products and other goods. Several products imported by these countries enjoy reduced tariffs or tariff exemption via various trade agreements. In the case of many developing countries – including ACP countries and LDCs – additional multi-lateral tariff reductions are viewed as negative, since they undermine their tariff preference. However, resistance to the undermining of preferences must not halt progress towards greater multilateral free trade. Instead, the problem should be tackled using special solutions and transition periods that take into account the particular requirements of developing countries. Among other aspects, technical assistance ought to be increased to counteract the losses that ACP countries and LDCs may suffer as a result of lost margins. This would increase the potential of the particular countries to participate in the overall welfare gains that can be expected from a general reduction in tariffs. Other measures that could be taken in this context include the streamlining of origin rules, especially for LDCs.

Thus, in a bid to minimize the negative and accentuate the positive effects of a substantial export of fishery products, one should consider the appropriate methods to promote exports and analyze the possible social effects of increased exports. Subsequently, efforts ought be made to offset any negative impacts. A focus on increasing foreign trade should not be viewed as a substitute for but as a complement to other development programs.

Conclusions

There is a potential for many developing countries to increase their exports of fishery products. However, some consideration is required if exports are to prove positive for the country – meaning that they lead to a reduction in poverty without fish stocks being jeopardized by overfishing and environmental deterioration.

Before measures are taken to increase trade, one should consider the underlying structures that will be affected in the event of increased trade. Trade is an amplifier. In an optimal situation, administration and democratic institutions should be in place and functioning before measures are taken to enhance trade. In reality, however, the fact is that revenue from trade is required to pay for administrative and democratic institutions. Hopefully, development can progress in a manner that ensures gradual adjustment.

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Photo: Peter Funegård, Swedish Board of Fisheries.

FISH TRADE – INCOME POSSIBILITIES AND THREAT OF RESOURCE DEPLETION[1]

Håkan Eggert, Mads Greaker

Abstract

This chapter deals with fisheries and trade focusing on developing countries, and discusses possible ways of addressing related problems. Fish is globally traded, and for many developing countries, it is an important net export good. In most of these countries, fisheries management is often de facto open access, where vessels with or without permission to fish land as much as they can catch, due to limited monitoring and enforcement activities. Even in developed countries, many fisheries are poorly managed, and recent studies indicate that marine ecosystems are in global decline. While trade generally is beneficial for growth and welfare, the combination of pure open access and trade liberalization may reduce both welfare and stocks for a country – an outcome that can be reinforced by the common use of bad subsidies. However, trade liberalization may have an additional positive impact by promoting the development of property rights in response to increased fish exploitation. The WTO can play a role by adopting a broader classification of subsidies to help eliminate bad subsidies, such as public support for vessel construction, fuel subsidies, or fishing rights outside developing coastal countries provided at limited or zero cost. The WTO can also assist by distinguishing good subsidies (e.g. improving fisheries management or improving monitoring and enforcement), which are desirable targets when rich countries allocate aid resource to developing countries.

Introduction

The global seafood market offers a lot of opportunities, but also raises challenges in terms of how such aquatic resources are managed. In developing countries, the exploitation of renewable marine resources like fish, crustaceans and molluscs is often characterized by poorly defined property rights accompanied with overcapitalization where too many vessels and fishermen catch too little fish from too small stocks. Management is often de facto open access. In developed countries fisheries management is in general most accurately depicted as Regulated Open Access in which ac-

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cess to fishing is limited, fishing authorities have some kind of restrictions of landings, and fishing may not be permitted throughout the whole year. Yet, the property right problem is not addressed, the race to catch is still on, and in fact, any management success in terms of stock conservation may reinforce the problem of overcapitalization (Homans and Wilen 1997). Despite the fact that a substantial amount of global catches, roughly 15 percent, nowadays are landed in rights based fisheries, the global conditions of major fish stocks are severe.

Trade is usually seen as a positive factor in improving the standards of living for a country's population. Based on the assumptions that countries combine their resources in an optimal way to produce goods and services, trade offers an opportunity to achieve higher levels of consumption for all involved parties, compared to a situation of self-supporting autarky. Hence, the general advice of economists has been to promote liberalization in trade, and that developing countries will be better off, if rich countries lower their tariffs, allowing import to increase. Similarly, foreign direct investment or joint venture projects in poor countries offer an opportunity of technology diffusion and increased welfare (Bhagwati 2001). More recently, a literature on trade and renewable resources has developed. Trade may be beneficial for welfare, but may be problematic for resource conservation. In fact, when property rights are completely absent, trade can be detrimental not only to stocks, but may also reduce welfare for resource exporting countries.

Economic development and trade – a historic review

The benefits from trade were first stressed more than 200 years ago by Adam Smith (1776). His argument was that labour division and specialization could benefit both parties in bilateral trading, where each party was assumed more productive in at least one type of goods production. This requirement of absolute advantages in order to gain from trade was relaxed during the next century by David Ricardo (1817), who showed in a simple two goods–two countries model that even if one country were more productive in producing each of the two goods, both countries could be better off from trading. This would be achieved by exploiting what Ricardo called comparative advantages, which only require that the difference in performance is not identical for all goods and that the low productive country should increase its production of the goods where the gap in productivity is the smallest. During the 20th century, these ideas have been refined, but the general conclusion is that countries can almost always benefit from trade. Companies within a country are likely to specialize in goods and services that require intensive use of input factors that are relatively abundant and consequently relatively cheaper in the country. When countries start to trade, factor price equalisation will occur, i.e. the relatively cheaper input will gradually gain a higher price and catch up with the price of the same input in other countries.

In the 1930s, the great depression lead to protectionist calls for tariffs in order to provide domestic employment in the US. Europe retaliated with increased tariffs and the following trade war substantially made the involved economies worse off and reinforced the negative impacts from the stock market crashes in the late 1920s. After the Second World War, the General Agreement on Tariffs and Trade (GATT) was created in order to reduce the high levels of tariffs and other trade barriers. After several rounds of negotiation, the World Trade Organization (WTO) was formed in 1995 (WTO 2009). In 2001, the most recent round of negotiation, the Doha Round, started with 144 countries represented, which had increased to 151 in 2007 (IMF 2007). Despite current critique GATT and WTO must be regarded as great successes. The average tariff level on dutiable imports has been reduced from 40 percent in the late 1940s to less than five percent by the beginning of 2000.

Free trade is also seen as an insurance against absence of competition. Companies that grow and enter the international export market often try to eliminate competition in their home market, and sometimes get informal consent from the domestic government as growth in export is assumed conditional on economies of scale. Under those conditions, free trade is one of the few options to increase competition and secure large values in terms of consumer surplus gains.

The benefits of trade

There is strong theoretical support for the importance of trade as a means of achieving economic growth. What about the empirical evidence? There is a comprehensive literature investigating the relationship between trade and growth. Some issues are still debated, as it is hard to fully prove a causal relationship (Rodriguez and Rodrik 2000). Still, it is undisputed that countries, which have had success in increasing their income levels, have also been doing well in the export markets. The advantages are partly static gains from specialisation, and partly due to dynamic gains in the form of positive effects on total factor productivity (Bigsten 2007). Therefore, trade policy is important for developing countries. A couple of studies that have estimated the potential effects of a full liberalization of global merchandise trade arrive at long-run figures in the range of a USD 200–300 billion increase of world GDP (Cline 2004, Anderson *et al*. 2006).

Concerning growth and the poor, there are distributional concerns for obvious reasons. Still, the general finding from economic growth is that the poorest get a substantial share of the proceeds. Similar projections are made on national level in trade liberalization studies, which predict that half (or almost half) of the gains will accrue to the developing countries.

These figures do not account for potential gains from service trade liberalization, trade facilitation and productivity gains from increasing trade. The major positive effect for poor countries of complete global trade liberalization would be in the agricultural sector, which also would entail positive distributional effects for developing countries as their farmers and unskilled labour are the ones most likely benefitting from trade liberalization (Hertel and Winters 2006). This, however, is not within reach in the near future.

Trade and renewable marine resources – some theories

In a first best world – i.e. in a well-functioning market economy – trade liberalization will lead to welfare improvements. At the same time, a first best policy may not be optimal in the presence of other imperfections. For example, when property rights are poorly defined for fisheries, trade liberalization may not always lead to welfare improvements. However, this general result does not provide much guidance, and for a long time economists did not look into the particular field of renewable resources and trade. Recently, however, this has changed. This section reviews some recent theoretical work in this area, which, *inter alia*, implies that trade may be problematic if fisheries management must deal with poorly defined property rights (see Bulte and Barbier 2005, including references).

Fish stocks are not simply a production factor in fisheries; they also play a part in providing ecosystem resilience. The aim here is not to provide solutions to the difficult task of designing new international treaties or suggest how the WTO should handle these issues, but rather to elaborate on what recent contributions say about trade liberalization, and how it may affect stocks and human welfare under various assumptions and management conditions.

An optimal fishery is often described from the perspective of how a single owner would manage one fish stock, where growth is assumed to follow a logistic function and harvest takes place according to the production function described by Schaefer (1957). An unexploited fish stock will then reach a stable equilibrium – the carrying capacity – where natural mortality is evenly offset by recruitment and natural growth. In the standard case, half of the carrying capacity stock will generate the maximum net surplus growth, or maximum sustainable yield (MSY). However, because the fish are assumed to be uniformly distributed, and the catch assumed to be proportionate to the stock size, the social optimal stock size is slightly larger than the MSY stock, where the reductions in costs of catching offset the reduction in revenues and thus maximize the positive profits (the resource rent).

For a country with optimal fisheries management, trade liberalization is welfare-improving. There will be distributional effects, and while groups (such as consumers and producers) may lose or gain, overall gains will be larger than losses. For a country with abundant fish resources, the free trade price will be higher than the previous autarky price, and the optimal stock will be reduced. Hence, trade barriers may appear to promote resource conservation. (Such arguments have been made concerning trade, for example, in sea horses.) However, if we assume a positive stock externality (such as biodiversity benefits) and that the harvest is sold both domestically and for export, it is unclear whether a tariff would increase or decrease the stock.

In a pure open access fishery, a large number of unregulated fishers harvest a fish stock without any barriers to entry or exit. Any positive profit generated by the fishery leads to an increase in fishing effort, until the total cost of fishing equals the total revenue from fishing, also implying pervasive over-capacity and dissipated resource rent. Fishers are completely myopic and disregard the effects their behavior today may have on the catching possibilities tomorrow. If a resource-abundant country with open access fisheries starts to trade, the higher world market price will lead to expanding fishing effort and decreasing fish stocks, leaving welfare unchanged. The two states – before and after trade – are equal in the sense that both have open access and that profits are zero.

To make things a bit more complex, we can look at a small, open economy where the open access fishery model is combined with a Ricardian model of trade. Two goods are produced in the country; one is manufactured which only uses labour, and the other is a resource good which uses labour and the resource stock. There is full employment and both sectors are assumed to produce with constant returns to scale. Since both goods are assumed essential, they are both produced under autarky and the wage level is thus equal in both sectors. As a result, all rents in the resource sector are dissipated due to the open access where harvest is produced according to the Schaefer production function. The ratio between the resource's intrinsic growth rate and the size of the labour force will determine the relative prices between manufactured and resource goods in autarky. If the ratio is high enough, the autarky price of the resource good will be lower than the world market price. The country can thus be considered resource-abundant and have a comparative advantage in resource good production. If the country starts to trade, it will increase production of the resource good and export all of it. Several scenarios are possible, but the main point is that, due to the open access condition, harvesting can drive down the resource stock, leading to decreased landings and lower wages for the larger fraction of the labour force now working in the resource sector. Consequently, a country that is heavily dependent on a resource industry may in fact be worse off with trade, compared to autarky (Chichilnisky 1994, Brander and Taylor 1997).

Developed countries often have better management than developing countries. Using the simple notion of "North" for developed countries and "South" for developing countries, we assume imperfect property rights in both North and South and no monitoring and enforcement in either country. Still, the problem with overuse of the resources is assumed worse in the South, because more people exploit the common pool resource. Further, the utility of consumers depends on two produced goods, both of which use the resource as input, but to a different degree. One is a subsistence good which is less resource-intensive. It is assumed the main consumption item at low-income levels, but if income increases, consumers will use all income above a given level to consume the second, more resource-intensive good. Furthermore, there are two production factors, the resource and labour, and both goods are produced with fixed proportions of inputs. As a result, labour cannot substitute shortage of the resource stock, and vice versa. The inability to substitute implies that there can be multiple equilibriums in autarky. For slow-growing species, there may be a uniquely low equilibrium where some of the labour force is not used, and with low stock levels – which resembles the situation in many developing countries.

When North and South start to trade, there are several potential outcomes. If all labour is employed in both countries, total harvesting is not influenced by trade. However, the output mix may change if the South, with its apparent comparative advantage, increases production of the more resource-intensive good. When some labour is unemployed under autarky, total extraction may also increase with trade. In this model, trade may lead to inefficient flows, which can outweigh the general benefits from trade and decrease overall welfare in the South. Trade also has the potential to induce a stock collapse in the South and trigger import and resource degradation in the North. This worst-case scenario can arise when property rights are also imperfect in the North. On the other hand, there are circumstances where trade makes both parties better off. Mixed outcomes are possible, of course, which can be interpreted as depending on parameter values. Trade liberalization can lead to either reductions or increases, both in terms of welfare and stock conservation (Karp *et al*. 2001). Ideally, an analyst may succeed in identifying the perspective most likely to occur for a set of given conditions. More generally, the model points to a key role for the intrinsic growth rate of a resource stock. In short, slow-growing species and poorly-defined property rights, combined with free trade, imply problems.

Property rights are not given to a country deterministically (like its geography), but are developed like other market institutions, in order to facilitate transactions and protect scarce resources in the country (Copeland and Taylor 2009). Trade liberalization changes market conditions, and may lead to changes in property rights. Therefore, rather than being given, like in the previously reviewed model, property rights are part of the market development and may change with other variables changing in a model. Copeland and Taylor (2009) used such a framework to study the impact of changes in world prices on the enforcement of property rights. The outcome depends on the resource growth rates, time-preference rates, population size, regulatory enforcement, and the technology level. Based on these parameters, resource-rich countries will differ in their ability to enforce property rights as world prices vary.

The first group of countries – with poorly defined property rights – often has a large number of resource users with high time-preference rates[2], slow-growing resources, and a government with limited enforcement abilities. In addition, they will be stuck in the open-access trap, where all of their resource rents dissipate. These countries are worse off with trade liberalization, because the poor property rights imply that increasing prices only will involve more users, without generating any more resource rents, and will reduce overall welfare long-term as stocks are depleted.

The second group of countries – with moderately defined property rights – has open-access conditions for low prices, but increasing prices afford some protection for the resource(s), and a little resource rent is generated. For these countries, the limited management is developed

2. The users are myopic and assign considerable weight to what they get today, and rapidly reduce the value of future outcomes the more remote that they become.

by the increasing prices. Thanks to more secure property rights, trade liberalization – leading to higher prices – can improve welfare in both the short and the long term.

The third group of countries (well-defined property rights) will also experience open access if prices are low enough. As prices increase, management will develop to the intermediate level, or even become fully efficient if prices are high enough. Hence, these countries are even more likely to benefit from trade liberalization and improve their welfare.

Trade and fisheries – the empirical cases of Argentina and Tanzania

The theoretical work reviewed in the previous section confirms that both critiques and proponents of free trade with renewable resources have some valid points. Trade may be harmful to stock conservation and may even lead to welfare losses, on the other hand trade does generate benefits, and may sometimes lead to improvements in stock conservation. What are the real world experiences so far? In this section, we review two cases, Argentina and Tanzania, which are two examples that provide various experiences reflecting some of the issues discussed.

Argentina

In the 1990s, the Argentine government adopted a far-reaching structural adjustment program, which implied several reforms including a fixed foreign exchange rate, a tight monetary policy, privatization of public utilities and enterprises, deregulation of markets and economic activities, and an open trade regime. As several conditions changed at the same time, the impact of the trade reform cannot be seen in isolation. The fisheries sector in Argentina saw many of these changes come into play. Although a country without a high domestic consumer preference for fish, Argentina expanded its fisheries sector to export. Fisheries were minor in the country until this change, but started to grow at unprecedented rates and became one of the country's most dynamic economic sectors. Value added increased steadily and exports grew by almost 500 percent between 1985 and 1995.

The fisheries sector was characterized by a high degree of economic protection in the 1980s, with the most important feature of the legislation being that only vessels with an Argentine flag could fish within the exclusive economic zone. Therefore, expansion of the fleet initially was mainly through incorporation of new Argentine-flagged ships, even though some of those were owned by foreign capital with firms settled within the country. Several rules were modified by the beginning to the 1990s, which allowed imports of second-hand vessels and reduction of the required proportions of domestic crewmembers. In 1994, an important agreement with the European Union was signed. It differed from the typical agreements previously closed between the EU and many African countries. One novelty was that it did not ask for a general authorization for EU vessels to fish in Argentine waters. Further, it was based on subsidies from the EU to establish joint ventures with local firms in order to provide access for EU vessels within the EEZ of Argentina. While some saw this arrangement as an improvement compared to previous ones, it turned out that severe deficiencies in law enforcement and other control measures and the existence of bribery and corruption led to a crisis in the Argentine fisheries by the end of the century.

The development of the Argentinean fisheries during 1985–2000 in many respects follows the textbook description of an open access fishery. In 1990, landings were 500,000 tonnes and then gradually increased to peak at 1,340,000 tonnes in 1997, followed by a reduction to 1,000,000 tonnes in 1999. At the same time effort increased; as an example the aggregate motor power of the fleet fishing increased from 25,000 horsepower (hp) in 1990 to almost 200,000 hp in 1995.

Developed countries, particularly the EU, played an interesting part during this period. The money spent on subsidies by the EU within the agreement is estimated at USD 230 million, and the money used to gain access to the Argentinean waters was classified as 'good' subsidies, because it was assumed to reduce pressure on stocks in European waters. Similarly, the collapse of the cod stocks outside New Foundland in the beginning of the 1990s led to a Canadian vessel buy-back program, where vessel owners received payments for withdrawing capacity and selling it to other parts of the world, mainly developing countries including Argentina.

Hence, public funds were used to shift excess capacity from rich countries to developing countries. Furthermore, the active role of the EU seems to have contributed to the use of bribes, and substantial corruption practices. Vessel licences were irregular, indications of non-reporting of catch was found, and practices with permits to fish often did not meet the requirements. The European Court of Auditors carried out a scrutiny in 1998 of subsidized programmes for joint ventures aiming at transferring capacity outside Europe, which at the time only took place in Argentina (Abaza and Jha 2002b). Several strange situations were found and categorized as "bordering on the toleration of fraud". Subsidies were granted and paid based on exaggerated capacity, for sunken and inactive vessels, for vessels not suitable for the fisheries, and even to non-existent companies. The audit concluded that EU should revise its monitoring and control procedures and recuperate misused grants.

The trade liberalization and the development of the fisheries sector in Argentina during 1985–1999 is an example of both positive and negative effects. Fisheries production has increased, like fisheries export and employment in the remote south, Patagonia, and in the harvest sector. The increased economic activities include improvement and growth of the fisheries fleet, technological innovations in the sector, creation of new markets and trade exchange, and development of regional infrastructure like new ports and roads. In addition, it has brought increased tax revenues.

On the other hand, several negative effects are documented. Fish biomass was degraded and marine ecosystems experienced decline. In addition, corruption practices developed during this time, overcapitalization developed both in terms of fleet, as well as ports and similar. Working conditions deteriorated and unemployment even caused social unrest, particularly at the end of the period when the declining trend in Agentine hake (*Merluccius Hubssi*) catches became apparent and led to stricter regulations. According to stakeholders directly involved in fisheries, the positive impact outweighs the negative, but that position has been criticized. Abaza and Jha (2002) use a cost benefit analysis framework to estimate the potential gains of an optimally managed fishery, using MSY stocks as optimal size, and found that at a fairly high real social discount rate of four percent, the net present value was USD 5,100 million. Although it seems fair to say that trade liberalization led to welfare improvement and reduced stocks, the development was far from optimal, as welfare gains could have been substantially larger.

In response to the declining fish stocks and catches in the late 1990s, Argentinean fisheries management was revised. In 1997, the National Fisheries Law of Argentina was adopted, which prescribed a quota management system for the fisheries. The government should set the quotas and shares of these, i.e. individual transferable quotas (ITQs) should be a requisite for fishing, and the ITQs should be bought and sold on a secondary market. This reform met a lot of resistance and the implementation has been a slow process. It is too early to assess the impact of the reform, and it is at the same time difficult to say what would have happened without it, both in terms of stock conservation and welfare effects. As an example, the hake stock that was severely overfished during the 1990s, yielded a catch of 1,000,000 tonnes in 1999, and the corresponding figure in 2005 was 900,000 tonnes. Still, we note that trade liberalization, and the increasing exports in the case of Argentina led to reconsideration of the fisheries management.

Tanzania

Lake Victoria is the largest tropical lake in the world, and the single most important source of inland fishery production in Africa. Its waters are shared between Tanzania, 49 percent, Uganda, 45 percent, and Kenya, 6 percent. In the 1950s and 1960s the non-indigenous species Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*) were introduced to compensate for depleted low-value small fish and get more easily caught higher-value species (Balirwa *et al*. 2003). This had a minor impact for many years, but during the 1980s, landed quantities were radically amplified and even more so in terms of value. Tanzania, as well as Kenya and Uganda, experienced the establishment of fillet processing industries by the lake, and the export nowadays contributes with a substantial share of the foreign currency earnings. During the 1980s the Nile perch provided a new source of inexpensive protein for people along the Tanzanian shoreline and fishers called it the "saviour". Later on, a growing share of the Nile perch catches has been exported, primarily to Europe.

The rapid growth of Nile perch came at the expense of a severe reduction of the available number of species. Lake Victoria was known for more than 600 endemic species of haplochromine cichlids (Balirwa *et al*. 2003). About 40 percent of these species disappeared, and the Nile perch seems to have been a key contributor to this mass extinction with contributions from environmental changes. Today the fisheries mainly consist of three commercially important species; Nile perch, the sardine-like Dagaa (*Rastrineobola argentea*) and the Nile tilapia. Recent estimates show that Nile perch, Dagaa and Nile tilapia constitute 45, 40, and 8 percent respectively of Tanzania's total Lake Victoria landings.

Entry into the Lake Victoria fisheries is open to anyone with enough capital and the necessary skills. There is no catch limit, thus participating fishers can catch as much as possible, given the stock level and their vessels capacity. Fishing requires an annual license fee of about USD 20, which, since it corresponds to gross revenues from two days of fishing, cannot be seen as a limited access policy or as a good management tool.

During 1968–1982 total catches were fairly stable at around 100,000 tonnes, with Tanzanian fishermen landing roughly half of that. Then landings started to increase dramatically during seven years, up to an all time high of almost 600,000 tonnes in 1989. Some reductions have been noted but total landings have been quite stable above 500,000 tonnes during 1990–2003 with a Tanzanian share of about 40 percent. The crude impression may be that Lake Victoria experiences a stable open access equilibrium, but there are several indications that stocks may collapse. A study based on data until 1990 found considerable depletion of the Nile perch stock and warned that increasing effort as in the late 1980s could soon lead to a stock collapse (Pitcher and Brundy 1995). The increase in vessels pretty much followed their worst-case scenario until 2000 and then increased even more rapidly in 2000–2002, but the stock has not collapsed so far. Yet, clear signs of a declining stock appear. A rough measure of catch per unit effort (CPUE) expressed as average catch per vessel and year indicates a relatively stable level of biomass during 1968–1982 with about ten tonnes per boat and year. 1983–1989 CPUE steadily grew to 35 tonnes and then, equally steadily, declined to less than ten tonnes in 2002. The reaction to the upsurge in landings, starting in 1983, was quite slow and the number of fishing vessels was stable around 10,000 during 1968–1985. At that time, each vessel had a larger crew and a rough guesstimate leads to a total number of fishers around 50,000 before the boom started. In 1986–2002 there was a dramatic increase in vessels. Some replaced sail with outboard motors, and reduced their crew size in response to lower catches. The total number of vessels in 2002 was 60,000, and the average vessel had a crew of three, which indicates that 180,000 fishers exploited the stocks of Lake Victoria (Eggert and Lokina, forthcoming).

Gillnet is the major fishing gear in Lake Victoria. The Tanzanian regulation requires a minimum mesh size of five inches for Nile perch and Tilapia, and ten millimetres for Dagaa. Previously, larger mesh sizes than required were frequently used, but today most fishers use the minimum size, which means that the average size of Nile perch is reduced from 70 kg in 1981 to seven kilograms in 1996. Catch per net declined by almost 60 percent in the Tanzanian section of the Lake, and some fishers respond with new techniques like multiple mounting of nets vertically to cover the whole water column. Such mounted nets are also tied on boats with engine and towed slowly over a large distance. A more recent study concludes that doubling of fishing effort over the next few years will result in a Nile perch stock collapse (Mkumbo *et al*. 2002). Still, recruitment is good, but lots of immature fish are being caught. Nile perch feed on Dagaa and other small fish in the lake. Hence, a reduction in Nile perch is likely to be accompanied by an increase in the Dagaa and other small species. Such development is confirmed for recent years and implicitly by landings of Dagaa that grew from 40,000 tonnes in 1986, via 100,000 in 1991, to 220,000 tonnes in 2000. The corresponding figures for Nile perch is 240,000 tonnes in 1987, via 400,000 in 1990, and down to 240,000 tonnes in 2000. The overfishing of Nile perch has not only meant an increase of the Dagaa stock, but several other native species in retreat or even thought of as extinct are now remerging. A high fishing pressure on Nile perch consequently appears to be good for biodiversity (Matsuishi *et al*. 2006).

Regulation measures used in Lake Victoria includes licensing, closed areas/seasons, the ban of using poison and dynamite. Other destructive gear like beach seine, dragged along the bottom, and fine mesh mosquito nets, catching undersized fish, are also prohibited. In 1998, the Tanzanian Government through the Lake Victoria Environmental Management Project introduced local management units commonly known as Beach Management Units (BMUs). These units were established to enhance community participation in the surveillance and management of the lake resources. Though the BMU leaders do not have legal power to arrest anyone, they can point out culprits to the enforcement officials. Their most important task is to help prevent the use of poison or dynamite, and they seem to have been successful. The most common infringements of regulations are the use of too-small mesh size and of beach seines. Tanzanian fishers' compliance with respect to the mesh size is low, compared to what is generally found in studies of fishermen in developed countries. Membership in a BMU did not influence fishers' decision of being non-violators, i.e. always obeying the mesh size regulation. An additional problem is the ubiquitous prevalence of corruption. According to Transparency International (TI), the TI Corruption Perceptions Index 2005 found rampant corruption in Tanzania. The fisheries sector is not exempt, and all of the almost 500 respondents in the study had experienced arrest and 40 percent had used bribes to avoid being taken to court. Also non-violating fishers often used bribes to avoid the bother of court proceedings and the risk of being convicted despite being innocent. A more promising part in avoiding systematic landings of immature fish, is the introduced slot size of Nile perch at 55 cm to 85 cm for the processing industry, which was found to promote mesh size compliance among those targeting Nile perch (Eggert and Lokina 2005).

Tanzania's open access fisheries in Lake Victoria and the export orientation since the mid 1980s have generated substantial welfare increases. At the same time, the rapid increase in export and the open access nature of the fisheries have lead to a situation where the major commercial stocks are overfished. So far, the reactions in terms of attempting to improve management have been fruitless. From other examples in resource economics, we know that reducing the value of a resource may be detrimental for conservation, e.g. banning ivory trade lowered the price for ivory and led to more elephants being shot. Similarly, high export revenues could be an input to reform management, which may be the case of Argentina.

It is too early to assess whether the reform process initiated in the late 1990s is successful, but it is likely to have halted the degradation of Argentinean fish stocks. A parallel development is missing in Tanzania. The BMUs seem like a first step towards a management reform, but so far, several field trips and interviews with management staff, BMU leaders and fishermen indicate that all agree that access to BMU membership, and hence fishing in Lake Victoria, should be open for all.

Fisheries subsidies and the World Trade Organization

Governments around the world still provide substantial subsidies to their fisheries. A World Bank study arrived at a figure of USD 14–20 billion annually which was estimated to "probably err on the low side, perhaps by a considerable margin". At the time, it corresponded to 20–25 percent of first sale global landing values. The OECD countries and China may be responsible for up to 75 percent of these subsidies (Milazzo 1998). A more recent study estimate subsidies to USD 30–34 billion per year (Sumaila and Pauly 2006). This study also provides a classification of subsidies, where 'good' subsidies support stock conservation through improving fisheries management, monitoring and enforcement. 'Bad' subsidies lead to growth in fishing effort and include public support to vessel construction and fuel subsidies. The third category is labelled 'ugly' subsidies where the effect on fishing effort may be ambiguous. Buyback schemes and decommissioning programs are examples of 'ugly' subsidies, which under ideal conditions may reduce fishing effort. However, in general buyback programs merely works as a subsidy to the remaining vessels that increase their effort (Weninger and McConnell 2000), and the overall effect of these programs is often very limited (Holland, Gudmundsson and Gates 1998). In fact, if fishermen expect future buyback schemes, it may increase their willingness to invest in vessels and support long run increases in fishing effort (Clark *et al*, 2005). As noted earlier, buyback programs often accept the export of vessels outside the domain of the subsidizer, meaning that effort is not at all reduced. Sumaila and Pauly (2006) found that 70 percent of the subsidies were 'bad' and another ten percent were 'ugly' with developing countries providing about 60 percent of the 'bad' subsidies.

The WTO has long considered subsidies as potential non-tariff barriers to trade. Currently the core multilateral subsidies disciplines are given by the WTO Agreement on Subsidies and Countervailing Duties. Articles 1 and 2 of the Subsidies Agreement define subsidy, which *inter alia* includes grants, loans, loan guarantees from a government, tax credits, and general price and income support (Schorr 1999). As often several potential loopholes exist, Article 8, e.g., protects subsidies to assist disadvantaged regions and adaption of existing facilities to new environmental requirements. Complaints to WTO against subsidies generally require the complainant to show trade-related harm. Article 6.1 under Subsidies provides presumptions from proving trade harm, referring to "serious prejudice". One example is when the value of the subsidy exceeds five percent *ad valorem*. With subsidies of almost twenty percent of revenues, there should be scope for establishing serious prejudice. Article 25 of the WTO Subsidies Agreement obliges all members to formally notify WTO of each subsidy. Schorr (1999) found that less than ten percent of global fishery subsidies, as defined in Articles 1 and 2, were actually notified in 1996. Overall, the current WTO agreements provide some room for action against a fraction of existing subsidies, but so far little has been achieved. Sumaila *et al*. (2007) argue that the current Doha round should aim for **1)** creation of a multilateral enforceable agreement, **2)** termination of the exemption for developing countries to subsidize fisheries in order to develop fisheries for local demand and exports, as fish stocks in developing countries are already over-exploited, and **3)** adopting a broader definition of subsidy, i.e. 'bad' subsidies according to Sumaila and Pauly (2006). Compared to Articles 1 and 2, 'bad' subsidies would also include government support to fuel, foreign access agreements, fishing port construction and renovation, tax exemptions, and general shipbuilding irrespective if they are specific to the fisheries sector or not. Foreign access agreements paid e.g. by EU are clearly a 'bad' subsidy increasing fishing effort, but at the same time provide valuable foreign exchange earnings to poor countries in West Africa and in the Pacific Islands. A shift in policy should be accompanied by some adjustment program for these countries in order to provide alternative earnings accompanying the reduction in overfishing.

Discussion

Marine ecosystems are in global decline. The main reason is unsustainable fishing practices, due to six factors; inappropriate incentives, high demand for limited resources, poverty, inadequate knowledge, ineffective governance, and interactions between fishery sector and other aspects of the environment (FAO 2002). In order to address this, focus should be on changing fisher motivation. By providing fishers with economic rights, and accompanying responsibilities, incentives can be turned right and governance improved, leading to individual and collective action to promote more sustainable fishing practices (Grafton *et al*. 2006). The most common form of rights-based fisheries, ITQs, dramatically reduces the risk of stock depletion (Costello *et al*. 2008).

Trade liberalization is an important tool to generate economic growth and hereby addressing poverty. Increasing trade may also promote management development. Yet, recent research shows that, combined with poor property rights, it is prejudicial to renewable resource management including fisheries. However, weak resource management corresponds to an export subsidy on producers, which could be met by countervailing duties under trade law (Reichert 1996, Yechout 1996). WTO should continue its work to facilitate, and not impede, trade. If agreement is reached within the WTO, measures can be taken against member countries that break the rules (cf. the suggested use of border tax adjustment to support stringent emission trading when addressing climate change, Ismer and Neuhoff 2007). A relevant example for fisheries is subsidies, which clearly make things worse. The extent of the success is ultimately determined by the member countries. Subsidies in fisheries clearly make things worse. OECD countries like Japan and EU members, but also Russia, Poland, Republic of Korea, and Taiwan should stop using subsidies, and together with other WTO members promote a broader definition, which could speed up the reduction. In addition, adjustment programs in order to get developing countries to abandon the subsidy exemptions available today are desirable.

Positive examples for developing countries exist. The Namibian government made serious efforts to improve fisheries management at independence in 1990 with some success (Bonfil *et al*. 1998). Monitoring and enforcement was improved *inter alia* with support from Norway. Aid programs often did and sometimes still, aim at increasing domestic fishing effort, which is unfortunate. Similarly, OECD country governments buying fishing rights from developing coastal countries, and giving them free to their fishing fleet, is another type of subsidy that should be abandoned. Acquiring fishing rights in developing countries also has distributional concerns. The government receives the money while poor artisanal fishers get reduced income. These fishermen also suffer from industrialized fishing fleets involved in illegal, unregulated and unreported (IUU) fishing in developing countries including so called roving bandits (Sumaila *et al*. 2006, Berkes *et al*. 2006). Hence, support from rich countries to the fisheries sector in developing countries should avoid increasing or reallocating domestic overcapacity, but rather support capacity building in fisheries management like stock assessment and monitoring and enforcement.

Copeland and Taylor (2009) point out that many countries are better off from trade, as it leads both to a direct welfare effect from higher prices and to an indirect welfare effect by improving management. At the same time, other countries due to *inter alia* poor institutions are trapped in an open-access state where trade lowers welfare. In conclusion, the greatest challenge for researchers, politicians and other policy makers is to find ways to support the development of institutions and property rights in open-access trapped countries to achieve a sustainable use of marine resources that would enable them to benefit from the welfare improving effects of trade.

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Fish processing facilities in Kayar, Senegal, and loading ice in Bandim, Guinea-Bissau. *Photos*: Kajsa Garpe (top) and Mikael Cullberg (bottom), courtesy of the Swedish Society for Nature Conservation.

FISH TRADE IN AFRICA – ITS CHARACTERISTICS, ROLE AND IMPORTANCE

Ann Gordon

Introduction

This chapter focuses on Africa and illustrates some of the ways in which fish trade affects development – with positive, negative and sometimes unclear outcomes. Although Africa is a minor player in global fish trade (Africa accounts for around five percent of global fish production and global fish trade), fisheries trade nonetheless has important local development impacts. Whilst some of those impacts are clear, others are underreported and poorly understood.

An overview of fish trade in Africa including aspects not evident in official data is given, together with selected case studies that illustrate different dimensions of African fish trade. The conclusions focus on important development considerations for the sector.

Africa's fish trade – according to statistics

The official data indicate that Africa has been a net exporter of fish by value since 1985 (FAO 2009) since when the value of both exports and imports has grown in equal measure. Béné and Lawton's (2008) analysis of sub-Saharan Africa's fish trade shows a net annual surplus in 1995–2001 hovering around USD 800 million or 2.5 percent of sub-Saharan Africa's trade surplus in merchandise exports (roughly USD 30 billion in 2006, World Bank 2007).

Yet, there is another side to this story. In volume terms, sub-Saharan Africa is a net importer. In short, Africa imports low value fish and exports high value fish. Béné and Lawton show an annual negative balance of roughly 600,000 tonnes (1996–2001). Delgado *et al*. (2003) projected an increase in sub-Saharan African imports of low value food fish, suggesting that the volume of imports would double between 1997 and 2020 ("most likely" projection). Nonetheless, there has been a marked decline in per capita fish consumption in sub-Saharan Africa since 1980s, reflecting stagnant or declining production, population growth and the upward trend in real prices of both domestic and imported fish.

Most of the recorded export trade is marine fish, including significant shrimp, tuna and sardine. Thus, 12 African countries have fish exports worth more than USD 1 billion (FAO data for 2006) and all but one of these exports mainly marine fish (the exception being Uganda, with its exports of Nile perch fillets from Lake Victoria). Exported fish is caught by industrial and artisanal fleets. In Senegal, for instance, where seafood accounts for 37 percent of merchandise exports (FAO, 2006) the artisanal sector is an important source of export products. Likewise, much of Lake Victoria's Nile perch is caught by the small-scale sector. Nevertheless, the industrial fleets are also important (e.g. in the small pelagic fisheries of north-west Africa and in much of Africa's shrimp and tuna fisheries).

In Africa, aquaculture is not yet a significant source of source of fish production or exports (with the notable exception of Egypt, where it represents more than 60 percent of national fisheries production – Egyptian Aquaculture Taskforce 2007). Imports of low value food fish include tinned pelagics and low value frozen fish.

Twelve countries account for 90 percent of the value of all African fish exports: Morocco, Namibia, South Africa, Senegal, Mauritius, the Seychelles, Tanzania, Madagascar, Tunisia, Uganda, Mauritania, and Côte d'Ivoire. The official data indicate that in value terms, the largest African importers are: Nigeria, Côte d'Ivoire, Mauritius, Egypt, South Africa and Ghana – together representing 66 percent of total African fish imports (FAO data for 2006).

Important elements not apparent from the official data on fish trade

Informal cross-border trade

Intra-regional trade in fish is very important in some parts of Africa – much of it "informal cross-border trade" (ICBT). It involves both marine and freshwater fisheries, including for example the Zambia-DRC[1] rift valley corridor (DRC production to supply the Copper Belt); marine fish from Ghana supplying the important Nigerian market; Mali's productive inland delta of the River Niger, with exports to neighbouring countries; and Mozambique, with a complex pattern of ICBT in fish (both imports and exports). Whilst the importance of this trade is increasingly recognised, there is still scant information on its volume, because in large part it escapes official trade records.

An interesting and important aspect is that these marketing chains can be very long and very resilient (e.g. in the face of insecurity or poor infrastructure) and, as a consequence, very important in inland and remote areas and often quite critical to food security. They sometimes reflect historic regional trading routes and the greater accessibility of cross-border markets, than domestic markets, where present day infrastructure may be heavily concentrated in coastal areas or in particular regions. Thus, a number of studies of ICBT conducted in the late 90s yielded the following observations:

- An isolated market in Niassa province in Mozambique offered dried/salted fish of different kinds and provenance, coming from as far away as Beira (1,100 km) and Metangula in Malawi (580 km); this diversity "…all supplied through informal channels, is a testimony to the dynamism of these networks" (Whiteside 1998, p. 17).
- Prawns (sent by refrigerated truck) were the

1. Democratic Republic of Congo ("Congo-Kinshasa").

most important item of unrecorded trade in a study of informal exports from Mozambique to Swaziland; surprisingly fish was the fourth most important informal import into Mozambique from Zimbabwe (black mackerel originating from Namibia); and seafood (mostly fish) was the second most important export, after vegetables, from Mozambique to Tanzania (Macamo 1998).

- Dried fish was a major item of ICBT from Uganda to neighbouring countries (Coote *et al.* 2000), dried salted Nile Perch was traded from Tanzania to Rwanda and Democratic Republic of Congo, and fresh Nile Perch is informally exported by Ugandan and Tanzanian fishers to processors in Kisumu (on Kenya's Lake Victoria shores) (Coote *et al.* 2000).

The role of women in fish trade

Although fishing itself is dominated by men (women in Africa are nonetheless involved in certain types of fishing activity), women play an extremely important and often dominant role in much of Africa's domestic and intra-regional fish trade (e.g. Ghana's famous "fish mammies", see Ames and Bennett 1995). Continent-wide, they are involved in fish retailing, but in many places their role is much more influential, effectively setting prices and controlling trade by advancing credit, operating informal exclusive cartels and expertly navigating a network of fishers, buyers, service-providers and officialdom. These roles are particularly evident in West and Central Africa.

Important local markets with strong upward pressure on prices

The incidence of intra-regional trade is just one manifestation of the importance of local markets in Africa. Whilst a superficial appraisal might suggest that African fish traders would target international markets, the continent itself has robust and growing markets, which are often more accessible (geographically and institutionally) and more remunerative – particularly where fish is sourced in inland areas and for those who lack the financial capital, knowledge and networks needed to access extra-regional markets. In many of Africa's most populous regions (largely coastal, riparian and lacustrine areas) there is a long tradition of fish consumption, where historically fish has represented an affordable, "divisible" source of animal protein, which could be eaten fresh or in a traditional processed form (smoked or dried). In Ghana and DRC, FAO data indicate that fish provides 45 percent of available animal protein, largely from the marine fishery in the former but in DRC from its large freshwater resources.

As capture fisheries plateau (and in some cases decline) and whilst fish farming is still poorly developed in Africa, there is strong upward pressure on fish prices. Moreover, with population growth and urbanisation, this market is growing and accessible and over the long term experiencing income growth. Current income levels in Africa combined with the dietary role of fish suggest that this is still a "luxury good" in much of Africa (i.e. demand will increase with income growth).

Case study

One case study is presented, the Nile Perch study, which illustrates the development trade-offs and ambiguity of Lake Victoria's export fishery. The discussion above points to the importance of markets within Africa – and the conclusions that follow point up some of the implications this has for the focus of fisheries development efforts in Africa.

TRADING FISH OR LIVELIHOODS IN DEVELOPING COUNTRIES – THE NILE PERCH CASE

Cambria Finegold

Although the international fish trade brings macro-economic benefits to many poor countries, the micro-level impact is often more ambiguous. The events following the controversial introduction of Nile perch into Lake Victoria are illustrative of this. Nile perch was introduced in the 1950s along with four exotic tilapia species in response to the near-collapse of the Lake Victoria fishery (Geheb *et al*. 2007).

In the 1980s, Nile perch production boomed. Employment in fisheries and support sectors soared, and in Tanzania, the Nile perch was nicknamed "Saviour" following dramatic improvements in communities' socio-economic status. The bulk of early Nile perch catches were consumed locally or processed artisanally (smoked, fried or salted) and traded locally and regionally.[1] Frozen fillets were first exported from Kenya in 1987, however, and by 1996 purchases by fillet factories accounted for approximately 75 percent of Nile perch catches (Gibbon 1997).

The net benefits of the Nile perch production boom and export oriented fish processing have been hotly debated. Species diversity has declined dramatically, largely due to predation by Nile perch (Geheb, 1997), and about 300 species are believed to be extinct (Bokea and Ikiara, 2000). The massive increase in fishing capacity and effort following the Nile perch boom has also led to over-fishing in some areas, and an overall decline in catches, raising concerns about the sustainability of the fishery. While the boom has generated significant employment in fishing, the shift to factory-based processing displaced many who had been engaged in artisanal processing and marketing (Abila and Jansen 1997).

The food security impact continues to be the subject of much debate, with critics pointing to high levels of poverty, food insecurity, and malnutrition around the lakeshore (Bokea and Ikiara, 2000), and declines in per capita fish consumption since the early 1990s (Abila and Jansen,

1. This increased local consumption of Nile perch is largely attributable to the effects of the introduction of this top predator on stocks of locally preferred species such as Haplochromis (*furu*), Clarius (*mumi*), and indigenous Tilapia, whose availability declined precipitously

1997). It is unclear, however, to what extent these problems are attributable to the Nile perch fishery. Geheb *et al*. (2007) find "no evidence to suggest that [malnutrition] has a direct link with Nile perch export", arguing that employment in the fishery could be expected to improve food security by bringing greater purchasing power to fishing communities, and that malnutrition is better explained by the fact that income is controlled by the men, while responsibility for feeding their families lies with the women. They also point out that malnutrition and poverty are hardly exceptional for East Africa, and that rates of malnutrition around the lake are actually lower than in the surrounding agricultural hinterland.[2] The argument that the export orientation of the fishery is to blame for malnutrition is further discredited by the fact that nutritional status of fishing communities declined dramatically during the export bans of the late 1990s, as incomes crashed and women could no longer purchase the staple foods with which they had fed their families.

The overall picture appears mixed, therefore, with largely negative effects on species diversity and employment in artisanal processing and trade, positive effects on current account balance, government revenue, and employment in fishing, and nutritional impacts which at best have not managed to significantly raise the nutritional status of fishing communities above regional averages, and at worst are at least partly to blame for continued malnutrition along the lakeshore.

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2. Malnutrition measured by stunting in children under five. Rates of malnutrition on the Kenyan section of the lakeshore were also lower than the national average, though this was not true for the Tanzanian and Ugandan sections.

Conclusions – implications for fisheries development efforts in Africa

Fish supply – overall growth in imports and aquaculture but not in capture fisheries

Capture fisheries production has mostly levelled out and in some cases declined. Future growth in African fisheries supply is unlikely to come from capture fisheries to any significant extent. Africa is likely to see growth in imports, increasing interest in aquaculture (already evident in many countries) and efforts to reduce post-harvest losses where these are high.

Local markets – accessibility, informality, profitability and scale

Domestic and intra-regional markets are extremely important and growing in Africa. Imports and aquaculture are likely to target accessible urban (often coastal) markets, but suppliers of locally sourced fish (be it in fresh or traditionally processed forms, such as smoked and dried products) will still find local markets profitable. For Africa's many small-scale producers and traders, these are the markets that are most easily accessed, with less onerous standards, requirements and institutional arrangements than extra-regional markets. Whilst the latter may appear to offer higher prices, the costs in accessing those markets, including the infrastructure (cold chain and handling) needs, are likely to be significant.

Improve handling – reduce losses, regulate where strictly necessary, focus on real needs

Africa's fisheries draw considerable comment for their apparently high losses, although there is significant uncertainty as to their true scale (INFOSA 2007). However, where this contributes to a significant loss of export revenues and/or food of high nutritional value for local populations, those losses are indeed a cause for concern. Initiatives to improve handling, however, must take a critical look at what the real needs are: those in the high value extra-regional export market chain are, for instance, quite different to those needed for traditionally processed products important in local trade. Careful risk assessment and market analysis is needed before making significant investments in, for instance, cold chain infrastructure in relatively remote areas. Similarly, care must be taken to design regulatory interventions that facilitate trade (including those that safeguard product standards) and do not act as an impediment. Some recent proposals relating to uniform cross-border standards and regulation in African trading areas, could act as significant deterrent to local trade unless carefully designed to reflect the diversity in that trade and the needs of local markets.

Example interventions to facilitate the development of intra-regional and domestic trade

The implied focus on intra-Africa trade has a number of implications for development interventions.

- Recognise the growth in demand in local urban markets, including growing markets for fresh and frozen fish, whilst not neglecting needs in other areas, where traditional products still play an important role in livelihoods and food security. Careful participatory needs assessment and market analysis is needed to identify appropriate investments.
- Small-scale producers and traders, whilst not necessarily interested in co-operative enterprise, may still benefit from collective action in a number of marketing arena (e.g. access to transport, micro-finance, training, information, negotiation with large-scale buyers). Developing capacity to organise, focusing on the real needs of this largely informal sector, is an important building block in strengthening intra-regional trade. Women are important players in much of this trade and their needs and role should not be overlooked.
- Give careful consideration to micro-finance needs (including savings, as well as credit) and appropriate delivery mechanisms, borrowing from the now considerable experience in other sectors; financing has historically played a particularly critical role in fisheries and how its spoils are shared.[2] The needs and opportunities are constantly changing, however, reflecting the overall dynamism in this sector, including its informal elements.
- Market information is another important element in trade facilitation, but also requires very careful design if it is to be useful and sustainable[3], Market information needs relate not only to relative prices in different markets, but also to improved information on preferred products and handling (dried, salted, or smoked fish, packaging, preferred fish size, type of cut/split for large processed fish, effective methods and materials for insulating fresh fish on ice, relevant regulations, and so on).
- Regulate only where strictly necessary, keep procedures simple and practicable, and publicise relevant information widely to reduce capacity for rent-seeking.

2. Artisanal fishers are often poor with uncertain, erratic and seasonal incomes, but have capital purchase needs (in the form of boats and gear) and day-to-day consumption needs. This has often led to an important role for traders in providing credit, which has significantly affected the terms of trade between the two parties.
3. Whilst this comment is true of any market information system, it is worth noting with fish that per unit (weight) prices are likely to differ depending on quality, time of day and size of fish, so that bald information without explanation or attention to this detail could be quite misleading.

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FISHERIES, DEVELOPMENT AND HUMAN RIGHTS

Chandrika Sharma[1]

Abstract

This paper discusses the imperative and rationale for adopting a human rights-based approach to development in fisheries. The principle of non-discrimination inherent in such an approach requires a special attention on those presently disadvantaged within the sector, whether in large- or small-scale fisheries. A specific focus on small-scale fishing communities, particularly on women, is warranted given available evidence of their vulnerability as well as their importance in any vision of sustainable development. The growing emphasis on issues of social development and human rights in the deliberation of the FAO Committee on Fisheries (COFI), a specialized global forum for deliberating major international fisheries issues, is traced. The last section dwells on the content of a rights-based approach to development in fisheries, articulated by the growing movement of small-scale fishworkers and support organizations. That many of the rights seen as important by small-scale fishworkers are already recognized in existing international law, including customary law, is emphasized. The concluding section underscores the critical need to honour international commitments to human rights.

Introduction

The international recognition of human rights[2] has its basis in the 1948 Universal Declaration of Human Rights. This Universal Declaration has been further elaborated with subsequent legally-binding human rights conventions and treaties, including the 1966 International Covenant on Economic, Social and Cultural Rights (CESCR), and the 1966 International Covenant on Civil and Political Rights (CCPR).

These instruments reflect the international consensus amongst members of the United Nations on a legal framework of entitlements and obligations to achieve human rights. They set a standard of rights for all people everywhere, recognizing the inherent dignity and equal rights of

1. Executive Secretary, ICSF (International Collective in Support of Fishworkers). This paper has been prepared with extensive inputs from ICSF members and secretariat, in particular from Jackie Sunde, John Kurien, Cornelie Quist and Sebastian Mathew. It draws on the outcomes of the Civil Society Workshop held prior to the Global Conference on Small-scale Fisheries (4SSF) and on five recent workshops organized by ICSF in Asia (2007), Latin America (2005, 2008) and Eastern and Southern Africa (2006, 2008), to explore the issue of rights for small-scale fisheries (See *www.icsf.net*).

2. Human rights are seen as those rights which are essential to live as human beings – basic standards without which people cannot survive and develop in dignity. They are inherent to the human person, inalienable and universal.

all members of the human family. Human rights are viewed as universal, inalienable, inter-related, indivisible and interdependent. Protecting and achieving human rights is recognized as an end in itself. These instruments recognize a wide variety of rights. They include *inter alia*: the right to life, liberty and security of person; just and favourable working conditions; food, housing and social security; education; freedom of association, expression, assembly and movement; the highest attainable standard of health; and to participate in cultural life (UN 2006).

It has also been noted that at times the equal worth and dignity of all can be assured only through the recognition and protection of individuals' rights as members of a group. Collective rights refer to the rights of such peoples and groups, including ethnic and religious minorities and indigenous peoples, where the individual is defined by his or her ethnic, cultural or religious community (UN 2006).

The foundation for a human rights-based approach to development was laid by the 1986 Declaration on the Right to Development that recognizes that all human rights, and in particular economic, social and cultural rights, must be realized in the process of development. The right to development is seen as an inalienable human right and the United Nations Millennium Declaration explicitly places both human rights commitments and development goals at the centre of the international agenda. The adoption of a human rights-based approach draws its intrinsic rationale from the tenet that achieving human rights of all citizens is an end in itself.

The recognition and promotion of human rights, and the legal frameworks that guarantee these rights, are important for their instrumental value in promoting agency – both individual and collective (Fukuda-Parr 2002). By adopting a human rights-based approach, citizens have a stronger basis to make claims on their States, and hold them accountable for their obligations and duties. A human rights-based approach stresses that everyone, and in particular marginalized groups, have legally mandated and recognized rights. As noted by the Office of the High Commissioner for Human Rights (OHCHR): "This recognition of the existence of legal entitlements of the poor and legal obligations of others towards them is the first step towards empowerment" (UN 2004).

In 1997 at the launch of the United Nations Programme for Reform, the Secretary-General called on all entities of the United Nations system to mainstream human rights into their various activities and programmes within the framework of their respective mandates. The political impetus for this was realized in September 2005 at the World Summit (UN 2005)[3].

3. 126: "We resolve to integrate the promotion and protection of human rights into national policies and to support the further mainstreaming of human rights throughout the United Nations system, as well as closer cooperation between the Office of the United Nations High Commissioner for Human Rights and all relevant United Nations bodies". *2005 World Summit Outcome: Sixtieth Session of UN General Assembly*. Accessed online at: *http://daccessdds.un.org/doc/UNDOC/GEN/N05/487/60/PDF/N0548760.pdf?OpenElement*

Human rights, development and fisheries

In a fisheries context, adoption of a human rights-based approach would mean that all development efforts contribute to securing the freedom, well-being and dignity of all fisherpeople everywhere, in the small- or large-scale sector. Further, it would mean that fisheries management approaches, such as ecosystem-based management, rights-based fisheries management, and resilience-based management, should be coherent with a human rights approach. There is particular need to find a balance between the growing focus on biodiversity conservation and human rights, given that the narrow ecological perspective that often characterizes biodiversity conservation initiatives completely neglects the human dimension.

The application of a human rights-based approach, particularly the principle of non-discrimination, would require a special focus on small-scale fishing communities. For, despite the vital social, economic and cultural contribution of small-scale fisheries, their communities continue to be disadvantaged. This is due to a range of factors, including insecure rights to land and fishery resources, unfair and unsafe working conditions, and inadequate or absent health and educational services and social safety nets. Women fishworkers experience particular discrimination.

According to FAO estimates (FAO 2002) there are about 23 million income-poor people, plus their household dependents, that rely on small-scale fisheries for their food security and livelihoods. The obligation of the State to prioritise disadvantaged groups requires them to take measures that explicitly benefit these groups – the persistence of poverty being acknowledged as a violation of human rights.

Small-scale fisheries currently contribute over half of the world's marine and inland fish catch, nearly all of which is used for direct human consumption (FAO 2005). They employ over 90 percent of the world's fishers and support another approximate 84 million people employed in jobs associated with fish processing, distribution and marketing. At least half of the people employed in small-scale fisheries are women (FAO 2009). Small-scale fisheries are known to be relatively more sustainable, given the diversity and seasonality of the gear employed, the minimal by-catch generated, and, as important, the lower levels of energy consumed per hour of fishing effort. Even though the sector has become relatively more technology and capital-intensive, it does still provide the model on which to sustain fisheries and fishery dependent livelihoods into the future.

It is a well recognized fact that when the small-scale sector is provided the right kind of support, it exhibits tremendous potential to significantly enhance its contribution to sustainable development and to the attainment of the UN Millennium Development Goals (MDGs) pertaining to eradication of extreme poverty and hunger and ensuring environmental sustainability. This recognition is well deserved.

Social development, human rights and fisheries at the FAO

Deliberations at the FAO's Committee on Fisheries (COFI) since 2003 have increasingly reflected international trends of a growing focus on issues of social development and human rights. Small-scale fisheries were included as a stand-alone item at COFI in 2003. In the context of the 1995 FAO Code of Conduct for Responsible Fisheries, COFI members welcomed the suggestion to elaborate technical guidelines highlighting the contribution of the small-scale fisheries sector to food security and poverty reduction (FAO 2003).

In 2007 COFI recognised that "progress in the implementation of international human rights instruments, including the conventions on the rights of seafarers and working conditions in fisheries were critical to both small-scale and large-scale fisheries" and stressed that "the recognition and adoption of human rights principles can help achieve poverty eradication and facilitate the adoption of responsible fisheries practices". There was consensus on the need to continue working on small-scale fisheries and the proposal by Norway that FAO examine the convening of a broad-based international conference focusing specifically on small-scale fisheries, was widely welcomed (FAO 2007).

The Global Conference on Small-scale Fisheries (4SSF)[4] held in October 2008, was a further step along this road. This Conference reaffirmed that human rights are critical to achieving sustainable development (FAO 2009).

Reviewing the outcomes of 4SSF, COFI agreed that action to support small-scale fisheries could include *inter alia*:

1. a special article on small-scale fisheries in the Code of Conduct for Responsible Fisheries;
2. an International Plan of Action (IPOA) on small-scale fisheries;
3. a sub-committee on small-scale fisheries; and
4. a dedicated global programme on small-scale fisheries (Mathew 2009).

Despite lack of consensus on the proposals, what remains clear is that this will be an issue that is likely to continue to be in focus in the coming period, with the FAO secretariat being mandated to explore all the above options.

It is important to stress that the onus of implementing a human rights-based approach to development in relation to fishing communities cannot rest with fisheries line agencies alone. Commitment and action from a wide range of actors, internationally, nationally and locally, and particularly from governments and multilateral organizations, are crucial. However, fisheries line agencies do have a crucial role in working with other relevant agencies and organizations to seek improvement in the quality of life of fishing communities and to secure their rights. They have the obligation to ensure that all policies adopted within fisheries, whether related to fisheries management or the post-harvest sector, are consistent with a human rights-based approach to development, and benefit particularly the disadvantaged groups within the sector (Sharma 2008).

4. *www.4ssf.org*

What a human rights-based approach would mean in practice

Small-scale fishworkers and their supporters have organized several regional workshops since 2007, all of which have called for a human rights-based approach to development in relation to fisheries and fishing communities. These processes have also thrown up concrete proposals of what a rights-based approach should mean in practice, from the perspective of small-scale fishworkers. The Bangkok Statement[5], adopted by participants of the Civil Society Workshop held prior to the 4SSF, represents a culmination of these processes. The workshop was jointly organized by the World Forum of Fisher Peoples (WFFP), the International Collective in Support of Fishworkers (ICSF) and the International Planning Committee on Food Sovereignty (IPC), organisations that have for long adopted a right-based framework for their work.

The rights highlighted in the statement include:

- Rights of fishing communities and indigenous people to their cultural identities, dignity and traditional rights, and to recognition of their traditional and indigenous knowledge systems;
- Rights of access of small-scale and indigenous fishing communities to territories, lands and waters on which they have traditionally depended for their life and livelihoods;
- Rights of preferential access to fisheries resources under national jurisdiction;
- Rights of fishing communities to use, restore, protect and manage local aquatic and coastal ecosystems;
- Right of communities to participate in fisheries and coastal management decision-making, ensuring their free, prior and informed consent to all management decisions;
- Rights of women to participate fully in all aspects of small-scale fisheries, eliminating all forms of discrimination against them and securing their safety against sexual abuse;
- Rights of women of fishing communities to fish resources for processing, trading, and food, particularly through protecting the diversified and decentralized nature of small-scale and indigenous fisheries;
- Right of women to fish markets, particularly through provision of credit, appropriate technology and infrastructure at landing sites and markets;
- Rights of fishing communities to basic services such as safe drinking water, education, sanitation, health and HIV/AIDS prevention and treatment services;
- Rights of all categories of workers in the fisheries, including self-employed workers and workers in the informal sector, to social security and safe and decent working and living conditions;
- Rights of fishing communities to information in appropriate and accessible forms.

Many of these "rights" seen as important by small-scale fishworkers are already recognized in existing international law, including customary law. The issue is really about implementation and

5. The civil society statement finalized in Bangkok on 13 October 2008 is reproduced in SAMUDRA Report 51, December 2008, pp. 7–9.

we draw attention here to some of the relevant instruments and their provisions. These include the following:

- The 1966 International Covenant on Economic Social and Cultural Rights (ICESCR) cites the right to adequate food as part of a fundamental right for everyone to an adequate standard of living (Article 11 [1]).
- The 1982 United Nations Convention on the Law of the Sea (UNCLOS) requires States to take into account relevant environmental and economic factors, including the economic needs of coastal fishing communities and the special requirements of developing States, while taking measures to conserve and manage the living resources of the EEZ (Article 61).
- The 1995 United Nations Fish Stocks Agreement (UNFSA) requires developing States to take into account the interests of artisanal and subsistence fishers, while giving effect to their duty to co-operate in accordance with the Convention (Article 5 [i]).
- The 1995 Code of Conduct for Responsible Fisheries (CCRF) has several provisions of relevance, such as those that call on States to: secure preferential access of small-scale and artisanal fisheries to traditional fishing grounds and resources in waters under national jurisdiction (Article 6.18); facilitate participatory and consultative processes (Article 6.13); ensure that rights of coastal fishing communities and their customary practices are taken into account in coastal area management (Articles 10.1.2 and 10.1.3); take into account traditional practices, needs and interests of indigenous people and local fishing communities while deciding on the use, conservation and management of fisheries resources (Article 7.6.6), and; document and take into account traditional knowledge in fisheries management (Article 6.4 and 12.12).
- The 1992 Convention on Biological Diversity (CBD) requires States to respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biological diversity (Article 8 [j]), and to protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements (Article 10 [c]).
- ILO Convention 169 on Indigenous and Tribal Peoples (1989) seeks to protect indigenous and tribal peoples, based on respect for their cultures, their distinct ways of life, and their traditions and customs; the ILO Work in Fishing Convention 188 (2007) seeks to secure the rights of fishers to decent work; and several other ILO Conventions set standard for workers in the organized sector, as well as for home-based workers.
- The 1979 Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) seeks protection for women against discrimination at home or in the workplace, and calls for protecting the rights

of rural women to participate in decision-making processes, to enjoy adequate living conditions, to benefit from social security and to access loans and credit.

- The 2007 UN Declaration on the Rights of Indigenous Peoples sets out the individual and collective rights of indigenous peoples, as well as their rights to culture, identity, language, employment, health, education and other issues.
- The Millennium Development Goals (MDGs) set time-bound targets, with clear indicators of progress, to meet eight agreed goals, including: reducing poverty, eliminating gender disparity in primary and secondary education, reducing the maternal mortality ratio and halving the proportion of people without sustainable access to safe drinking water and basic sanitation.

Conclusion

There is a strong international framework and universal commitment to the adoption of a human rights-based approach to development. By focusing on 'rights' such an approach has the potential to empower, and to hold duty bearers accountable. The effective implementation of a human rights-based approach to development is critically dependent on two dimensions: the extent to which the capacities of rights holders to claim and exercise their rights, as well as the capacities of duty-bearers to fulfil their human rights obligations, can be developed. The importance of such capacity building, as well as the substantial and concrete investment required to be made by international and national organizations in this process, cannot be overemphasized.

The challenge, sixty years after the adoption of the 1948 Universal Declaration of Human Rights, is really implementation. There is enough evidence, for example, of unacceptably high levels of inequity and poverty, persistent hunger, gender violence and discrimination in fishing communities. There is enough evidence to indicate that the interests of small-scale fishing communities are being sacrificed for causes that range from economic growth and development to environment protection and conservation, in violation of all accepted principles of human rights.

Given the economic and financial crisis facing the world today the need for taking decisions consistent with a human rights-based approach to development, especially in relation to small-scale fisheries, is more critical than ever. The provision for 'progressive realisation' of social, economic and cultural rights must not be used to postpone necessary action for realization of these rights. The achievement of human rights – civil, political, social, economic and cultural rights – is not a means to an end. It is a legitimate end in itself.

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DISTANT WATER FISHING – A CASE FOR IMPROVED OCEAN GOVERNANCE

Jessica Battle and Inger Näslund

Introduction

As inadequate fisheries management leads to more and more fish stocks becoming depleted in industrialized and large fish consuming nations' waters, many vessels venture far from home to catch enough fish to keep their businesses running and to feed an ever-growing market demand. These vessels belong to the distant water fleets, fishing in waters at great distance from the flag state, mostly within other states' exclusive economic zones (EEZ) but also on the high seas. The largest distant water nations are Spain, China, Taiwan, South Korea, France and the Netherlands.[1]

This chapter highlights two principal distant water fishing practices; states negotiating fisheries agreements with developing countries, and fishing on the high seas. It sets out seven principles that need to be adhered to in order to create fisheries agreements that ensure sustainability of fish stocks and livelihoods for coastal communities in developing countries. It also looks at the practice of registering fishing vessels under flags of non-compliance and how these are used to conceal illegal, unreported and unregulated (IUU) fishing activities. The chapter ends with recommendations for ocean governance reform, in particular through reviewing current organizations charged with managing the main high seas fisheries and through ensuring that all flag states ratify and implement international agreements to exercise adequate management control over vessels under their jurisdiction – wherever they are.

Fisheries agreements

For centuries, fishers have traveled to remote waters in pursuit of their livelihoods. As early as 1575, vessels from Europe were fishing for cod in the waters of the New World, off Newfoundland in present-day Canada. In the 1970s, many coastal countries established offshore 200-mile EEZs – particularly to protect their traditional fisheries. This meant that foreign vessels then had to negotiate with the country concerned to obtain legal access to their waters.

Many coastal African and small island states started selling fishing rights to distant water fishing nations as a means to obtain foreign currency, and today, many large fishing countries, mainly the EU, the US, South Korea, China and Japan, sign deals with developing countries to access

1. Prof. Tony Pitcher, The Fisheries Center, University of British Columbia, pers. comm. *N.B.* Vessels from the Netherlands mainly fish in distant waters via its Aruba flag.

their fish stocks for cash payments. In the case of Asian distant water fishing nations, the agreements are not always with states, but with other entities, such as associations of ship-owners.

For example, the European Commission negotiates fisheries agreements with third countries – Fisheries Partnership Agreements – under the auspices of the European Union's Common Fisheries Policy. It currently has such agreements in place with 15 countries in Africa, the Indian Ocean and the South Pacific.

Fisheries agreements with developing countries can, if properly designed, provide substantial foreign exchange revenue for the developing country and contribute to sustainable development. They can generate and help develop the infrastructure needed for monitoring and enforcing fisheries management efforts.

Under the United Nations Convention on the Law of the Sea (UNCLOS), any coastal state not utilizing its fisheries fully has the obligation to give other nations access to fish for 'excess' stocks in their waters. UNCLOS also sets out that a fisheries agreement should be signed only if fish stocks are not fully utilized.

Criticism of fisheries access agreements

Most developing nations have little or no capacity to monitor their fish stocks, nor to control and enforce bilateral agreements. The lack of capacity leads to many access agreements having no limit to how much fish can be caught, causing severe environmental damage, by-catch of sometimes threatened species, and ultimately to the depletion of fish resources on which local communities and industry of the coastal state depend for income and food supply.

In the past, access agreements have rarely had adequate provisions for ensuring sustainable fisheries management, nor considered the protection of the marine environment. These deals have therefore been widely criticized for contributing to overfishing, threatening the food security of developing countries, and preventing the development of local fishing industries.

In addition to being biologically untenable, the economic benefits from most current agreements are not fairly shared between producer and extractor nations. Unfairly designed access agreements often entail negative consequences for fisheries and local communities, for example by depriving local communities and local fishing industries from development opportunities, and are in breach with the development goals agreed upon by the international community. Developed countries have also been accused of paying minimum fees for rich fishing grounds and paying little attention to illegal fishing by their fleets in distant waters.

Towards fair fisheries access agreements

Sustainable use of domestic natural resources is for many developing countries the only means to eradicate poverty, prevent food shortage and fuel development. To ensure the future for local communities that depend upon a healthy marine environment, fisheries access agreements must respect both local fishers and marine resources and be part of an integrated approach to environmental sustainability and development. They should be envisaged as temporary and ensure development of local fishing capacity – and cease once this local capacity is achieved. As such, they must be carefully designed, managed and enforced.

Through the inclusion of sustainable fisheries management practices, fisheries partnership agreements can be a valuable tool for poverty reduction and good governance of marine resource exploitation.

By carefully designing each agreement, they can help manage fisheries and alleviate poverty, as good deals can promote coherence between fishing, development and biodiversity protection policies. By striking deals between governments, a solid foundation for promoting sustainable fishing and increased opportunities for local economies can be created, and IUU fishing, a major threat to global fish stock, can be addressed. Additionally, not all nations have the ability to fully exploit their marine resources, so access agreements can provide an opportunity to promote the development of sustainable domestic fishing industries, if transfer of technology and know-how is done correctly.

Agreements should ensure a comprehensive, ecosystem-based approach to management of all activities. Management should include measures to promote selective fishing gear to reduce by-catch, close spawning and nursery grounds to fishing during key periods and the establishment of fully protected areas. This needs to be addressed in negotiations between fishing powers and third countries. Once fulfilled, negotiations can begin, following seven key principles (see box).

NEGOTIATIONS' SEVEN KEY PRINCIPLES

1. **Cooperation on research and reporting** – knowledge on state of target stocks and the level of catch is essential for sound fisheries management. Distant water fleets should cooperate with the coastal state in scientific research on stocks and accurately report catches and fishing effort.
2. **Sustainable fishing levels** – total catches should be compatible with sustainable fishing levels, based on a scientific assessment of the state of stocks. If data are unavailable, the precautionary approach should be used. The negotiation of fishing deals should only take place when analysis shows a surplus of stocks. Fishing deals should also allow for yearly adjustments to the level of catch over the duration of the agreement based on regular analysis of stock levels, and the use of seasonal closures.
3. **Environmental costs** – foreign fleets should cover their share of the environmental costs of fisheries.
4. **Driving development of local fisheries capacity** – the interests of small-scale fishers must be protected; fishing deals should be used to promote local employment and the development of the local fishing industry to sustainably harvest fish stocks. Agreements should explicitly set out to ensure

this, and only last as long as local capacity is underdeveloped. Fishing deals should also minimize the impact of foreign fleets on national fishing interests by restricting access to inshore areas or stocks on which local communities or the local fishing industry depend.

5. **Review** – before agreements are renewed, their impact on the marine environment and local economy and livelihoods should be assessed via effective impact assessments. The impact on fish stocks, the wider marine environment, the livelihoods of coastal peoples, the local fishing industry and the economy of the host nation should be assessed. The results should be used to improve the ecological and social sustainability of deals.
6. **Transparency** – as part of good governance, negotiation of terms and conditions of the agreement should be transparent. The negotiation of access agreements should be in the public domain and the agreement texts should be available. The analysis of the status of stocks should also be made available.
7. **Monitoring and enforcement capacity** – the coastal state should have adequate capacity to monitor and enforce fishing agreements. To foster good governance of fisheries, money should be used to develop infrastructure for effective monitoring and surveillance, and the data gathered evaluated, made public and used in future management. However, many coastal states do not have adequate capacity and in such cases fishing agreements should seek to strengthen capabilities. For example, a proportion of the payment by the fishing state could be allocated for monitoring activities.

Fishing the high seas

The high seas account for almost two-thirds of the world's oceans. These international waters host economically important natural resources, such as the majority of the large tuna stocks, and highly diverse ecosystems such as deep sea coral reefs, seamounts and hydrothermal vent fields. Many species found in the high seas are very long-lived and slow growing, and/or have life histories that span several oceans. Such species are particularly vulnerable to industrial activities and overexploitation. Much of the biodiversity of the high seas is still undiscovered and unmapped, let alone developed, such that each time a new area is surveyed, new species are discovered. The most important human activity affecting high seas biodiversity is industrial fishing, carried out by distant water fleets, especially for tuna and straddling fish stocks.

UNCLOS confirms the notion that the high seas are global commons, with open access to all, but also establishes the rights and duties of coastal and flag states in exercising jurisdiction beyond territorial waters and States that the use of natural resources must be exercised responsibly. A patchwork of international and regional agreements (such as Regional Fisheries Management Organizations, RFMOs, see below, and Miller and Jacobsson, this volume) is designated to regulate the use of the resources on the high seas, but in order to be effective, individual countries must become party to and implement these. As all activities on the high seas take place from vessels, the flag states registering those are responsible for ensuring that a genuine link can be established between the flag state and ship-owner, and that the activities comply with national law. What constitutes such a genuine link, however, is not made clear by UNCLOS.

However, most governments have either not signed or not ratified existing regimes to manage fisheries on the high seas, or if they have, have not yet fully implemented them into their legislature. The Food and Agriculture Organization of the United Nations (FAO) Compliance Agreement has not even come into force due to an insufficient number of ratifying countries, despite being adopted over a decade ago. As a first step to strengthen oceans governance, WWF is encouraging governments to sign, accede to, and ratify these three treaties, as well as to fully implement and enforce them.

Flags of Non Compliance and IUU

The practice of registering vessels under Flags of Non-Compliance (FONC)[2] is increasingly used by less scrupulous vessel owners and operators to avoid growing costs and controls imposed by reputable states to meet environmental, safety, security and labour standards set by the international community. This is a cause of concern as the environmental and social consequences of avoiding international regulations are large and include environmental degradation, biodiversity and habitat loss, as well as social costs when coastal communities are affected by overfishing and other consequences of bad vessel management.

FONC facilitate and protect owners and operators involved in illegal, unregulated and unreported (IUU) fishing – a serious threat not only to the sustainable management of fish resources and the ecosystems which sustain them, but also to dependent communities and consumers. Many of the worst offenders in IUU fishing have a convoluted owner and flagging picture, for example a fishing vessel operating illegally off the East coast of Africa may be flagged in Sierra Leone and owned by company registered in Taiwan, in turn owned by a Spanish national.

IUU nets catches worth an estimated USD 10–23.5 billon annually, representing between 11 and 26 million tonnes of fish. There are regional differences in the level and trend of illegal fishing over the last 20 years, and a significant correlation between governance and the level of illegal fishing. Developing countries are most at risk from illegal fishing, with total estimated catches in West Africa being 40 percent higher than reported catches.

IUU will continue as long as no immediate action is taken. The ministerially led High Seas Task Force (HSTF) in 2006 devised a set of practical proposals intended to tackle the root causes of IUU fishing, to expose IUU activities, deter them and improve enforcement against those responsible. These include ensuring a strong Monitoring, Control and Surveillance (MSC) Network that can provide training and support to developing countries to develop legislation, detect

2. Flag states that register vessels (for a fee), without having the capacity or the will to enforce applicable international agreements regulating the activities of these vessels – either by failing to become parties to relevant agreements or by failing to enact and enforce relevant domestic implementing legislation.

IUU activities and enforce rules and regulations against IUU actors. They also include developing a global information system on high seas fishing vessels, as well as ensuring that all flag and port states become parties to all relevant international agreements. These measures still need to be taken by all flag and port states to curb the problem of IUU (see box).

HSTF PROPOSALS FOR ACTION TO STOP IUU

- **Strengthen** the International MCS Network.
- **Establish** a global information system on high seas fishing vessels.
- **Promote** broader participation in the United Nations Fish Stocks Agreement (UNFSA) and the Food and Agriculture Organization of the United Nations (FAO) Compliance Agreement.
- **Promote** better high seas governance by:
  - developing a model for improved governance by RFMOs;
  - independent review of RFMO performance;
  - encouraging RFMOs to work more effectively through better coordination; and
  - supporting initiatives to bring all unregulated high seas fisheries under effective governance.
- **Adopt and promote** guidelines on flag state performance.
- **Support** greater use of port and trade measures by:
  - promoting the concept of responsible port states; promoting the FAO Model Port State Scheme as the international minimum standard for regional port state controls and supporting the FAO's proposal to develop an electronic database of port state measures;
  - reviewing domestic port state measures to ensure they meet international minimum standards;
  - strengthening domestic legislation controlling import of IUU product.
- **Fill** critical gaps in scientific knowledge and assessment.
- **Address** the needs of developing countries.
- **Promote** better use of technological solutions.

Getting access to fisheries resources within a country's exclusive economic zone is also done by re-flagging vessels to the coastal state or establishing joint ventures with a coastal state company. Joint ventures can, if well regulated, facilitate transfer of know-how and technology, securing long-term development of the fisheries sector of the partner.

In reality, however, they often enable foreign owned vessels to fish in countries with a minimum of fisheries management in place, and allow unscrupulous vessel owners to avoid any monitoring or restrictions imposed upon foreign vessels, and escape the penalties for operating in violation of the regulations established under bilateral access agreements. In essence, such measures to access fish resources in a developing country lacking the means to sustainably manage its resources qualify as use of flags of non-compliance (see above), and should therefore be regarded as IUU and thus be subject to import restrictions. Re-flagging and joint ventures must therefore only be allowed when a strong management structure is in place, have strict terms of references, and their actual benefit to the coastal state is assessed.

Reforming high seas fisheries management

RFMOs bring interested nations together to manage and monitor fish stocks in a specific region of the high seas. They are established by treaty and generally have the authority to close areas to fisheries to safeguard fish spawning or aggregation sites, and could also potentially establish protected areas for vulnerable habitats and fish stocks. Their mandates differ widely: some are tasked with managing all living marine resources in a given area (such as CCAMLR[3]), while others focus on a single species (such CCSBT[4]).

While there are a few good examples, reviews of RFMOs show that many have failed to prevent over-exploitation of highly migratory fish stocks and straddling stocks (those harvested in both national and high seas waters), to rebuild overexploited stocks, or to prevent degradation of marine ecosystems where fishing occurs.

Reform of the current regional fisheries management organizations is a key element to ensure adequate management of high seas fishing. In order to work as intended and ensure sustainable fisheries, RFMOs need to be strengthened and member states must ensure that all vessels fishing within the remit of a RFMO adheres to relevant international and regional fisheries agreements. Additionally, no fishing should be allowed by vessels licensed in states not member of the RFMO. The inclusion of ecosystem based management into both new and existing management arrangements is also crucial to ensure sustainability. In areas where no fisheries management organization exists, new management arrangements should be set up using best practice, the precautionary principle and best available scientific advice to ensure ecosystem-based management and fair access for developing states.

Conclusion

In order to ensure long term sustainability of fisheries, it is essential that all fisheries, both in coastal waters and on the high seas, are adequately managed using ecosystem based management principles including the precautionary approach.

Industrialized nations have a responsibility towards the future of people in developing nations, and have agreed to work towards the commitments set out at the World Summit on Sustainable Development in 2002. Industrialized countries must ensure that developing countries can develop their own capacity to sustainably manage coastal fisheries, including monitoring

3. The Convention on the Conservation of Antarctic Marine Living Resources. *www.ccamlr.org*.
4. The Commission for the Conservation of Southern Bluefin Tuna. *www.ccsbt.org*.

activities of distant water vessels, and to participate on equal terms in the sustainable harvesting of living marine resources on the high seas.

Flag states must exercise their responsibility under the UN Law of the Sea by becoming party to all relevant international and regional agreements, implementing their provisions into their national legislation and ensuring all vessels under their flag comply with provisions, or are no longer authorized to fly their flag.

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THE CHALLENGE OF HIV/AIDS IN THE FISHERIES SECTOR IN DEVELOPING COUNTRIES

Simon Heck and Katrien Holvoet

Global overview of HIV/AIDS in the fisheries sector

People in the fisheries sector in developing countries are among those at highest risk to HIV and AIDS. Global data suggest that fisherfolk, including fishers, their families, fish processors and traders, are among high risk groups with infection rates that are five to ten times higher than in agricultural communities in the same areas.

Geographically, the spread of HIV/AIDS in the fisheries sector mirrors the spread in the general population, with sub-Saharan Africa showing the highest incidence. Importantly, however, absolute numbers of HIV positive fisherfolk are very high in Asia due to large fishing populations, and case studies from Cambodia, Vietnam and Indonesia suggest that here, too, fisherfolk are among the high risk groups.

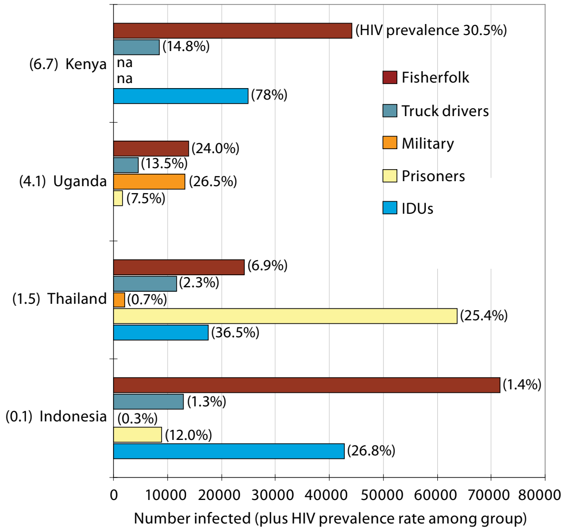

Figure 1. Estimated HIV prevalence (%) and numbers infected (bars) among sub-populations (Kissling *et al*. 2005).

Vulnerability of fisherfolk to HIV/AIDS

Drawing on case studies from around Africa, the 2006 International Workshop on Fisheries and HIV/AIDS identified the following main factors of vulnerability among fisherfolk:

- Demographic structure with high rates of single men in sexually active age groups.
- High rates of mobility and migration.
- Generally poor health and hygiene status in fishing camps and among mobile populations interacting with these communities.

- Easy availability of cash income on a regular basis without tangible investment or savings opportunities.
- Poverty and gender inequality that marginalize women in commercial transactions, making them more vulnerable to sexually exploitative relations.
- Poor health service infrastructure, condom availability and access to specialized centres where voluntary testing is available.
- Culture of risk taking and perception of low social status among many fishermen. (WorldFish Center 2006.)

Working in West and Central Africa, the Sustainable Fisheries Livelihoods Programme (SFLP) of the FAO identified further institutional constraints arising from the omission of the fisheries sector from national HIV/AIDS strategies as well as from local government services and NGO initiatives. As a result, even basic health technologies and HIV/AIDS messages are not commonly available in fishing communities.

Implications for the future of fisheries

The implications of the epidemic for the future of fisheries are far reaching. The small-scale fisheries sector, where over 90 percent of the world's fishers operate and over 60 percent of the world's capture fisheries production occurs, is facing the risk of losing valuable human resources, knowledge and experience without having the capacity to replace these through formal processes. As part of this, the substantial investments in improving management of fisheries resources which have been made by governments throughout the developing world are at risk as the value of long-term planning and of stewardship of natural resources is less compelling when life expectancy declines and communities disintegrate. The economic and social costs to developing countries have not been specifically quantified, but they are likely to be substantial at all levels. Allison and Seeley (2004) differentiate between impacts in the fisheries sector at four levels (see Figure 2), from the individual to the resource base. These include declining human development, economic inefficiency, reduced management capacity and weakened conditions for sustainable fisheries. The overall economic impact of HIV/AIDS in sub-Saharan Africa has been estimated at one percent to 1.5 percent of GDP. This cost is likely to be greater in highly affected sectors such as fisheries.

Responding to the challenge

Governments in developing countries and international organizations increasingly recognize the importance of HIV/AIDS as a development challenge in the fisheries sector. In several countries, including Uganda and Malawi, national policies and strategies specifically targeted at fisherfolk have been developed. FAO's SFLP reports institutional impact of their work in several West and Central African countries (Benin, Cameroon, Gabon, Côte d'Ivoire, and Republic of Congo). National HIV/AIDS plans in these countries now include fishing communities, fisheries departments are working more closely with HIV/

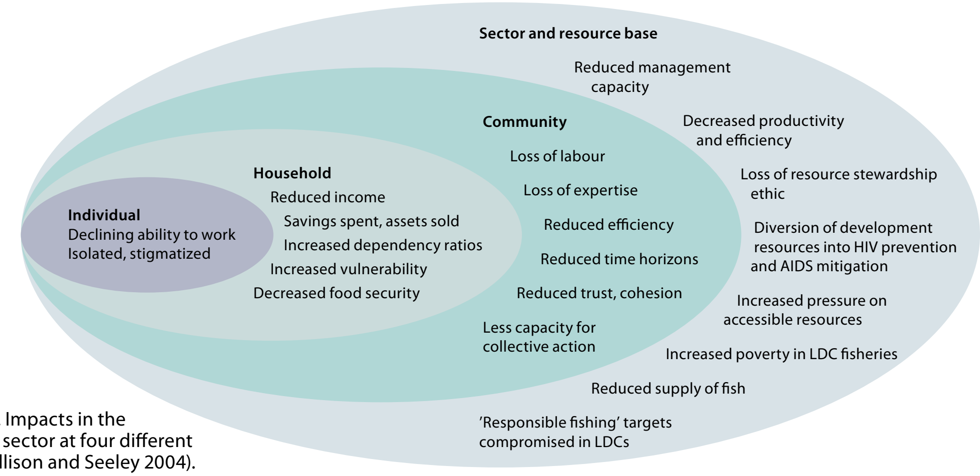

Figure 2. Impacts in the fisheries sector at four different levels (Allison and Seeley 2004).

AIDS and livelihood support programs, and NGOs and other health service providers are increasingly targeting fishing communities.

Regional economic blocks such as the Southern African Development Community (SADC), the East African Community (EAC) and the South Pacific Commission (SPC) are supporting wider regional HIV/AIDS programs that target the fisheries sector. A current program by the WorldFish Center and FAO, with support from Sweden and Norway, seeks to identify viable investment opportunities that can reduce known risk factors among fisherfolk. For example, the program supports innovations among fish traders and fisher associations to improve business relations along fish marketing chains and develops more effective approaches by NGOs and community organizations to deliver HIV/AIDS services to fishing communities and mobile fish traders.

A critical institutional challenge is to foster partnerships between fisheries management institutions and health sector agencies. In most cases, fishing communities are among the most marginalized in terms of health service entitlements and actual service delivery by governments or civil society organizations. While institutional incentives for cross-sectoral collaboration are often lacking, opportunities are increasing through the decentralization of government functions, health service reforms and stronger community participation in fisheries management. Practical guidelines and workable models are now urgently required for integrating HIV/AIDS objectives into local fisheries management plans.

There is need to show the relevance and role of the fisheries sector in both the transmission of HIV/AIDS and the fight against it, and for the inclusion of specific aspects in the diagnosis and formulation of community action planning. This includes targeting differentiated groups of fisherfolk (accounting for the differences between industrial and artisanal fisheries), developing partnerships to strengthen the capacity of agencies working on HIV/AIDS to understand the specificities of fisherfolk, and supporting fisheries organizations to prioritize HIV/AIDS objectives in their plans and strategies.

Multi-sectoral and multi-level approaches are required that combine regional and national policies with community responses. SFLP findings further emphasize the importance of livelihood support and diversification programs to complement health sector and educational interventions at community level. Promotion of small-scale enterprise and non-fisheries based income options through strengthening of technical and financial services can be targeted at highly vulnerable groups such as youth and women and can help reduce vulnerability and bring about behaviour change. SFLP's work with communities in Benin and the Republic of Congo to develop and implement Community Action Plans to combat HIV and AIDS (*Plans d'Actions Communautaires de Lutte Contre le VIH & Sida* - PACLS) has shown positive socio-economic results that should be considered for wider dissemination.

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CONCLUSIONS AND WAYS FORWARD

Per Wramner, Hans Ackefors and Mikael Cullberg

The various chapters in this book show clearly how most issues concerning fisheries, sustainability and development are closely interrelated and inter-dependent. In addition to this, they depend on and influence the environment and natural resources. *Fisheries* is based on fish (including shellfish), not only a natural resource of great value to man but also a key component of aquatic ecosystems. Fisheries managed in a sound way, adapted to the natural conditions and the environment, and in line with the ecosystem approach, contribute considerably to food provision, income, employment, recreation, etc. *Sustainability* – both ecological and socio-economic – is a precondition for human well-being in the long run and a goal for most sectors in society. *Development* is the key to a better life, particularly for the countless multitudes of poor people in developing countries, but also for a majority in the rest of the world. Its links to fisheries and sustainability are obvious.

The global interrelations are complex. Both inter-sectoral and geographical links are common. For example, fish consumption in Sweden impacts fish stocks, aquatic environments and socio-economic conditions in other countries all over the world. Trade in fish products, purchase and exchange of fishing rights, illegal fishing in foreign waters, global change, transboundary environmental degradation, invasive alien species and development aid are examples of such links.

As noted in the book, the lack of a holistic view of these issues is a major factor underlying the shortcomings and problems that considerably affect the food supply, natural environment and overall basis for life, including the development potential, for a vast number of people in developing countries. These shortcomings and problems also influence the developed countries in various ways and thus – directly and indirectly – affect us that belong to the privileged part of mankind. Thus, an obvious starting point for a discussion of these issues is how a holistic view of them can be achieved.

The international community has agreed at state and government levels on a number of key resolutions that offer objectives and guidelines for future development as well as political undertakings to promote their fulfilment, e.g. the UN Millennium Development Goals. These objectives and guidelines are of major importance as lodestars for development at all levels (global, regional, national and local) and in all parts of the world, even if there is a certain focus on developing countries. Their key messages may be summarized in the concept of sustainable development. It is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Both ecological and socio-economic progress is included. Sustainable development has been in focus of most development activities during the last two decades, at least in theory. The general nature of the concept has unfortunately made its actual content the subject of various interpretations and adaptations to selfish interests.

The discussions and conclusions in this chapter proceed from the concept of sustainability as a development goal. The original interpretation of the concept, as defined by the UN Global Conference on Environment and Development in 1992, has been applied. We attempt to summarize and analyze the various sections primarily from the sustainability perspective and highlight aspects that we feel should be underscored for various reasons.

Ecological sustainability is an imperative necessity for fisheries. Unlike other kinds of biological production (e.g. agriculture and forestry), capture fisheries utilize the yield of more or less natural ecosystems. That means that a sustained production capacity of these ecosystems is a precondition for sustained fisheries which, in its turn, means that conservation of aquatic environments is a high priority concern for the fisheries sector. Environmental degradation affects fisheries more than most other sectors.

The chapters in this book are by authors with different backgrounds, focuses, starting points and perspectives. Problem formulations, analyses and conclusions vary. Overlaps occur. Broad overviews alternate with exemplifying discussions of specific issues. This arrangement was chosen in view of the subject's considerable range, complexity and controversial character. The scientific knowledge base is weak in some respects. A variety of opinions on a number of issues are dealt with in the book. Apart from providing a forum for these viewpoints, the goal has been to ensure that the combined inputs cover the most important points of the subject. However, for practical reasons, certain aspects have been handled in a more general manner than others. The book is divided into four parts which are discussed separately here.

Part One: Water, fish and fisheries

The first part of the book presents basic prerequisites, from a natural science perspective, for fish and fisheries all over the world. Both marine and inland waters are covered. Global overviews are then given of environmental degradation, climate change and other factors which affect fisheries. Also environmental impacts of fisheries are covered. Different types of fisheries, marine and inland, in different parts of the world are described. Fishing activities, stock situations, socio-economic importance etc. are dealt with.

Global overviews of oceanographic conditions and Large Marine Ecosystems (LMEs) set much of the scene for the description of marine fisheries in the book. Nutrient supply and nutrient recirculation set the limits for primary production which is the basis for fish and shellfish production. Strikingly, shelf areas including upwelling areas along the eastern side of the Atlantic and Pacific Oceans, which cover only about 10 percent of the sea, yield more than 80 percent of all marine catches. However, it is underlined that fisheries management regimes also play an important role and to a large extent have affected fish production negatively.

It is strongly emphasized that marine environments all over the world show serious negative impact caused by man. Their ability to provide ecosystem services of value to mankind – e.g. fisheries – is decreasing. In many marine areas the cumulative and cascading impacts of various human activities have caused dramatic changes in ecosystem structures and functions. The problems are substantial in industrialized countries – despite environmental laws, administrations, etc. – and increasing in developing countries. Pollutants causing chemical contamination constitute major problems which may directly affect fisheries. For example, eutrophication causes profound negative ecological changes. Toxic long-lived substances, such as dioxine, accumulate in the food chain and hit top predators – including man – especially hard. Pollution is a problem of global concern but often shows specific severity in coastal waters in developed countries.

Habitat degradation is another serious problem, not least affecting coastal habitats in developing countries, as pointed out by several authors. Fisheries are badly affected, especially because the reproduction of many fish species is impaired. Well-known examples are siltation of coral reefs and sea grass beds, exploitation of mangroves and drainage of wetlands. Habitat degradation is also caused by fishing itself, e.g. bottom-trawling – especially on rocky habitats – and dynamite fishing. An issue of great concern is trawling on seamounts and similar habitats in high seas with unique and diverse ecosystems extremely sensitive to physical damage and overfishing. Such devastating fishing operations – comparable to mining – have been carried out at an increasing scale during the last 10–20 years. The deleterious effects on biodiversity, including sustained fisheries, are far-reaching. It is noteworthy and regrettable that the international community has not yet managed to stop or at least regulate these excesses. By-catches of seabirds and marine mammals constitute another environmental problem caused by fisheries. The magnitude varies but is frequently significant. Intensified measures to reduce the problem are urgently needed in many areas.

Ecological and environmental consequences of overfishing are described and discussed by several authors. The unanimous general opinion seems to be that overfishing causes serious problems, even if somewhat diverging views on the magnitude of the problems and the prospects to overcome them in the future are expressed. However, it is a fact that many fish stocks all over the world are managed in a non-sustainable manner, mainly due to bad governance. It seems to be evident that the recent, massive biomass declines in various LMEs essentially are due to overfishing. Trawling shows a general tendency to overexploit fish stocks.

Large predators are usually first affected by overfishing and their depletion causes ecosystem changes which may be far-reaching and difficult to reverse. The expression "fishing down the food web" is a reality. It is evidently the most common underlying factor behind the declines of the mean trophic level in fish catches, a fact which has been observed all over the world. In addition, cascading effects throughout the entire ecosystem may occur.

In a pessimistic – but plausible and well substantiated – contribution, the global development of fisheries is described as a continuous expansion. It started in industrialized countries over a century ago, extended gradually all over the world and is now being completed by industrial fleets operating in the southern oceans. One factor behind this development seems to be an extensive occurrence of illegal, unreported and unregulated (IUU) fishing, especially in high seas and the economic zones of developing countries. Fisheries have also spread from a few targeted species to a situation where all palatable species are targeted. Major consumer countries, e.g. the EU, have been able to compensate decreasing catches in their own waters by increasing imports. It is anticipated that the development, if it continues, in the next decades will lead to extensive stock collapses and even to a succession of local extermination, followed probably by global extinction of a number of large marine fish species. These predictions – or at least fears – are important, both from a scientific and a management perspective. The situation is definitely so serious that the precautionary approach should be immediately applied.

There are, however, also successful rehabilitations of deteriorated fisheries described in the book. It seems as if collapsed stocks under certain conditions can recover, provided that strict management regimes are applied. For example, gradually more successful management regimes have been applied in Norway, Iceland, USA, Australia and New Zealand, while the EU has been less successful. The best way quickly to improve the present distressing situation is probably to establish a sufficient number of large marine reserves where marine ecosystems and their species can rebuild some of their past abundance.

The key to sustainable fisheries is good governance. To bring that about, the basic problems have to be addressed, particularly the frequent mismatch between the production capacity of the resource, the fishing capacity and the demand for fish. Open access to insufficiently regulated fisheries should be replaced by well managed fisheries with efficient regulation of access, fishing effort etc.

A rather new threat to fisheries, which most authors deal with, is climate change. Evidently it will affect aquatic environments globally – and thereby fisheries. Various consequences, beyond the basic increase of temperature, and ways to reduce their impacts on fisheries, are discussed in the book. One potential problem for marine environments in general, which is associated with climate change, is the acidification of the oceans due to increased absorption of carbon dioxide from the air. The consequences for coral reefs, organisms with calcareous shells, etc., may be severe and fisheries may also become badly affected.

The introduction of the concept of LMEs as a basis for regional management of coastal waters around the globe was an important step forward in the efforts to build up an international framework for such management. The presentation of global warming broken down to the 64 LMEs underlines this. Their size and delimitation makes it possible to assess temperature trends in relation to fisheries biomass yields and is suitable for the application of the ecosystem approach. Data from the last 25 years show that there is a consistent warming of LMEs, with the exception of two upwelling areas. Fast warming LMEs are found primarily at higher latitudes and slow warming LMEs primarily, but far from exclusively, at lower latitudes. Fisheries biomass yield is increasing in a number of fast warming LMEs, for example in the northern parts of the Atlantic, but decreasing in others. It is increasing in a majority of the slow warming LMEs. The importance of management regimes for fisheries biomass yield is evident also in this case.

The impacts of climate change on fisheries biomass yields in LMEs seem to differ a bit between various areas and show no clear trend. This is of great interest, but it should be noted that the differences are based on a relatively short time period and are affected also by fisheries. The consequences of climate change seem to be aggravated in coastal waters closer to the shore, particularly in developing countries. At the local level in such countries, climate change is a real threat, particularly to small-scale fisheries. In many coastal areas a combination of climate-related stresses and widespread overexploitation of fisheries reduces the scope for adaptation and increases risk of stock collapse. It is evident that healthy ecosystems (intact coastal habitats like coral reefs and mangroves, large and diverse fish stocks, etc.) increase resilience and capacity to withstand consequences of climate change in coastal areas.

Capture fisheries are extremely diversified. Most catch figures are rough estimates which in many cases are marred by errors. Various estimations and official figures are presented in the book. According to a probable estimation, total global marine catches – including discards and IUU-fisheries – peaked around 120 million tons per year about 25 years ago, and subsequently decreased somewhat. The magnitude of this catch figure indicates the immense importance of marine fisheries, emphasized by several authors, through provision of nutritious food, generation of employment and income, generation of taxes and export revenues, enabling recreation, etc. The fisheries sector includes about 40 million professional fishermen and four million vessels. The estimated first-hand value of the global capture (marine and freshwater) fisheries is about USD 85 billion.

Freshwater as a basis for fisheries is dealt with from different angles. A common conclusion is that freshwater resources and habitats are under severe pressure, which constitutes a serious threat to freshwater fish and fisheries, particularly in developing countries. Therefore, the most urgent measure to keep and develop thriving freshwater fisheries seems in many parts of the world to be environmental conservation focusing on freshwater and habitats linked to it. Freshwater bodies, such as lakes, rivers and wetlands, are increasingly affected by changed hydrological regimes (e.g. increased flow variations, damming up, blocking of flow, drainage and water removal), as well as pollution, siltation and the like. A major factor behind the pressure on freshwater is agricultural development (leading to intensification, irrigation, deforestation, land clearing, erosion, use of chemicals, etc.). Another factor is hydropower development with the construction of dams and changed water regimes. The need for conservation of freshwater and freshwater ecosystems, including fish, is often neglected in planning for the development of agriculture and hydropower. There is an urgent need for a holistic management of freshwater resources, based on the ecosystem approach to the management of watersheds, where fisheries and aquaculture are given due consideration. This approach should consider not only water quantity and quality but also connectivity of river systems, biodiversity conservation etc.

Alien species constitute a general threat to aquatic biodiversity which is highlighted in the book. It is of specific significance to freshwater fisheries. There is an urgent need for increased consideration of that problem in the management of such fisheries.

Climate change constitutes a further pressure on freshwater fisheries. For example, freshwater availability is projected to decline, most significantly in southern and northern Africa and a number of other hot spots. This is an obvious and serious threat to fisheries. The impact of climate change on the small-scale fisheries of inland waters is of great concern. The majority of the world's millions of freshwater fisherfolk live in areas that are highly exposed to climate change. Climate change threatens the multiple benefits of fisheries, notably the contribution to poverty reduction. It decreases biodiversity and production, affects human health and damages physical assets.

Also inland fisheries are affected by overfishing. Its consequences are similar to those recorded in marine waters. Fishing down the food web has occurred in many places. Overfishing has contributed to collapse of stocks and even extinction of fish species.

The importance of freshwater fisheries to man is strongly underlined in the book. According to official estimates, freshwater catches are about 10 million tonnes per year and are still increasing, especially in developing countries. On the contrary, most industrialized countries show decreasing catches. There is a potential for further increase in production in many areas, provided that the environment is not further degraded and sustainable management regimes are applied. Inland fisheries are an important source of income for 50–100 million people and of animal protein for still more.

One category of fisheries, which is often more or less neglected when the importance and the benefits of the sector are discussed – especially compared to commercial and subsistence fisheries – is recreational fisheries. Its great importance from both economic and social perspectives is strongly underlined in the book. In many parts of the world, particularly in fresh and coastal waters in industrialized countries, recreational fishing is becoming the most important beneficiary of fish stocks. About a tenth of the population across all industrialized countries engages regularly in recreational fishing. It provides much social, economic and ecological benefit to society; especially its role as a major economic driver should be emphasized. In many rural areas, recreational fishing is an important part of the tourist industry. For many fish stocks, e.g. the Atlantic salmon in the Baltic Sea, the economic revenue per catch unit of recreational fishing is much higher than that of commercial fishing. Recreational and commercial fisheries are usually carried out side by side. Conflicts do occur but are usually negligible or of minor importance, and can be avoided or reduced by proper planning. Finally, it should be emphasized that recreational fishing, generally speaking, exerts less pressure on fish stocks and causes less environmental damage than commercial fishing. Furthermore, within the context of recreational fishing a lot of voluntary work is devoted to restoration and conservation of fish stocks and habitats.

Part Two: The science and politics of fisheries management

The second part of the book presents different aspects on governance and fisheries management: legal, scientific, socio-economic etc., both in developed and developing countries. Focus is on conditions for sustainable fisheries. Management strategies and instruments, problems and failures, case studies etc. are discussed from different perspectives. It is underlined by all authors that good governance is the basis for fisheries management regimes aiming at sustainability. Such governance must include appropriate legislation, efficient management structures, qualified scientific advice, pronounced political will, etc. Shortages regarding only one of these components may be sufficient to jeopardize the sustainability of fisheries management. In practice, however, political will seems to be the individual factor which most frequently is the key to management failures. Successful fisheries management should:

- adopt a long-term perspective aiming at sustainability,
- be based on sound scientific advice,
- apply the ecosystem and precautionary approaches, and
- consider – and bring about a reasonable balance between – all relevant aspects and interests (also outside the fisheries sector itself, e.g. impacts of fisheries on socio-economic conditions and biodiversity).

Qualified scientific advice is a prerequisite for successful fisheries management based on biological conditions and aiming at sustainability.

However, as underlined by several authors, such advice does not automatically lead to management success. Actually, most management failures are not due to the lack of qualified scientific advice, but to the lack of will to follow the advice given. One well-known example is fisheries in EU waters in the north-eastern Atlantic whose management has not been successful – despite access to excellent scientific advice and management capacity to make use of that advice.

The important role of scientific advice is discussed thoroughly in the book. The work of ICES – the international scientific body for the north-eastern Atlantic – is the starting point. Fisheries management advice should be right, relevant, responsive and respected. The first three can easily be addressed within the scientific community itself. The fourth issue – getting the advice accepted – is more difficult to address and probably presupposes involvement of fishers and other stakeholders in the scientific advisory process. How to effect this is a real challenge for science in fisheries management.

The ecosystem and precautionary approaches are two cornerstones of sustainable fisheries management. They are partly linked to each other and are being applied to an increasing extent. However, there is still an urgent need for a more frequent, systematic and strict application of both approaches, at national and international levels. The ecosystem approach to fisheries is discussed in detail in the book. The importance of the concept, as a management tool, and its wide application are underlined. It should be specifically emphasized that the approach stands for both the sustainable yield of aquatic ecosystems and for their integrity, species stock etc. Up to now, the important biodiversity conservation aspect has not always been fully considered in the application of the ecosystem approach to fisheries management.

A joint Swedish/FAO-initiative in the 1990s laid the foundation for the application of the precautionary approach to fisheries management. The concept has then successively been specified and made more operative. It should not only focus on maintaining the reproductive capacity of specific stocks, as is often the case in fisheries applications, but also address impacts on the whole ecosystem which is affected by fishing activities. Four basic foundations for the precautionary approach are:

- All fishing activities have environmental impacts which should not be neglected until it is proven – from a sustainability perspective – that it is appropriate to do so.
- Cessation of fishing activities with potential serious adverse impact may be required. However, it does not imply a total fishing moratorium until potential effects have been assessed and found to be negligible.
- All fishing activities should be subject to prior review and authorization and carried out in accordance with a concrete, all-embracing management plan.
- The standard of proof used at authorization of fishing activities should be commensurable with the potential risk. The expected benefits of the activities should also be considered in the authorization process.

This book gives a comprehensive overview of the legal framework for fisheries management at the international level. It consists primarily of two global agreements – UNCLOS and UNFSA[1] – and a number of regional agreements. An important conclusion is that much more could be done – based on the existing legal framework – to bring about sustainable fisheries management at the international level than is done today. There is a need for improved legislation in some respects, but the main reasons behind the present unsatisfactory – but slowly improving – governance situation are insufficient capacity (particularly in developing countries) and lack of political will, not deficiencies in the legal framework.

Management problems include insufficient and uncertain scientific advice, insufficient regulation, faulty compliance, IUU[2] fishing, etc. According to international law, countries are obligated to cooperate in the field of fisheries management. In most cases, however, such cooperation does not comprise all concerned countries. Of particular concern is that flag of convenience is a common phenomenon and that many states do not take the required responsibility for vessels flying their flag.

The problem of IUU fishing is specifically dealt with in the book. Its magnitude is underlined, but it is also shown that the problem is tackled by the international community, especially within the FAO. Slow progress is made but a lot remains to be done. For example, IUU fishing is a major factor behind the degradation of unique and valuable bottom habitats in high seas through trawling. Many vessels involved in these activities are owned by companies in the EU and other industrialized parts of the world but fly flags of convenience.

It is often stated that fisheries management can be made more efficient by involving local fishers in management decisions, both in developed and developing countries. This is certainly generally true, but the statement needs to be shaded off a bit. For example, it is evident that in many industrialized countries – including Sweden – a strong political influence of the commercial fisheries sector has been an important factor behind the failure of the public fisheries policy as regards stock conservation and sustainability. The fisheries lobby is much stronger than – for example – the environmental lobby and does not always seem to think of its own good in the long run.

African experiences, both positive and negative, of fisheries co-management programmes are described in the book. Successful cases are characterized by, inter alia, enabling policies and legal frameworks, effective institutions, real participation by fishers and other stakeholders and incentives for individuals to participate. In many cases, however, co-management programmes failed to improve governance and were detrimental to the local fisherfolk. It is evident that co-management alone is not a general solution to management problems.

Part Three: Aquaculture and seafood

The contribution of aquaculture to food for humans is substantial. At present this corresponds to nearly 50 percent of fish and shellfish con-

1. United Nations' Convention on the Law of the Sea, and Fish Stocks Agreement.
2. Illegal, unregulated and unreported.

sumed by man. Fish is mainly produced in freshwater, and shellfish in marine areas. The aquaculture sector still maintains a high annual rate of increase. Asia continues totally to dominate aquaculture production with about 90 percent of global weight and 75 percent of value. China dominates the Asian production to a similar extent. Only two countries outside Asia – Chile and Norway – belong to the top-ten producers of the world. The dominating species produced are carps and molluscs, and in the second place crustaceans, mainly shrimps, and salmonids.

Feed is often the key factor in aquaculture. It represents the largest cost for farmers and is the key to further development. Fish species in temperate waters are mainly carnivorous, like salmonids, and obtain nearly 100 percent of their energy from external sources (intensive fish farming systems). Fish species in tropical waters are usually omnivores or herbivores, e.g. tilapia and carps, which are not given fabricated feed (polyculture or extensive systems). There is a plethora of various aquaculture systems on land (mainly ponds), as well as net pens in freshwater and marine waters. Of great interest are integrated systems where grazing animals on land fertilize ponds with their faeces. Most fish cultivated in net pens are raised in lakes and coastal sea areas, but also in off-shore production in large net pens or other devices. On land, closed recirculating systems or other systems supplied with warm water are increasingly used in temperate areas and evidently offer potentials for further development. In such systems, pollutants can be collected to prevent eutrophication of the recipient.

Feeding technology has made great progress; pelleted feed leads to less waste and substantial gains in the production process. Compared to terrestrial animals, the retention of the protein content of the feed is much higher. From an environmental point of view, water pollution is a disadvantage of fish farming compared to the production of terrestrial animals, because it is more difficult to prevent eutrophication from fish farms, especially pens. However, great progress has been made to reduce the environmental impact by better technology and above all better feed. The amount of released nitrogen and phosphorus, per kg produced fish, to the environment has decreased substantially. 20–30 years ago, adult salmon was given a high-protein and low-energy diet; about 2.5 kg feed was needed to produce 1 kg of fish. Today the about 1 kg of low-protein, high-energy diet is sufficient.

With increasing prices of fish meal, there is an incentive partly to replace fish protein with plant protein. More importantly, this is desirable from a natural resources perspective. However, there are drawbacks with plant protein; the so-called "anti-nutrient substances" must be processed in various ways before they are added to the feed. Replacing fishmeal with plant protein has nevertheless become so efficient in modern salmon diets, that 25–50 percent of the fishmeal now consists of plant protein. At present, focus is on the use of fish oil, since aquaculture uses 4/5 of the total world production, although 50 percent of the oil in, for example, salmon feed is of plant origin.

Measures to reduce emissions from fish

farms, in combination with increased efforts to find suitable locations, have a great potential to reduce conflicts between fish farming and other interests. Important tools to this end are physical planning and environmental impact assessment.

Seafood contains a number of valuable components from a nutritional point of view, which make them potential members of the so-called functional food family. Increasing awareness of this remarkable quality will certainly affect future demand for fish. Seafood is a good source of valuable proteins, omega-3 and other important fatty acids, vitamins and minerals.

Unfortunately, potential risks also have to be taken into consideration, first of all due to environmental pollutants, e.g. chlorinated hydrocarbons and methyl mercury, which accumulate in the food chain and may reach unwholesomely high levels in fish meat. Greater attention should be paid to this problem, both in environmental and fisheries management. Certification and increased traceability are also measures which could improve the situation. Other problems, which also affect fish consumption negatively, are the occurrence of toxins in mussels emanating from toxic phytoplanktons and allergic reactions provoked by naturally occurring proteins in fish and shellfish.

More than a billion people on earth are, more or less, dependent on seafood as the main source of animal protein. Globally, about 12 percent of the human consumption of animal protein consists of fish – or 16 percent if China is included. Seafood consumption is highest in Asian countries, with Japan in the lead, but the consumption is also high in countries like Korea and Malaysia. Statistics are uncertain, as clearly shown in the book, but it is evident that fish protein is of specific importance to national food supply – and public health – in many developing countries. This fact should be better reflected in development policies.

Part Four: Fisheries, trade, development and poverty reduction

Fisheries and aquaculture contribute to meeting the Millennium Development Goals through employment, provision of nutritious food, generation of revenues for local and national government from licenses and taxation on landings, from export revenues, and from various upstream and downstream multipliers. For example, fisheries and aquaculture employ over 50 million people worldwide – a quarter of them in aquaculture – 98 percent of whom are from developing countries. In a global export business worth nearly USD 80 billion annually, African export earnings from fishery products and services are calculated to be over USD 2.7 billion per year, and fisheries sectors in countries such as Namibia, Uganda, Ghana and Senegal contribute over 6 percent to their national GDPs.

Despite the significant contributions that fisheries and aquaculture make to employment, nutrition, and trade in the developing world, they are rarely included in national development policy and donor priorities. Part four of this book shows that this lack of attention to the sector is particularly problematic given that capture fisheries are currently being utilized at capacity and that further increases in production will have to come from expansion of aquaculture.

The contribution of fisheries and aquaculture to development has consistently been underestimated, as several authors point out. The Sustainable Fisheries Livelihoods Programme of the FAO developed methods to reassess the contribution of fisheries to development in Africa. It also managed to raise awareness in some targeted countries. However, it is difficult to valuate small-scale fisheries, and policy makers often do not have access to data which reflect the importance of fisheries and aquaculture to development. Knowledge of artisanal, subsistence and inland production, fish-based livelihoods and consumption patterns in developing countries tend to be very poor.

Employment in fishing and aquaculture has grown rapidly over the past few decades – from 13 million people in 1970 to over 41 million in 2004 – and at a higher pace than both world population and employment in agriculture. Authors emphasise the particular importance of the sector for women: millions of women in developing countries are employed in fisheries and aquaculture, participating at all stages in both commercial and artisanal fisheries, though most heavily in fish processing and marketing. The post-harvest sector is an important source of employment for the poor, with an estimated three people for every fisher. One author reminds us that fish landing sites – often centres of the cash economy in otherwise remote areas – stimulate the kind of monetisation of the rural economy that is seen by development policy makers as the means to reduce rural poverty. In small island states and fishery dependent regions of larger economies, this sector is a significant contributor to the overall economy and society.

The post-harvest sector therefore provides an opportunity for both enhancing the livelihoods of the rural poor and meeting ever-increasing food needs. However, post-harvest losses reduce revenues of fishers and traders and the overall food fish supply. One author explains this with a lack of adequate infrastructure, inadequate preservation technologies, and poor market access. In some countries in sub-Saharan Africa, an average of 30 percent of the landings is lost. Strikingly enough, the remedies suggested are "low-tech": improved processing technologies such as screens against insects, improved 'chorkor' smoking kilns, and mesh trays to elevate the fish off the ground. This could reduce losses significantly, and give both greater food security and increase incomes for processors and traders.

In sub-Saharan Africa per capita fish supply is declining, due to rapid population growth, a stagnant capture fishery production, and the slow expansion of aquaculture in the region. Even when consumed in small quantities, however, fish often is a nutritionally important part of people's diets in developing countries. This is emphasised several times in this and the previous part of this book: it is a vital source of protein and micronutrients, and improves the quality of protein in largely vegetable and starch-based diets by providing essential amino acids. It is particularly important in the diets of the poor, as the most affordable form of animal protein: "Rich food for poor people".

An expansion of aquaculture production in sub-Saharan Africa is stressed by several authors as a means to allow the region better to meet its rapidly increasing demand for fish. Though the obstacles are manifold, it is however pointed out that aquaculture is often easier to manage than capture fisheries. Access to water is a key issue, causing problems for landless wishing to farm fish in cages, for farmers wishing to abstract additional water for fish and for downstream users where large numbers of farmers wish to harvest rainwater for pond culture. Encouraging multiple uses of water, however, can increase its productivity and allow for simultaneous development of several sectors. Often cumulative effects are not taken into account, in association with other sectors such as agriculture, industrial development, tourism or hydropower. An ecosystem approach to aquaculture (EAA) could provide a more holistic water management.

Over 30 percent of the fishery commodity production in developing countries is exported, and it is an important source of foreign exchange for many countries, including Chile, Mozambique, Senegal, and Thailand. According to one chapter international trade in fisheries products has been shown to have a positive effect on food security in many developing countries, stimulating increased production, and generating foreign exchange which can be used for food imports. One author emphasises that production for export can help to raise the incomes of poor fisherfolk and people employed in fish processing, enabling them to achieve greater food security through enhanced purchasing power. In contrast, another contribution states that, exports may deprive a section of the domestic consumers of a variety of fish, leading to a potential loss of food security for them. Fish import for human consumption can help to stabilise or reduce fish prices for poorer fish consumers. However, this can have an adverse effect on the income of fishers in the importing country by lowering their food security.

Yet other authors draw the conclusion that trade per se is neither positive nor negative for the environment or natural resources, but that trade acts as an amplifying factor. The theoretical work reviewed in one chapter confirms that both critiques and proponents of free trade with renewable resources have some valid points. Trade may be harmful to stock conservation and may even lead to welfare losses; on the other hand trade does generate benefits, and may sometimes also lead to improvements in stock conservation. While trade generally is beneficial for growth and welfare, according to one chapter, the combination of pure open access and trade liberalisation may both reduce welfare and stocks for a country. This can be reinforced by 'bad' subsidies – support to the industry that contributes to increasing fishing pressure. However, according to these authors trade liberalization may have the positive effect of promoting property rights in response to increased fish exploitation. This means that if the underlying structures are defective or weak – that for example subsidies make it more profitable to fish – trade will amplify the effects, with the potential of negative results for the environment, food supply and livelihoods.

Therefore, sustainable resource management is a necessary condition for sustainable international trade. The WTO can play a role by adopting rules to help eliminate bad subsidies, such as public support for vessel construction, fuel subsidies, or fishing rights outside developing coastal countries provided at limited or zero cost. This can emphasise good subsidies, such as to improved fisheries management or monitoring and enforcement. Weak resource management corresponds to an export subsidy on producers, which according to this chapter could be met by countervailing duties under trade law according to present rules.

The main obstacles to increased export from developing countries, says one author, are stringent and increasing requirements for food safety, animal health, environmental and social standards. On the other hand, in view of the high global demand for fish, and the limited assets available, losses and illness caused by spoilt seafood, are sufficient reasons to take measures to improve quality and safety, as one chapter points out. International harmonisation of rules is urgently needed, since this would reduce the need for special national rules.

To conclude, it is difficult to understand the low priority of fisheries and aquaculture in national efforts to reduce poverty and in international development cooperation, given their substantially beneficial role for economies, food security, health and livelihoods – and the potential to contribute even more. However, even if donors do not care much for fisheries and aquaculture, they could hardly disregard the need for sustainable management of natural resources, living and other, aquatic and terrestrial – and for good governance in general. Overfishing, poor or non-existent fisheries management and control, fisheries access agreements, ad hoc licensing of foreign fleets, as well as poaching – often a form of international organised crime at a large scale – are all disastrous to the natural resources and a consequence of poor government structures in general. Many of these factors, not least foreign fisheries both legal and illegal, also directly contribute to aggravating bad governance in many poor countries. How can policy makers and donors still turn a blind eye?

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This 'Academy Blue Book' describes global fisheries and aquaculture from the points of view of sustainable ecosystems, economy, trade and development. The main objective is to provide an overview of fisheries and aquaculture, their natural conditions and their significance for economic development and people's livelihoods. A further objective is to show the impact of rich countries on the developing world within this sector through trade, aid and global fisheries.

The target group is broad in scope: policy makers, general public, students. The Royal Swedish Academy of Agriculture and Forestry wishes to take part in an ongoing discussion, sometimes bordering to a public row, with a scientifically based and easily accessible book. This book should be seen as a source of information intended to raise the level of knowledge in general.

Threats and possibilities in fisheries and aquaculture are brought forward in the contributions from fifty-two authors from academia, international organisations and public administrations. It is striking that few countries, rich or poor, have succeeded in creating a comprehensive management system for marine and freshwater resources. Fisheries are not only important to a great many people as a source of food and livelihoods, fisheries cause ecological and socio-economic problems that are detrimental not only to people that depend on fisheries, but to biodiversity and the ecosystem as a whole. In this respect, it is essential to make the right connections between the ecological impact and poverty reduction.

Fisheries and aquaculture are essential to the economies, trade revenues and food supply of a large number of developing countries, but are generally ignored in development and trade policies. However, rich countries still influence fisheries and aquaculture and the contribution to development in many ways. Neither in natural resource management, nor in development co-operation, are fisheries and aquaculture treated in their proper context.

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