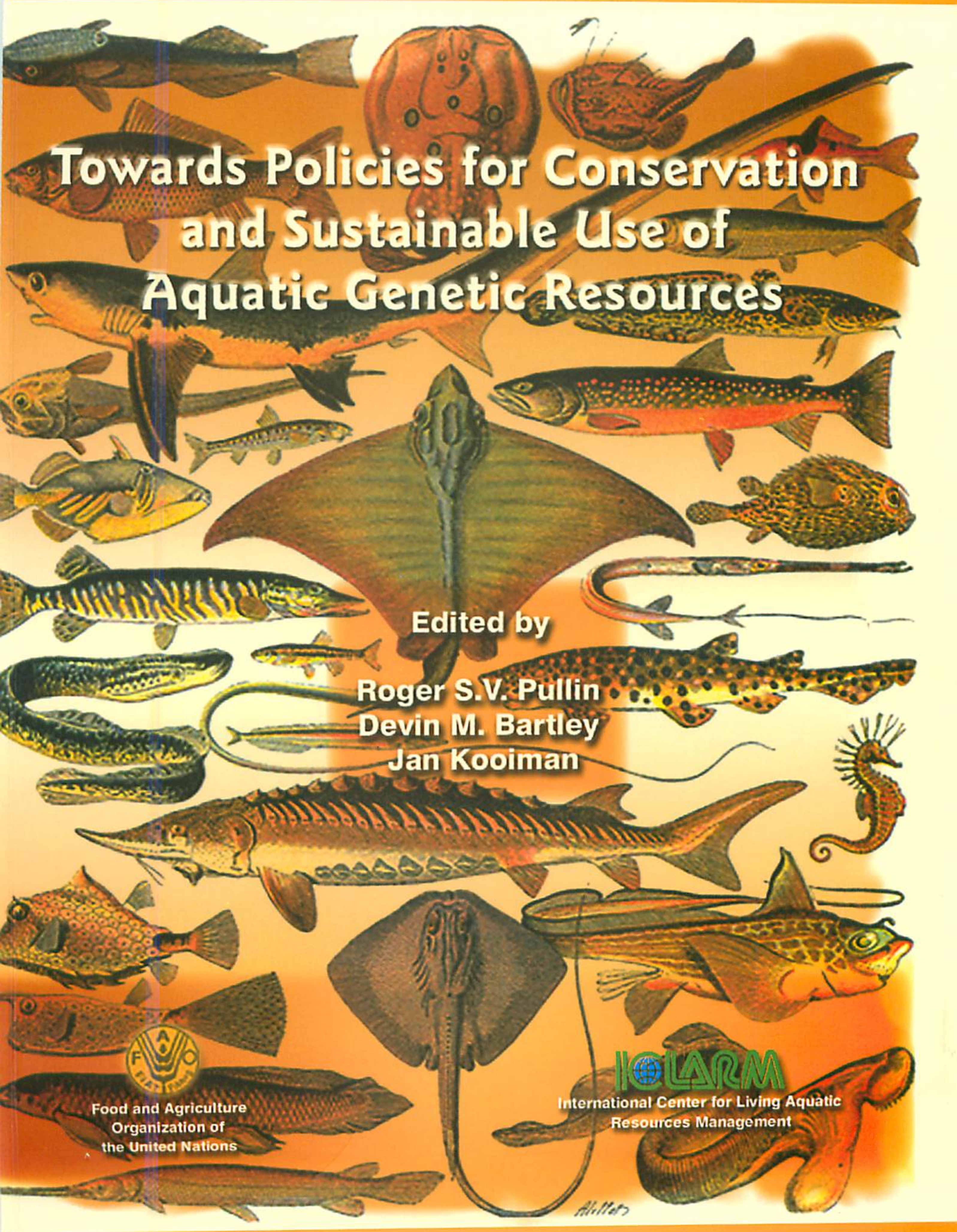

Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources

Edited by

Roger S.V. Pullin
Devin M. Bartley
Jan Kooiman

Food and Agriculture Organization of the United Nations

ICLARM
International Center for Living Aquatic Resources Management

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Foreword

International, regional and national policies for the conservation and sustainable use of aquatic genetic resources are urgently needed. Without such policies, fisheries will continue to decline. With increasing conflicts over diminishing stocks, aquaculture will fail to realize its potential for growth in developed and developing countries, and much of the aquatic biodiversity, upon which the environmental health of the planet's fresh, brackish, and marine waters depended, will be reduced or lost. The Convention on Biological Diversity (CBD) requires the establishment of such policies for the conservation and use of aquatic ecosystems, organisms and genes.

Genetic stock identification is increasingly needed for fisheries management. Genetic technologies are being developed to increase food production from aquaculture and to document and evaluate aquatic species, subspecies and strains for use in breeding programs. Hybridization, selected breeding, chromosome manipulations and gene transfer are starting to blur the differences among aquatic species and alter the genetic makeup of utilized species. The use of alien aquatic species and genetically modified aquatic organisms is also increasing and the development of new biotechnologies is outpacing the development of policies needed for their safe, equitable, ethical and sustainable use. Indeed, policymaking for aquatic biodiversity and genetic resources lags far behind that for exploited plant species and livestock.

The FAO Expert Consultation (FAO 1993) on the utilization and conservation of aquatic resources noted that general policies or mechanisms to resolve conflicts that may arise from the use and conservation of global aquatic genetic resources are lacking and recommended policy and legal instruments for cooperation in this area be developed. ICLARM, under the auspices of the System-wide Genetic Resource Program of the Consultative Group on International Agricultural Research then convened further a consultation on fish genetic resources (Pullin and Casal 1996). The Consultation recommended that an international conference on fish genetic resources policy be convened as a contribution towards the guidance of policies for effective management of aquatic genetic resources.

The international conference became a reality thanks to the generosity of the Rockefeller Foundation in offering its Bellagio Study and Conference Center as the venue, and the willingness of FAO to assist with organizing and funding the meeting and the publication of its proceedings. Many of the participants paid their own expenses.

The results are to be found in these proceedings: a compilation of state-of-the-art reviews on aquatic genetic resource issues, and summaries of discussions and recommendations from one of the few "think tanks" focused on aquatic genetic resources policy.

ICLARM joins FAO and all who contributed to this effort in offering the information in this book as assistance to those charged with formulating and implementing policies on aquatic genetic resources, especially at this time when aquatic biodiversity is being prioritized in the agendas of the CBD and related agencies and institutions.

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Pullin, R.S.V. and C.M.V. Casal, Editors. 1996. Consultation on fish genetic resources. ICLARM Conf. Proc. 51, 61 p.

Foreword

The Food and Agriculture Organization of the United Nations (FAO) and the Consultative Group on International Agriculture Research have had a long tradition of collaboration in the area of applied agricultural research and development, in particular with respect to genetic resources. As part of this collaboration, FAO places great importance on efforts to develop policies for the management of aquatic genetic resources. The decade of the 1990s has witnessed the significant developments in the conservation and sustainable use of the earth's biological diversity, including the establishment of the Convention on Biological Diversity, the acceptance of the FAO Code of Conduct for Responsible Fisheries, and the agreement to expand the FAO Commission on Genetic Resources for Food and Agriculture to include aquatic genetic resources. The international community and national governments have realized that the sustainable use and conservation of aquatic genetic resources are vital to provide increased food and nutritional security.

Indeed, the potential and promises of genetic technologies in fisheries and aquaculture are great, and the field is progressing at an astounding rate. Technological advances in molecular genetics will soon provide a description of the complete genome of several commercially important fish species. On an experimental level, genes can now be moved among species; genes that have a profound effect on growth have been identified, reproduced and used to improve farming efficiency drammatically, while other genes that confer disease resistance have also been identified. Very soon these pilot and experimental projects will be commercialized.

Traditional animal breeding has only recently been applied to farmed aquatic species, but the results are impressive–growth rate, fecundity, environmental tolerances, and a variety of other commercially important traits have been increased. Genetic improvement of farmed fishes will allow for more cost-effective and efficient culture and may allow fish farming to develop in areas poorly suited for other food-producing activities. New species have been identified using genetic analyses, and genetic data are being used to manage aquatic populations, including many endangered species, in many corners of the world. Genetics, ecology and fishery management are coming together to provide more and better information on how to sustain natural aquatic populations and fisheries.

However, the development of sound policies governing the use of aquatic genetic resources has, in general, lagged behind the impressive technical developments. These policies will need not only to provide for sustainable fisheries and aquaculture, but also to ensure the fair and equitable sharing of the benefits derived from fisheries and aquaculture development. To endure and adapt to new situations, the policies must be underpinned with the best scientific information available. Policies must, therefore, integrate a variety of elements from the biological, ecological, genetic, social, business and economic sectors. The FAO/ICLARM Bellagio Conference Proceedings contained in this volume represent one of the first efforts at bringing together the diverse information necessary for the development of policies for the sustainable use and conservation of aquatic genetic resources. FAO is pleased to be a partner in this extremely worthwhile endeavour.

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Towards Policies for Aquatic Genetic Resources[1]

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ABSTRACT

Policies for the conservation and sustainable use of aquatic genetic resources are poorly developed. This paper provides definitions of terms and reviews the major issues that must be addressed for the formulation and implementation of more effective policies in this area. The main issues reviewed are: the importance of aquatic genetic resources; conservation of aquatic biodiversity at the gene, species and ecosystem levels; the complexities of resource systems, including change (degradation and restoration), uncertainty and the policy of precaution, ownership and access to aquatic genetic resources; status and trends of resources and policies; and the difficulties of communication in light of the diverse perceptions among humans who govern and who depend upon aquatic genetic resources. Future strategies are discussed for the development of policies on aquatic genetic resources that incorporate new ideas, such as the ecosystem approach to conservation and development, and that acknowledge the important roles of education and public awareness in policy implementation.

Introduction

Two recent international consultations on aquatic genetic resources (FAO 1993; Pullin and Casal 1996) have recommended the development of policies governing the conservation and sustainable use of aquatic genetic resources. These consultations were attended primarily by fish geneticists in order to address technical issues and hence aspects of policy and legal frameworks specific to fisheries and the aquatic sector were only partially examined. There is a need to examine policy development more closely by including legal, political, ethical and economic issues in conservation and use scenarios, and to acknowledge that action is needed urgently, despite scientific uncertainty. The purpose of this paper is to address elements and issues of policy development for the conservation and sustainable use of aquatic genetic resources.

Definitions and Concepts: What is Policy; What are Genetic Resources?

Operational definitions state that, "policy is a course of action aimed at achieving one or a set of objectives and (usually) adopted on the basis of an assessment of opportunities, constraints and alternative options", (D. Greboval, pers. comm.). Campbell and Townsley (1996) defined policy as, "a formulated set of choices which are made between: a) possible objectives, the constraints to achieving those objectives and the strategies necessary to address those constraints; b) the relative priority of each of these components; c) the ways in which conflicts between component parts will be resolved and the various objectives and strategies

[1]ICLARM Contribution No. 1492.

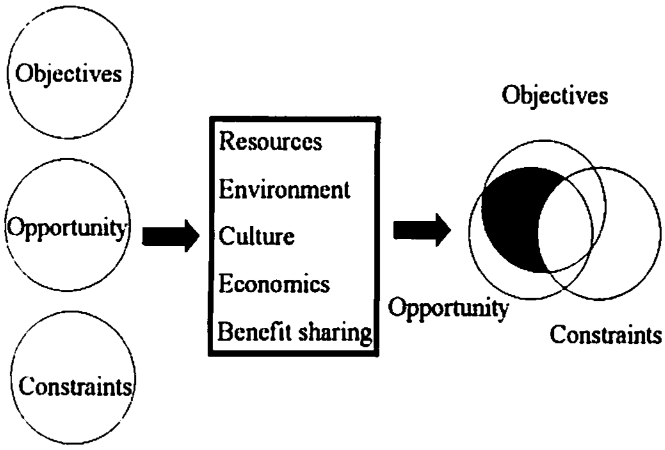

Fig. 1. Policy (shaded area) is the blending of objectives, opportunities and constraints (circles) in light of present situations (box).

harmonized." Thus, policies involve clearly stated objectives, choosing among options based on opportunities and constraints, strategies to implement them, and instruments that facilitate implementation and resolve conflicts[2] (Fig. 1).

In order to progress "towards" policies it will be necessary to understand the resources that humans wish to use and conserve and to understand the people that will be involved. Aquatic genetic resources are defined by the Convention on Biological Diversity (CBD) as: "(Aquatic) genetic material of actual or political value." Moreover, genetic material is defined by the CBD as: "any material of plant, animal, microbial or other origin containing functional units of heredity." Are aquatic genetic resources then the sum total of all the aquatic plants, animals and microorganisms on the planet? Does everything aquatic and alive and all of its DNA have actual or potential value? This might indeed be the best assumption at present, because of the large knowledge gaps that remain in (a) understanding how aquatic ecosystems function to support fisheries; (b) how to choose aquatic species for domestication; (c) how to make rapid progress in domesticating them; and (d) how to harness aquatic biochemicals and biological processes for the benefit of humankind.

[2]Although important, the aspect of conflict resolution is given minimal treatment here. Major policy instruments such as the Convention on Biological Diversity (CBD) (CBD 1994) address this issue.

Such a broad definition would make, for the time being, the terms 'aquatic genetic resources' and 'aquatic biodiversity' synonymous: in effect, an application of the precautionary principle to assessing the potential use of all wild and cultivated aquatic organisms. It would also allow for a broad definition of 'use', including non-extractive uses. These include the reverence for all life that is a tenet of some major religions and the basic love of nature that is part of a feeling of well-being for millions, as well as the "use" of aquatic habitats and biota, for example, by sport divers, ecotourists and artists. Policy for aquatic genetic resources must therefore address multiple levels of organization: genes, strains or breeds, populations, species and ecosystems.

Just such a broad definition is recommended here. The fish stocks that are exploited by commercial and subsistence fisheries, and the populations of their relatives that are unfished for various reasons (cost, regulations, taboos, inaccessibility, undiscovered etc.) can *all* be considered as fish genetic resources. What then should be conserved? The abundance (renewable stocks and effective breeding numbers) and the genetic diversity of such stocks that must be conserved so as to maximize use options for this and future generations of humans is usually a matter for debate and often the required data on genetics are inadequate or lacking. That it is prudent to aim for conservation of as much as possible all aquatic ecosystems and all their biota was recognized as far back as the United Nations Conference on the Environment, Stockholm, 1972, which had, in its Declaration of Principles, the following:

"2. The natural resources of the earth including the air, water, land, flora and fauna and especially representative samples of natural ecosystems must be safeguarded for the benefit of present and future generations through careful planning or management as appropriate."

In the Executive Summary for Policy-Makers of the Global Biodiversity Assessment (UNEP 1995), the opening sentence is: "The Earth is home to a rich and diverse array of living organisms, whose *genetic diversity* (present authors' emphasis) and relationships with each other and with their physical environment constitute our planet's biodiversity."

The prime directives of the CBD, namely the conservation and sustainable use of genetic resources and the fair and equitable sharing of the benefits derived from such use, can be taken as being globally applicable. The FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO 1995a) also embraces these in framing its objectives, which include: "promote the contribution of fisheries to food security and food quality, giving priority to the needs of total communities" and "promote protection of living aquatic resources and their environments..."

To establish policies that meet the objectives of the CBD and the CCRF with respect to aquatic genetic resources, it is necessary to understand these resources and the full implications of their conservation and use by humans.

Conservation and Use

Hierarchies of diversity

Why the concern about conserving a diversity of genetic resources? Because genetic resources provide the basis for the diversity of all life on the planet. In addition to providing variety (the "spice of life") genetic diversity provides the raw material for genetic improvement in fish, animals, trees and crops and is the basis for fitness in natural populations. Aquatic biodiversity comprises a hierarchy of aquatic ecosystems, communities, populations of aquatic species, the genotypes of individual organisms and their actual genes. To what extent do these constitute genetic resources of actual or potential use to humans and what should be the focus of conservation and use?

Each level of the hierarchy has specific functions as well as providing the base supporting the next level. For example, specific genes have been identified in fish that code for biologically and potentially commercially important compounds, such as the anti-freeze protein gene in Arctic flounder *(Pseudopleuronectes americanus)* (Shears et al. 1991). Moreover, groups of genes work together to confer specific phenotypes on individuals, e.g., quantitative traits, major histocompatability complex, and functions that allow occupation of particular ecological niches. Groups of individuals form populations with diverse life history strategies, e.g., spring and fall runs of salmon; populations form species, different species constitute communities and communities form the living components of ecosystems. The variability at each level produces some defense against adverse impacts and an aid to recovery from such impacts.

Defining units of use and conservation

Conservation and sustainable use of aquatic genetic resources should be thought of as a management continuum, encompassing the management of resources that are as yet unused, so that they can perhaps be used in the future, and management of resources that are utilized at present in a manner such that options for future use remain. Thus, defining the future "use" of a resource must accompany defining the unit(s) of conservation. In fisheries management, there is a concern to conserve the intraspecific genetic variability of populations that comprise evolutionarily significant units (ESUs). An entire symposium was recently devoted to the subject (Nielsen and Powers 1995) at which Waples (1995) provided a thorough appraisal of the concept of ESUs. Allendorf et al. (1997) noted the heavy reliance on molecular genetic methods for describing ESUs and cautioned against ignoring other useful approaches that would increase our understanding of the phenotypes with the statement "We are trying to conserve organisms, not molecules". This statement reflects a deep concern for fish populations. Molecules or genes can and should be conserved for their future use, but conservation of whole organisms and populations is crucial. Molecular analysis has revealed that cows are genetically more similar to dolphins than to horses, but one would not want to put cows in the ocean or dolphins on the open range (paraphrased from Lewin 1998), nor see either one disappear from the planet as whole organisms.

Conservation should be seen as separate from preservation in that the latter implies a "hands off" policy of maintaining the present state of something (which often implies preserving the wild state of a resource or ecosystem), whereas the former recognizes that many natural resources will need to be managed, at least at some level, to meet the needs and impacts of modern societies. The focus of conservation efforts will depend on the level of the hierarchy that is being exploited or impacted with the prime consideration being that the unit of conservation should maintain the function of the hierarchical level. For example, to conserve the gene(s) that code for growth hormone in, say, a given species of salmon, it would be appropriate to maintain the gene(s) in vectors, or even in frozen tissue or semen. Thus the function of the gene(s) would be maintained, though expression may differ in different contexts, such as other species and environments.

However, conserving such a species only in frozen form would not maintain the function of the fish and would not be appropriate alone as a conservation measure. Hybridization, either between or within species, may conserve the genes, but not the genotype, and thus would be inappropriate as a sole mode of conservation, if other alternatives exist. Clearly there is a need to conserve native aquatic genetic resources at all levels of organization.

The Value of Aquatic Biodiversity

Change, resistance and fluctuation

Cycles and physical changes in ecosystems are natural and human-influenced phenomena that affect aquatic diversity. Botsford et al. (1997) pointed out that El Niño causes shifts in species distribution, and reduced growth and survival of salmon, anchoveta and mackerel in the California Current. Other so-called "regime shifts" occur every two to three decades across entire ocean basins. Such effects have included increased salmon catches in Alaska and a shift from shrimp to gadoids and flatfish in catches in the Northern Gulf of Alaska. Ecosystems with alien species also have fluctuations between native and alien species over time (Moyle and Light 1996). Thus, ecosystems are constantly drawing on the pool of aquatic genetic resources to withstand both natural and anthropogenic impacts. If a component of this diversity is lost, then the ability of the ecosystem to adapt and continue to function will be reduced. The ability of species and populations to respond to the challenges of climate change, disease, etc. is of course the basis for evolution and this depends upon genetic diversity.

Genetically diverse ecosystems, communities and species may be more stable (i.e., more resistant to and more able to recover quicker from adverse environmental affects) and more productive (Johnson et al. 1996). So coral reefs and tropical rain forests would then be the resource systems that we should exploit because, by this reasoning, they are more stable, able to resist or recover from change, and would therefore, not be affected. However, this generality does not hold for all areas and ecosystems. For example, in attempts to predict the success of invading alien species, Moyle and Light (1996) referred to a generalization that invasion success decreases with species richness of the receiving ecosystem. However, their experience with Californian stream and estuarine communities indicated that if an invading species can tolerate the abiotic elements of these ecosystems then it will become established regardless of the resident biological diversity (Baltz and Moyle 1993). The review of Moyle and Light (1996) challenged a well established belief in the discussions on aquatic invasions, namely that communities with low diversity and complexity are the most susceptible to invasion.

Determining the role that diversity plays in the functioning and persistence of the hierarchies of biological diversity is currently an important area of study that will help resolve such conflicting viewpoints. For example, it is known that eliminating the antifreeze protein gene from a winter flounder would have a major (single gene) effect on an individual's ability to tolerate cold water. But how much other variability could the whole population lose before it would cease to be healthy? Kincaid (1983) assessed effects of reduced variability due to inbreeding in rainbow trout and determined that a level of 12.5% (the level from one generation of half-sib matings) affected percent hatch and survival, whereas levels greater than 25% reduced fecundity, growth and survival. At levels of aquatic diversity higher than the gene, studies to determine how many salmon runs can be eliminated before a fishery collapses or how many species of cichlids can go extinct before the Lake Victoria ecosystem undergoes major functional changes are completely lacking.

Genetic resources are the crucial basis for the expression and maintenance of the biological diversity at the ecosystem level as well. Functionally similar species within an ecosystem will have different environmental tolerances to perturbations due to their genetic diversity, thus the stability and resiliency of the system may be increased with increased diversity (Chapin et al. 1997). Thus, as Chapin et al. (1997) stated, "no two species are ecologically redundant, even if they appear similar in their ecosystem effects..." Diverse systems may also use resources more efficiently.

The complex communities present in soils and the pests and pathogens of plants have been shown to be extremely important in sustaining productive terrestrial ecosystems (Matson et al. 1997) and can be affected by agricultural practices and reductions in diversity. However, the significance of the changes in soil biota are not well known and reductions in diversity of soil biota in agriculture are sometimes compensated for, in the short term, by the addition of fertilizers, pesticides and mechanical tillage. Despite a large literature on the management and fertilization of fishponds, their biodiversity and role in sustaining production have been little researched beyond broad categorization into phytoplankton, cyanobacteria, etc.

Recovery and restoration

Natural ecosystems have had to cope with and to recover from adverse impacts due to natural causes, such as glaciation and vulcanism, since life began and the natural diversity of life and the connectivity of many ecosystems helped in the recovery process. Ecosystems now face anthropogenic impacts, but humans can also assist in the recovery process. Because habitat conversion and degradation are the leading causes of biological diversity loss, habitat restoration should become a standard tool to help conserve aquatic biological diversity.

Innovative and cost-effective approaches to restoration biology also rely on components of biological diversity that play vital roles in natural ecosystem processes to facilitate restoration processes (Dobson et al. 1997). Wetlands were created in southern Florida to remove nutrients from the agricultural storm runoff water that was polluting the Everglades (Guardo et al. 1995). Dobson et al. (1997) listed several physiological functions in different species of plants that remove toxic metals, i.e., phytoextraction, and that immobilize or stabilize potentially toxic metals, i.e., phytostabilization, from soils. Liming of waterbodies to counteract the effects of acid rain can restore some or all of the species richness and levels of diversity of nonacidified lakes, given recolonization by opportunistic species, such as perch (*Perca fluviatilis*), and less opportunistic or competitive species, such as cyprinids and coregonids (Appelberg et al. 1995). Bioremediation has proven to be one of the most effective and least destructive means to clean up oil spills by using nutrient supplementation, primarily nitrogen, to increase the abundance and efficiency of naturally occurring bacteria to degrade organic compounds, i.e., oil (Bragg et al. 1994). A common element in most restoration projects is that recovery efforts should start as soon as possible to prevent additional loss of biological diversity.

Holling and Meffe (1996) noted that as humans put more demands on natural resources, their efforts increase to command and to control, i.e., to modify, ecosystems so as to fit their needs. This modification is usually in the form of reduced diversity (e.g., monocultures), reduced variation (e.g., flood control) and increased control over natural phenomena (e.g., wildfire suppression). Many policy and natural resource management decisions fail to appreciate the natural diversity and fluctuations necessary for proper ecosystem function. Hollig and Meffe (1996) concluded that, "Policies and management that apply fixed rules for achieving constant yields...(e.g., constant sustainable yields of fish, wood or water) lead to systems that gradually lose resilience–systems that suddenly break down in the face of disturbances that previously could be absorbed". These authors coined a golden rule that natural resource management "should strive to retain critical types and ranges of natural variation in resource systems in order to maintain their resiliency."

Uncertainty and the Policy of Precaution

To avoid or to minimize the adverse impacts resulting from utilization and development of natural resources that may arise because of lack of information or scientific uncertainty, a precautionary approach has been recommended in internationally negotiated documents such as the Convention on Biological Diversity (CBD 1994) and the FAO Code of Conduct for Responsible Fisheries (FAO 1995a). The Preamble to the Convention on Biological Diversity states that "where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimise such threat". The Rio Declaration states that, "In order to protect the environment, the precautionary principle shall be widely applied by States according to their capabilities". The term "precautionary" has become very popular but its meaning is often not well defined. Scientific rigor needs to be introduced into the precautionary approach if it is to have use for the development of policies that address both utilization and conservation.

The Government of Sweden and FAO helped to define the precautionary approach in a scientific rigorous manner for major capture fisheries and species introductions (FAO 1995b). Principles of this approach state that:

- reference points should be established to help determine desirable situations and undesirable impacts, e.g., limit reference points such as lowest allowable population size of a fishery resource, and target reference points such as optimum sustainable yield (undesirable outcomes should be preidentified, as should measures to correct them);
- pre-agreed actions or contingency plans should be implemented in a timely manner when limit reference points are approached, or when adverse impacts are apparent;
- priority should be given to maintaining the productive capacity of the resource where there is uncertainty as to the impact of development;
- adverse impacts of a development plan should be reversible within the time frame of 20-30 years, i.e., one human generation; and
- the burden of proof should be placed appropriately according to the above requirements.

The FAO/Sweden consultation noted that, "all fishing activities have environmental impacts, and it is not reasonable to assume these are negligible until proven otherwise", and this could be extended to almost all development activity in or around aquatic habitats, e.g., aquaculture development, introduction of exotic species, or water diversion projects. According to Lugten (1997), these statements are taken to mean to environmental lawyers that fishers, or others users of aquatic resources, have the responsibility to demonstrate they are not harming the environment. The Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) judged that it is nonfishing nations that must demonstrate that fishing does have an impact, but this would not be in the spirit of the precautionary approach.

Other groups are also applying the precautionary approach to specific activities and asking the question, "Does the activity or our management strategy fulfil the criteria to be called precautionary?" For example, the North Atlantic Salmon Conservation Organization (NASCO) is examining, in this light, the management strategy for Atlantic salmon populations; the CCAMLR has reviewed its procedures for conserving the Antarctic resources; and aquaculture groups are examining how the precautionary approach could be applied to the use of new species in aquaculture.

The precautionary approach includes risk assessment and evaluation of development activities. Peterman (1990) pointed out that this risk assessment often tests the null hypothesis (Ho) that an activity will have no effect, e.g., fishing will not affect the abundance of an endangered species, and then sets a significance level, alpha, of usually 0.05. Thus there is only a 5% chance of rejecting Ho when it is actually true, i.e., concluding that fishing does have an effect when actually it does not. This is a Type I statistical error. However, there is also the probability, beta, of failing to reject Ho when it is actually false, i.e., saying that fishing does not have an effect when it actually does. This is a Type II error. Obviously, in this example, the consequences of making a Type II error are much more severe with regards to conservation of fisheries. A Type I error would lead to extra management and fishing restrictions where none was needed, but Type II would lead to a collapse of the fishery because needed actions were not taken. Peterman believes that too much emphasis is placed on reducing the probability of creating a Type I error and has listed several recommendations for scientists and decisionmakers to help correct this imbalance. Where the costs of a Type II error are greater than those of making a Type I error, there is added reason to shift the burden of proof onto those claiming no effect.

Policies on Ownership of and Access to Aquatic Genetic Resources

The last few decades have seen a rapid shift from the historical perception that some of the planet's lifeforms are truly wild and are common property-a common heritage of humans-to increasing assignment and claims to ownership of genetic resources, with consequent restrictions on access and the need for contracts with respect to use and benefits. Pullin (1998) has summarized these trends with respect to genetic resources for aquaculture. With the possible exception of the biological resources of the seas and seabeds beyond territorial (EEZ) limits, every aquatic genetic resource can now be considered to be 'owned' by one or more parties: the nations that are parties to the CBD, the land and waterbody owners within their boundaries, indigenous peoples, public- and private-funded institutions, and the private sector, including farmers.

'Wild' animals and plants still exist, in the genetic sense that they are wildtypes and nondomesticated, but most are no longer common property and most, including those in gameparks and nature reserves, are managed by humans.

Property rights are also being applied to many capture fisheries where traditionally common property and open access philosophies existed and were at least partially responsible for declines in many of the world's fisheries (FAO 1995c). For example, the entry into force of the United Nations Convention on the Law of the Sea restricted foreign access to States' EEZs, individual transferable quotas (ITQs) developed for New Zealand fisheries are being used to manage fisheries in the Northern Hemisphere, and territorial user rights for fishers (TURFs) that have been a form of traditional fishery management in Pacific Island States are being considered for management elsewhere. In culture-based fisheries, the stocking and ranching of waterbodies, ownership of hatchery-produced fish and access to the enhanced fishery is crucial to ensuring that those who pay for and support the hatchery program harvest the benefits (Welcomme and Bartley in press).

The assignment of property rights to living organisms and to genetic material has been mostly highly developed for plants used by humans. There is an International Association of Plant Breeders (ASSINSEL) with over 1,000 members from the private and public sector in 26 developed and developing countries. ASSINSEL (n.d.) summarized the results of a 1996 survey among its members as follows: 88% of plant breeding companies maintain plant genetic resources at a cost of about 5% of their research budgets (total, about US$50 million/year); 80% of these companies participate in national programs and 31% in international programs on genetic resources conservation. ASSINSEL (n.d.) argued for intellectual property rights for plant breeders that produce new varieties - under the International Convention for the Protection of New Varieties of Plants (UPOV) and or 'breeders exception' that allow the use of protected varieties by other breeders for the creation of other improved varieties. Despite these mechanisms, and the recently formulated Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (FAO 1996), complexities remain, as can be seen from the following excerpts for ASSINSEL (n.d.),

"Plant breeders believed that, regarding the future use of genetic resources, it is absolutely imperative that:

- Access to genetic resources remains freely available, which does not necessarily mean without cost.
- Genetic resources *per se*, conserved in the framework of an eventual multilateral accord, should not be protected by intellectual property rights.
- Improved cultivars developed with the genetic resources can be protected by plant breeder's rights in order to offer the breeders a financial incentive, when the specific conditions of protection are fulfilled.
- Inventions (i.e., isolated genes, DNA sequences) can be protected in order to guarantee an adequate revenue to the inventor, if the requirements for patenting are fulfilled." (ASSINSEL n.d.).

There are as yet, no equivalent mechanisms for aquatic genetic resources, but these are likely to develop, albeit with modifications that reflect that most of the world's aquatic genetic resources are still nondomesticated and are located in aquatic ecosystems, not in *ex situ* genebanks. The wild relatives of most farmed aquatic species greatly exceed, in abundance and genetic diversity, the farmed populations. For livestock and plants, the reverse is the case. Therefore, Pullin et al. (1998) recommended for a broad definition of aquatic genebanks, encompassing not only (the presently limited) *ex situ* collections of breeding populations, cryopreserved gametes and tissues and microbial culture collections, but also the growing numbers of *in situ* aquatic protected areas.

In 1995, the FAO Commission on Genetic Resources for Food and Agriculture broadened its mandate from plants alone to include livestock and aquatic animals. For aquatic genetic resources, there is no clear scope yet for agreements of the size and complexity that this Commission has made with plant genebankers, principally the germplasm collections designated as held in trust by some centers of the Consultative Group on International Agricultural Research (CGIAR). However, ownership of and access to aquatic genetic resources, whether *in situ* or *ex situ* will increasingly require new policies to be made and implemented by institutions, and at local, national, regional and global levels. Aquatic genetic resources will become increasingly the subject of debates over patenting resources. Intellectual property protection is seen by some as a constraint to the fair and equitable sharing of benefits derived from the use of the components of biological diversity. It will be seen by others as necessary for the continued development of genetic resources and the continued flow of research money and information (Singh Nigar and Chee 1994; A. Gupta, this vol.; Correa, this vol.).

Status and Possible Trends: Aquatic Genetic Resources and Policies

Policies for the conservation and sustainable use of aquatic genetic resources are poorly developed in most countries. There are examples of policy formulation and action plans to deal with crisis situations–for example, closure of a vanishing fishery, e.g., the Nova Scotia cod fishery in the early 1990s (Hutchings 1996), and protection of seriously threatened species (e.g., Wager and Jackson 1993), but, until very recently, aquatic genetic resources have rarely been considered in policymaking for fisheries and aquaculture, let alone in making policies for water resources, agriculture, forestry, etc. This has meant that, despite the upsurges in public awareness of and increased mechanisms for addressing environmental issues since the Earth Summit in Rio de Janeiro in 1992, gross mismanagement of aquatic resource systems has continued.

Fisheries policies have not been generally useful. Many of the the world's major marine fisheries for which assessments have been made are overexploited (FAO 1997), the limits to their growth have been generally ignored (Pauly and Christensen 1995) and the consequences of the overharvesting of target species on the very basis of aquatic productivity, the foodwebs, are only now being widely publicized (Pauly et al. 1998). The expansion of aquaculture, expected to contribute much to world fish supply, has sometimes had adverse environmental and social impacts and brought short-lived benefits (e.g., Pullin 1993; D'Abramo and Hargreaves 1997). These problems of overexploitation, environmental degradation and loss of natural resources are particularly serious for inland aquatic resource systems and freshwater fish.

At the species level, freshwater fishes are the most threatened of all vertebrate species groups that are widely exploited by humans (Bruton 1995). The rapid growth of human populations and the consequent increased demands for freshwater and watershed lands (for agriculture, aquaculture, domestic water supply forestry, human settlements, industry, power generation, recreation, transportation, and waste treatment and disposal) have devastated freshwater biota and habitats across the world. The introduction of invasive aquatic animals has severely exacerbated these other impacts. Recent estimates of the proportion of freshwater species currently at risk of extinction (e.g., IUCN 1996) are universally considered to underrepresent the severity of the problem, as much of the world's freshwater fished are poorly known and, apart from a few notable exceptions, no comprehensive assessment has yet been undertaken.

This serious situation is likely to worsen rapidly. According to the World Bank (Interview with Vice President Ismail Serageldin, Newsweek, 14 August 1995, p. 52), 40% of the world's population already face water shortages and solutions to water supply problems will require investments of US$600 to 800 billion over the next decade. Hence, water will cost more and privatization of water supply will increase. In addition to the threats that such increased demands for water and 'waterspace' will impose on freshwater fish populations, overfishing and disturbance by the introduction of alien species are also increasing. These pressures and problems have been widely reviewed by, for example, Beverton (1992), Kaufman (1992), Bruton (1995) and Maclean and Jones (1995).

Development activities greatly affect aquatic biodiversity. There are very few environments left in the world that are not impacted by the influence of rapidly growing human populations (Vitousek et al. 1997). Twenty-six percent of the water evaporated or transpired from land and 54% of the available surface runoff is now used by humanity; per caput water consumption increased by 50% from 1950 to 1990 and use of available runoff is expected to increase to more than 70% by the year 2025 (Postel et al. 1996). The impacts of humanity are increasing the global extinction rate of species by 100 to 1000 times over the background extinction rates of prehuman times. More than 300 stocks of native Pacific salmonids are at risk of extinction in the Pacific Northwest and there are not enough resources, even in a developed country such as the USA, to conserve them all (Allendorf et al. 1997). Therefore, criteria are often needed for prioritizing what to conserve.

The rapidly increasing human population will continue to place demands on the earth's ecosystems for food security. Various projections have focused on demand for fishery products in the future and how best to meet them (New 1997). However, it is certain that increases will be needed. With capture fisheries expected to produce not much more than 60 million mt of food fish, aquaculture has been identified as a means to meet these demands. Predictions have been made that an extra 35-37 million mt of production will be needed by 2010 just to maintain the present per caput availability of food fish (13.5 kg·year^{-1}). Many nations are promoting fish products for better nutrition and food security. Given a 1% annual increase in the availability of food fish, so that by 2010 availability per caput for direct consumption by humans would be 15.9 kg·yr^{-1}, 51.8 million mt would be required (New 1997). Although doubts exist that aquaculture will be able to provide all of this increase, Gjedrem (1997) noted that increases in production from genetic improvement can be in the order of 10-23 % per generation. To meet the projection of 37 mt of increased production by 2010, aquaculture production would only need to increase at 3.36% per year; to meet the 51.8 million mt figure production needs only to increase 6.1% year. Gjedrem (1997) found that based on annual (as opposed to generational) genetic improvement of 5%, through selective breeding alone, aquaculture could meet most of the projected demands. However, not all farms will be able to take advantage of such genetic improvements. Moreover, there is a growing scarcity of fish meal and marine oils for inclusion in fish feeds. In 1995, 31 million mt of fish were reduced into fish meal and fish oil for animal feeds or industrial uses (Tacon 1997). Therefore, in order to keep the same per caput availability of these *feed* ingredients, humans will need about 10 million additional mt (for a total of 40 million mt) of fish or other sources by 2010. It is, of course possible that new areas, unsuited for other types of food producing systems, might be developed for aquaculture, with new breeds of fish. These various conflicting factors make it difficult to forecast the real scope for growth of aquaculture.

The inaccessibility of much of the aquatic realm and the difficulty of making policies for and policing what cannot be seen have contributed to a reactive rather than proactive approach to living aquatic resources management, more often in a policy vacuum. Systematic reporting systems on the status of aquatic genetic diversity, agreed limits on exploitation and development, and some changes in the basic philosophy of some policies will all be required in reformulating and developing policies. Policies may need to be adapted or even created to deal with new technologies. National policies for the environmentally sound utilization of genetically modified organisms are lacking in many parts of the developed and developing world, although many countries in principle adhere to recommendations and guidelines of international/intergovernmental bodies such as the FAO Commission on Genetic Resources for Food and Agriculture, the World Intellectual Property Organization, the Organization for Economic Co-operation and Development (OECD), the United Nations Industrial Development Organization (UNIDO), the International Convention for the Protection of New Varieties of Plants (UPOV), CBD and CCRF (Bartley and Hallerman 1995).

Communication and Diverse Perceptions: the Human Factor

Why have things been allowed to get so bad and why has policy formulation to correct this bad situation been so slow? Some of the reasons might lie in long-held perceptions of many of those who manage living aquatic resources and who harvest, farm and consume aquatic produce that aquatic production is inexhaustible, that it can always be renewed and increased, and that fish supply is primarily determined by market forces and investment, not by biological processes.

A lack of complete information on the state of many living aquatic resources may also contribute to misconceptions on management of aquatic biological diversity. FAO maintains fishery production statistics that represent one of the best time-series data sets on aquatic resources. FAO is often cited (e.g., Botsford et al. 1997) as stating that 22% of the world's fisheries are overexploited or depleted, whereas 44% are fully to heavily exploited (FAO 1995c). However, it is not so often reported that those percentages did not include over 160 stocks whose level of exploitation was not evaluated. Using the most current information that now takes about 140 unassessed stocks into consideration, 5% are underexploited, 5% are depleted, 16% are moderately exploited, 36% are fully exploited, 11% are overexploited, 1% are recovering, and 26% of the world's major stocks have not been been assessed as to their level of exploitation (FAO 1997). Thousands of smaller stocks are excluded from the statistics that Member

Governments report to FAO. For example, the Nassau grouper, *Epinephelus striatus*, is thought to be one of the few marine fish species to be at risk of extinction due to fishing (Malakoff 1997; J.L. Munro, pers. comm.), yet this species is only reported in fishery statistics by two countries, Colombia and Cuba, that report a harvest of a total of 106 mt; other countries in the region simply report "*Epinephelus* spp."

Many fishery policies reflect the perception that fish and other living aquatic resources in open waters are common property, though within a wide range of access regimes, from community-based management and customary tenure to tradeable licenses and catch quotas. The public at large, has also tended to regard fish in open waters as 'fair game' for all and, unless a fishery had failed, to permit a laissez faire approach to commercial and sport fisheries. Even farmed fish are perceived differently to livestock in many developing and developed countries. Aquaculture is, of course, a fairly new idea in most countries. If fish escape from a farm, they are often taken by the public with an impunity that would be unthinkable for farmed birds and mammals. Because of the large amount of escaped farmed salmon in the Pacific Ocean off of Chile, there are efforts there to mark genetically cultured salmonids; fishers catching these identifiable farmed fish would be required to compensate the farms that produced them (FAO, unpubl. report). However, the escaped salmonids are "captured" in public waters; who has a right to them?

Diverse definitions of aquatic genetic resources can give rise to present problems in communication and interpretation of statements. For example, at the second meeting of the Conference of the Parties to the Convention on Biological Diversity, a lobbyist for the fishing industry circulated information stating, "There has been no 'global loss' of marine and coastal biodiversity to date" (International Federation of Fishery Associations 1995, unpubl. observations). This statement was based on the conclusion that no *species* diversity had been lost due to fishing, i.e., no marine fish extinctions could be blamed solely on fishing. At a recent conference on conservation of fish genetic diversity (Harvey et al. 1998), the Honorable John Fraser, Canadian Ambassador for the Environment, compared a glowing report in a sports fishing magazine on the great abundance of salmon in the Pacific Northwest with the real situation. The alleged abundance is actually due to an extensive hatchery program, whereas marine survival of native coho salmon was below 2% in 1990 and hatchery-raised coho now comprise 65-75% of the fishery. The wild coho, and numerous other native salmonid stocks are in danger of extinction (Nehlsen et al. 1991). This same speaker stressed the need to get the *facts* about such situations and to publicize these.

Hatchery managers in many parts of the world are slow to change and to embrace new ideas, especially ideas concerning utilization of genetic resources. This is understandable, because one of the prime motivations in any farmer activity is the desire to avoid risk; any change involves a new risk scenario, compared to the present situation. For example, when the potential contribution of applying genetics in Australian aquaculture was assessed (Mosig 1997/98), many fish breeders felt that much more should be done to improve water quality and general husbandry, *before* genetic techniques are applied. Ignoring the genetic aspects of aquaculture can, however, result in a deterioration of broodstock over time and a need to introduce wild fish into broodstocks. In the Islamic Republic of Iran, trout eggs from genetically improved Norwegian and Scottish stocks are introduced into the country's farms to revitalize broodstock after approximately every three years (Bartley and Rana 1998). However, because some farmers in Australia have shown that genetic resource management and improvement in their broodstock give much better results than relying on periodic infusion of wild (and therefore unimproved) stock and because there is a trend in countries, such as Iran and Chile, to limit the routine importation of germplasm (i.e., eyed eggs) from abroad, support for genetic management programs is expected to grow.

A further complication for policymakers is that perceptions and valuations of the earth's biological diversity vary greatly among users. For example, is an old growth forest in the Pacific Northwest (USA) more important as a home for spotted owls or as a source of income for those people working in the timber industry? During a United Nations/Norway Conference on alien species, in July 1996, Australia's description of the economic and ecological devastation from introduced rabbits promoted interest from Ghana in utilizing rabbits to supply badly needed protein from impoverished and over exploited areas. Similarly, the Nile perch experience in Lake Victoria, where a multimillion dollar fishery was created at the expense of perhaps hundreds of endemic species, sparked interest from economists from Honduras (Baskin 1996). Even within the fisheries conservation sector there are differences in attitudes that make formulation of harmonious policy difficult. For example, in Venezuela, some fishery managers are opposed to the continued introduction of red tilapia (*Oreochromis* spp.) for aquaculture because of the potential for escapes and the adverse impact to the freshwater biota. However, these same scientists are hybridizing numerous species of native catfish and characins in facilities adjacent to natural waterbodies (Bartley et al. 1997). The hybrids of native species might pose a very significant risk to the integrity of the native gene pools.

Another major constraint to the establishment of policy is the vast level of uncertainty concerning the functioning of genes and genotypes in aquatic systems, both in nature and on farms. Policy needs to be underpinned by the best scientific information available. This is now internationally agreed in binding conventions such as the CBD. In an editorial in the journal *Science*, Gro Brundtland, former Prime Minister of Norway, stated that, "Politics that disregard science and knowledge will not stand the test of time" (Brundtland 1997). She further stated, "Never before have we had so much knowledge on which to base vital policy decisions. Never before have we had a greater capacity to act."

As true as these statements are, they tell only half the story - never before have humans had a greater capacity to impact adversely the environment and never before have they realized how complex their environment really is. The Nova Scotia cod fishery, one of the world's most productive fisheries and managed with the benefit of advice from some of the world's leading fisheries scientists, has collapsed (Hutchings 1996). Genes have been moved from fish to plants (Snow and Morán Palma 1997), i.e., between biological kingdoms, yet the risks or benefits of such novel and unnatural combinations of animal and plant genes are unknown (Kapuscinski et al., this vol.). Tremendous amounts of genetic variation have been found in nature-in the form of allozymes, restriction fragment length polymorphisms, mitochondrial DNA, and micro- and mini-satellite DNA. The significance of this variation, whether it is neutral or has some selective (fitness) advantage, and whether it is being used correctly in population/conservation analyses are all matters of ongoing debate (Campton 1995; Rand 1996; Reisenbichler 1997). Therefore, the precautionary approach has been put forward: to acknowledge uncertainty, to take steps to protect biodiversity, and to minimize the risks from human actions (see above).

The Future: Strategies for Success and Hopeful Signs

A variety of strategies exist or are being developed to assist in the implementation of policy for the conservation and sustainable use of aquatic genetic resources. There are broad conceptual strategies such as the adoption of the precautionary principle and ecosystem-based approaches, both of which are recommended for the implementation of the articles of the CBD. The Governments of the Netherlands and Malaŵi recently convened a workshop that developed the following 12 principles of an ecosystem approach to conservation and sustainable use of biological diversity (UNEP 1998):

- Management objectives are a matter of societal choice.
- Management should be decentralized to the lowest appropriate level.
- Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems.
- There is a need to understand the ecosystem in an economic context.
- A key feature of the approach includes conservation of ecosystem structure and functioning.
- Ecosystems must be managed within the limits of their functioning.
- The ecosystem approach should be undertaken at the appropriate scale.
- Objectives for ecosystem management should be set for the long term.
- Management must realize that change is inevitable.
- There must be a balance between conservation and use.
- All forms of relevant information should be considered, including scientific and indigenous and local knowledge, innovations and practices.
- All relevant sectors of society and scientific disciplines should be involved.

There are more specific strategies, such as, *inter alia*, promoting *in situ* conservation, supported where appropriate by *ex situ* conservation; the use of aquatic protected areas; cross-sectoral and multidisciplinary planning and management; and the certification of environmentally friendly products (ecolabelling), by such as the International Federation of Organic Agriculture Movement (IFOAM), WWF and Unilever's Marine Stewardship Programme. Fisheries management is an obvious strategy that could help implement policy, however, the real goals of fishery management are often simply to maximize production or to perpetuate existing activities, despite their nonsustainability and needs for subsidies. Fishery management should be seen as *in situ* conservation. International treaties such as the FAO Code of Conduct for Responsible Fisheries are making strides in this direction by advocating the elimination of perverse subsidies, the reduction in the overcapacity of the world's fishing fleets, and the conservation of native aquatic genetic resources.

Trends are emerging around the world that give course for hope that policies for effective conservation and sustainable use of aquatic diversity will be devised and implemented. Some of these trends can be summarized thus:

- A global and intersectoral effort to understand sustainability and to embrace this as a development goal (e.g., Becker 1997; UNEP 1998)
- Wider realization of the seriousness of the world situation with respect to food, water, development needs and genetic resources (e.g., IFPRI 1997)
- Wider recognition of the interdependence of conservation and use of water with conservation and use of living aquatic resources, for example, the newly established IUCN-World Bank Commission on Large Dams and recent policy statement from development banks; e.g., "The management and conservation of freshwater biodiversity should be wholly adopted as part of water resources policy" (Kottelat and Whitten 1996).
- Wider availability of the information necessary for better policies and better governance of natural resources, because of the information technology resolution, databases, and the internet and because of the media's willingness to inform the public about the problems of nonsustainable policies (e.g., the extensive media coverage of the issues raised by Pauly and Christensen (1995) and by Pauly et al. (1998).
- The beginnings of the use of genetic indicators for environmental reporting (e.g., Brown et al. 1997).

Overall Conclusion: Policies Depend Upon People

Policy must have the support of those that must follow it. This support will only come from understanding the issues, understanding the underlying scientific basis for policy decision, and having confidence in decisionmakers. This is no small task for policy on aquatic genetic resources. A recent survey on attitudes on coho salmon restoration policy in Oregon (USA) found that coastal residents mistrusted federal government policymakers. They found the state government to be only the lesser of several evils, and they mistrusted scientists who provided information that was contrary to "popular" beliefs (Smith et al. 1997). This survey further revealed that when coho salmon management "became more concerned about genetic diversity, wild fish, and ecosystem management, volunteers (lay people working on the restoration project) became frustrated...(and this lead to) opposition to the ODFW (Oregon Department of Fish and Wildlife)". The reasons for the opposition were reported to be that the rationale for stressing genetic and ecosystem management was not well explained and hence people did not listen to the explanations or did not agree with them. From this it appears that public opinion regards genetic and ecosystem concerns as being of little importance.

To remedy this perception policy must be underpinned with science (Bruntdland 1997), but with an awareness that the public expect policy to reflect the information that *they* get through television, other mass communication, word of mouth and personal experience (Smith et al. 1997). It will be important to recognize when science and public information sources are at odds, and then to reconcile the matter through better communication (Raymond, this vol.) and through publicizing the demonstrable improvements that occur when science-based policies are used.

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Discussion

Kapuscinski: For Devin Bartley, in your bullet points about the Precautionary Approach, there is one that refers to being 'able to reverse the effects', and I assume that you mean adverse effects 'within 20-30 years'. I was considering this in relation to the fisheries that I am familiar with, such as the salmon runs in North America. Do we have a concrete case of an overexploited fishery in which there was a backoff and then we were able to see recovery in 20-30 years? In most of the fisheries that I know, even when there has been a major intervention like closing the fishery, either populations have not recovered as quickly as anticipated or, as in the example published by Ricker (1973), for Pacific salmon fisheries, there was a climbing back up the stock recruitment curve, but not quite along the same lines as before. So, the overall productivity still declined. This phenomenon is called hysteresis. I'd be interested in your comments. Your point about recovery is important, but I wonder how realistic it is?

Bartley: At a meeting convened by Brian Harvey a few weeks ago (Harvey et al. 1998), this same point was brought up–that a lot of the moratoria on fishing haven't resulted in the stocks being rebuilt. It's my impression that this is because it's not only fishery that is impacting the resource. So, this is really based on theory–if fishing was the only effect, and if we stopped fishing, what would happen? Some of the information presented at the FAO meeting on fish genetics at Grottaferrata (FAO 1993) showed that when some fisheries were interrupted by World War II, some of the fish stocks went back to their pre-fishery life history forms. For example, the fisheries had led to earlier fish maturation at smaller sizes. When fishing stopped, maturation became later and growth slower.

The other aspect of the precautionary approach is that some interventions are, by definition, not precautionary, for example, introductions of reproductively viable alien species in the marine environment. But, there are still elements of the precautionary approach that could be explained to such interventions, to minimize the risk of adverse effects.

Smith: Beverton (1992) looked at the collapsed stocks of pelagic fishes and showed that only about 1 in 10 stocks that had collapsed actually recovered over the last 20 years. So, recovery might take a long time.

Schei: As far as I can remember, FAO has said that only 3% of world fish stocks are recovering.

A.Gupta: I refer to Dr. Pullin's slide, which asked the question, "are there any more common properties?" Common property has become, if anything more important, both at the subnational and international levels. Within some countries, like Bangladesh and NE India, large areas become inundated and, in effect, then common properties. It is true that the various stakeholders are becoming more aggressive and possessive of their rights in such areas and that the institutions concerned are coming under stress. Similarly, beyond 200-mile EEZs there is common property. Why do you ask the question whether common properties still exist?

Pullin: I guess I did it to spark comments like yours. Indeed, as you correctly point out, the seas beyond

EEZs are common property. However, the living aquatic resources that are within EEZs and those in inland waters are less 'up for grabs' than those in international waters. There are bound to be claims for ownership of or access to these, based on traditional rights; historical use, place of birth, etc. I guess we need to define here the meaning of 'common': does it mean open to all? or just to special interest or stakeholder groups?

Fowler: I guess that we will be comparing, over the next few days, the situation of aquatic biodiversity with that of plant biodiversity, particularly the domesticated plants, and to see how the policies that are evolving for plants might fit the aquatic situation. This paper, like some others to be presented here, discusses aquatic biodiversity as if that biodiversity is fish, without much mention of aquatic plant biodiversity–whether for use by fish or by humans. Could you give us a quick snapshot of aquatic plant biodiversity and genetic resources? Also, to what extent is it necessary to make distinctions between aquatic animals and plants in our deliberations?

Schei: I'm afraid that we don't have the time now to review this–but let's bear it in mind in our future discussions.

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Fish Genetic Conservation in Canada and Brazil: Field Programs and Policy Development

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ABSTRACT

The paper relates the policy response of several levels of government in Canada and Brazil following field genebanking activities. Reasons for fish genebanking are first presented, including broodstock programs for enhancement and aquaculture, and insurance against extinction. The governmental response to field actions is described and analyzed in relation to concerns about spread of disease, choice of stocks for conservation, introductions and transfers, and ownership and control of genetic resources.

Introduction

Canada and Brazil are big countries. Both have big rivers with big, valuable and highly migratory fish. Canada has seven species of salmon on its coasts, and the six major river basins of Brazil are home to roughly a dozen species of large migratory fish which, while less renowned internationally than salmon, are of inestimable importance to local economies and a rich repository of biodiversity. All of these migratory fish are what some conservationists call charismatic species, and they are presently living under threats that range from slow but steady declines in numbers to imminent extinction. Their life histories and stock structures are very different, but many of the root causes of their declines are shared: overfishing, dams, habitat destruction, industrial and agricultural pollution, perhaps even the great 'X Factor' of climate change.

When evidence of decline in fish numbers becomes commonplace and inescapable, people and their governments act in predictable ways. Denial, the strategy often favored by government, can be relied on for quite remarkable periods but, when conservation actions finally follow, they usually come not only from government but also, these days, from a diverse collection of community groups, NGOs and indigenous peoples' organizations. In Canada, some aspects of fish conservation, especially habitat restoration, seem almost to have been handed over completely to community groups and NGOs and, over the past six years or so, there has emerged an appetite for stewardship that sees NGOs sallying boldly into technical fisheries territory where, a decade ago, only the official agencies operated.

One such area is genetic conservation. World Fisheries Trust (WFT) has played a leading role in Canada and Brazil, increasing awareness and facilitating the collection of fish genetic resources. The fieldwork part of the experience has been the most enjoyable but, in terms of time spent, the long, drawn-out process of dealing with the policy fallout has taken priority. The issue of genetic resources is sensitive, and has been so since long before the Convention on Biological Diversity (CBD) provided nations with a framework for protecting, using and sharing their own resources. Issues like access, equitable sharing of benefits, and local and indigenous peoples' rights were big ones in the world of plant genetic conservation long before the Earth Summit in 1992. In reality, the increasing worldwide preoccupation with fisheries declines in the early 1990s and the signing of the CBD are merely a fortunate coincidence because policymakers now have a document to which they can turn when they grapple with fish genetic resources conservation.

The purpose of this paper is to summarize how Canada and Brazil have reacted to fish genetic conservation issues and have begun to develop policy. It focuses mostly on the experiences of WFT and most of it is set in Canada. It needs to be considered along with the experiences of other countries, like Norway and India, where fish genetic resource conservation is also well established, and against needs and opportunities worldwide.

Reasons for Conserving Fish Genetic Diversity

Broodstock programs for enhancement

Canada has a long history of operating salmon hatcheries to enhance the production of certain stocks for commercial harvest (Glavin 1996). Hatcheries have also been used extensively to enhance fish migrations that were affected by human activities like logging and construction of dams. The emerging North American perspective on hatcheries as the cause of decline in wild genetic variability has meant much more emphasis on small supplementation hatcheries for local stocks (Williams and Williams 1995). This means that the associated programs must know and manage the genetics of their broodstocks. In some cases, genebanking is an obvious tool for maintaining genetic variability.

Brazilian law gives hydroelectric corporations two options for maintaining healthy migratory fish populations upstream of their dams: build a fish passage structure or build a hatchery (Quiros 1989). Most have chosen hatcheries, which after a decade of operation, now face the same problem of small supplementation hatcheries in Canada–where to get the broodstock? In some parts of the Sao Francisco River, for example, it is nearly impossible to find broodstock of matrincha *Brycon lundi* (E. Zaniboni, pers. comm.). Genebanking of the few specimens that are caught is an obvious way to maximize what has become very precious genetic variability.

Collection of fish genetic resources for hatchery broodstock programs is usually of interest to government agencies, resource corporations working with government, and indigenous peoples' agencies.

Broodstock programs for aquaculture

Although most of the salmon farmed in Canada is Atlantic salmon (*Salmo salar*) bred from Norwegian founder stocks, about 10% of the farms also produce at least two species of Pacific salmon, coho (*Oncorhynchus kisutch*) and chinook (*O. tschawytscha*). For a few large operations, Pacific salmon is the only product (Keller and Leslie 1996). In Brazil, fish farmers are slowly converting from culture of alien species (like Chinese carps and tilapias) to local migratory species that command a much higher price (Lovshin and Cyrino 1998). In both countries, wild genetic material is needed for breeding programs. Genebanking is a tool for collecting and managing such genetic material, not only for convenience but also because, in many cases, wild broodstock, like the matrincha, are becoming harder and harder to find. Collection of fish genetic resources for breeding programs is increasingly of interest to private corporations.

Insurance against extinction

Extinction of many genetically distinct stocks of Pacific and Atlantic salmon in Canada is a fact. The best available estimates, conservative and compromised by patchy and unreliable official data, rank about one quarter of all Pacific salmon stocks considered as extinct, at risk of extinction or of special concern (Slaney et al. 1996). Fisheries closures have failed to bring back many declining Pacific and Atlantic salmon stocks, and the effect of climate change on ocean survival is an alarming complication.

Impending loss does not, however, always provoke effective action. Collecting genetic resources as insurance against further declines in specific stocks is especially unpalatable to some national agencies, not only because it involves making choices about which stocks to preserve, but also because the idea of banking a stocks to preserve, but also because the idea of banking a stock has emotional and professional connotations for managers: How late is too late? Does genebanking mean that I have failed to do my job?

What will the public think? Where will this end? Collection of fish genetic resources for insurance against extinction is usually of interest to local and indigenous peoples' organizations, NGOs and government agencies.

Action: Field Genebanking

The genetic conservation activities in Canada of World Fisheries Trust started in 1992 in response to a request from the Shuswap First Nation for technical assistance in preserving the dwindling genetic variability in several species and stocks in their territory in southwestern British Columbia (B.C.). Three years of collection and training of aboriginal workers followed; the Shuswap have so far collected and cryopreserved genetic material from six stocks of *O. kisutch*, *O. tschawytscha*, and *O. mykiss*, although none of the collected material has yet been used. WFT has also trained workers from several other First Nations groups; one of these, the Carrier-Sekani First Nation has pursued its own small genebanking program for the past three years.

The Canadian Department of Fisheries and Oceans (DFO), the agency responsible for management of most of Canada's anadromous fish species, enlisted WFT's technical assistance in a two-year pilot genebanking program. This was prompted by concerns for certain Fraser River sockeye (*O. nerka*) stocks. WFT collected and cryopreserved sperm samples from 750 fish, representing 15 stocks, in 1995 and 1996. All of this genetic material is currently held in storage. In 1998, in response to serious conservation concerns for coho salmon, DFO entered into a partnership with WFT that will provide training to DFO biologists on field genetic conservation techniques.

Since 1993 WFT has provided technical assistance to 11 B.C. salmon farms interested in preserving broodstock lines.

In Brazil, WFT began a formal genetic conservation training program in 1997, following up on several years' field trials with a variety of migratory species in Venezuela, Colombia and Brazil. The Brazilian project is a partnership with Brazilian universities, hydroelectric companies, government and NGOs, and will equip biologists from these institutions with the tools for collecting and using genetic material from migratory species. Unlike the situation in Canada, WFT's activities in Brazil are aimed at three uses for genetic resources conservation: broodstock programs for restocking, broodstock programs for culture of indigenous species, ance genebanking.

Reaction: Policy Development

Before considering the attempts at policy creation that followed WFT's field activities, it is useful to review briefly the *ad hoc* mechanisms by which fish genetic resources have actually been collected and stored over the past five years in Canada. Both the Canadian federal and provincial governments did, after all, sponsor collection of salmon genetic resources between 1992 and 1997. How was this accomplished in the absence of policy?

The answer is straightforward: for a government agency mandated to manage salmonid species, collection of germplasm is regulated simply by issuing to itself a Scientific Collection Permit that allows the fish to be caught and milt samples obtained. The procedure was the same when a First Nations group wanted permission to bank fish sperm: they wrote up an application for a Scientific Collection Permit and received permission to collect. In the rare cases where a private aquaculture company has collected wild genetic resources, permission has been granted by the DFO, although with the stipulation that disease screening be carried out on the broodstock.

In Brazil, small pilot projects on the cryopreservation of sperm from migratory species have concentrated mainly on sampling broodstock on farms, apart from a few collecting trips to natural waters. The latter were covered by permits analogous to the Canadian Scientific Collection Permit.

If, then, it was possible to collect genetic resources from salmon in Canada and from migratory fish in Brazil without explicitly stated policies in the past, why is there now a move, at several different levels in their governments, to develop policy? Why not apply the folk wisdom of 'If it ain't broke, don't fix it?' The answer, at least in these two countries, seems to lie in four areas of concern to agencies:

- spread of disease among watersheds
- choice of stocks
- introductions and transfers
- ownership and control of use of genetic resources.

The following sections consider each of these, using the DFO *Draft Policy on Gene Banking* and the B.C. Ministry of Environment, Lands and Parks (BCMELP) *Draft Policy on Gene Banking* as examples. It must be emphasized that each of the policies considered is a working draft, and being revised before official adoption.

Concerns about the spread of disease among watersheds

The DFO's draft policy requires that all broodstock, wild or cultured, from which germplasm is obtained, be tested for infectious viral diseases. If diseases are detected, the germplasm cannot be used in fish to be reared or released in facilities or river basins in which the detected virus(es) is (are) not known to occur. While the intention of this requirement–to prevent the spread of disease–is clear, there is some question as to whether the expense is justified. Because none of the known salmonid viral diseases has been shown to be transmitted by semen, the risk, according to the DFO's own scientists, is negligible (T.P.T. Evelyn, pers. comm.). A screening protocol closer to that in use in Norway, in which tissue samples are collected along with milt for later analysis if needed, would seem less costly and less restrictive (Gausen 1993).

The BCMELP policy makes no mention of disease screening.

Concerns about choice of stocks

The DFO draft policy suggests general criteria for selecting biological units for preservation of the genetic diversity of wild stocks. These include: immediate and anticipated danger of extinction, and high probability of recovery upon reintroduction. Criteria are not provided by BCMELP.

Concerns about introductions and transfers

Judging by agency responses to genebanking efforts in Canada and the United States, there is considerable concern on the part of fisheries managers that collections of cryopreserved semen will make it easy for a variety of groups to transplant stocks and species into watersheds beyond their natural ranges. Such movements of genetic material were once popular for enhancing salmon stocks in B.C. Historically, government biologists were engaged in the wholesale movement of stocks and strains around the province in an effort to boost production. Now such activities are frowned upon, and agencies are anxious to avoid abetting any further transplants through the use of frozen sperm, which could, for example, be used to fertilize ova from a different stock in a different watershed.

Both the State of Washington (Department of Fish and Game) in the U.S.A. and the BCMELP have expressed concern about 'Johnny Appleseeding' for fish stocks - a term taken from North American folklore that describes the broadcasting of fruit varieties as a way of boosting production for settlers in the New World. BCMELP policy regulates fish transfers by stating that collection, transportation, possession and use of viable gametes from fish populations must be approved by the Director of the Fisheries Program - the person ultimately responsible for all operational decisions related to fisheries research and management in the province.

The DFO suggests that the "collection, storage or use of germplasm will be subject to at least the same level of review as for other introduced or transferred aquatic organisms." Proposals for using germplasm for fish to be released to the wild in watersheds other than the one from which the germplasm was collected must be reviewed by the DFO's Introductions and Transfers Committee and approved by the DFO.

In summary, both the Canadian federal and the B.C. provincial governments have addressed the risk of introducing foreign genetic material to watersheds by creating approval procedures.

Concerns about ownership and control

Probably the most contentious issue raised by field genebanking and the one most responsible for development of policy is that of ownership and control. This is not surprising; the Convention on Biological Diversity itself emphasizes these issues very strongly. In many developing countries, the desire to prevent unfair exploitation of the local or national genetic heritage is prompting restrictive policy and legislation that might, in many cases, severely limit exchanges. This trend is especially marked for plant genetic resources, but the situation for fish genetic resources is likely to follow suit.

The language used in policy can tell us something about the thinking behind it. In the BCMELP policy, one finds the unambiguous "...all trade of fish gametes remains in control of the Ministry", and "...the collection, transportation and use of viable gametes from fish populations for the purpose of gene banking is generally incompatible with the Ministry's primary objective." These two statements leave little doubt that this Ministry is less than sanguine about the prospects for responsible management of *ex situ* germplasm collections by non-governmental organizations in the province. As stated in the preamble to this policy, one reason for the policy is "to ensure that the natural genetic diversity of fish populations is maintained primarily *in situ*" - a strategy that, by definition, virtually ignores *ex situ* conservation. The DFO's draft policy requires that the disposal or sale of wild germplasm to other countries be approved by DFO, and stipulates that genebanks submit an annual report to the Department.

In Brazil, there is also evidence that policy in this area, when it is made, will address the issue of ownership and control. Such policy will be developed by the Instituto Brasiliera do Meio Ambiente e dos Recursos Naturais Renovaveis (IBAMA), and while the position taken on permits and transfers within Brazil is still anybody's guess, it is worth noting that one condition of WFT's transfer of genetic conservation technology to Brazilian public and private institutions is that germplasm from Brazilian fish will not be transferred to another country.

What are the Forces Shaping Policy?

Why are the policies summarized above so different in tone and intent? The DFO of Canada has contributed to research on genebanking technology and promoted pilot projects in germplasm conservation. Its proposed policy could fairly be said to facilitate genebanking; the emphasis on disease transmission probably reflects the birthplace of the policy, which was within the branch of DFO concerned with aquaculture. The BCMELP policy has a more restricting flavor, which might reflect the interlocking jurisdictions that make management of anadromous fisheries a challenge in the province. To complicate the picture, attitudes concerning fish genetic resource conservation vary within and among government departments: the B.C. Ministry of Agriculture, Food and Fisheries, for example, supports genebanking as a means of maintaining threatened genetic diversity that might otherwise be lost.

But after all, what is policy? Is it not simply the reflection of a collective attitude held by a government at a point in time? What shapes policy on fish genetic resources is not only the philosophy of conservation biology but also the existing (and often long-standing) political relationships between the groups and agencies that are the stakeholders interested in managing or exploiting the resources. This is hardly a surprising conclusion, as any delegate to any number of international conferences on environmental policy, from Rio to the recent international meetings on global climate change in Kyoto, will attest. Perhaps, though, it is worth pointing out one more time that, as Canada's Ambassador for the Environment John Fraser has said: "when conservation policy and "official" pronouncements become disconnected from the evidence of science the result is unlikely to be solution of the problem; at best, we will only achieve a stay of execution.

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Discussion

Mires: For genebanks, we speak only about the cryopreservation of sperm. Have there been any advances towards cryopreservation of embryos or ova? What is the use of being able to cryopreserve only half of the stock?

Harvey: There are advances being made, but cryopreservation of fish embryos or ova is not yet technically feasible. I know that some Israeli groups are working on this. Given a large enough sample of males, the genetic variability of a particular stock can be well represented by cryopreserved sperm. When a stock is becoming extinct and numbers are small, any action is preferable to no action, but your point is well taken.

Schei: I was a bit surprised at your account of the reluctance of some authorities in your country to adopt genebanking. In Norway, it was actually the authorities that pushed for the development of sperm banking. This was done with salmon conservation in mind.

Kapuscinski: A general question–can this conference come up with general flexible recommendations about what the relationship should be between *in situ* and *ex situ* genebank approaches, especially for the long term, not just for crisis situations? I have not yet seen a good treatment of the relationships between *in situ* and *ex situ* approaches for different situations.

Harvey: In our recent Vancouver workshop (Harvey et al. 1998) we considered genetic conservation, not either/or *in situ/ex situ*. We found a number of practical examples where living genebanks and collections of cryopreserved sperm were kept in the same situation. I think that this is the way that things will go. The one complements the other. *In situ* conservation, as the CBD states, is the method of choice but this is not always possible.

Pullin: If we are going to discuss further this question of complementarity, we must be very clear about the definitions of *in situ* and *ex situ*. Note that for domesticated species, under the CBD's definitions and in common usage for plants by the CGIAR, *in situ* can include 'on farm'.

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Biotechnology and Aquatic Genetic Resources: Genes and Genetically Modified Organisms

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ABSTRACT

This paper focuses on the genetic changes, which may be brought about in captive populations of aquatic organisms as a consequence of the captive environment and management regimes or by intentional human actions. These changes include adaptation to captive environments (domestication); improvement of specific traits; interspecific hybridization; monosex male or female populations; triploidy or tetraploidy; gynogenetic or androgenetic lines; nucleocytoplasmic hybridization; and transgenic strains. Such changes may occur in populations maintained for aquaculture, fisheries enhancement, ornamental fish breeding or research. Genetic improvements through breeding programs have led to great improvements in productivity in other agricultural animals and are an increasing feature in aquaculture. Formulation of policies addressing biotechnology is hindered by inconsistent nomenclature, e.g., the term "genetically modified organism" (GMO) is currently used with varying definitions by different organizations, which is likely to be confusing. While organisms that would be included within the narrowest definition of GMO (principally transgenic organisms) are likely to cause the broadest level of concerns, some other types of captively produced organisms could also have negative environmental impacts and may need to be included in policy considerations.

Introduction: Human Interventions and Genetic Change in Aquatic Organisms

Human intervention in the reproductive cycle of aquatic organisms can bring about a variety of genetic changes, both intentional and unintentional. These vary from minor alterations in the level of genetic variation or traits affected by the captive environment, to major changes which may be brought about by many generations of selective breeding or gene transfer.

The more traditional genetic techniques, such as selective breeding, have been the basis of much of the development of domesticated strains of terrestrial agricultural animals. Although most terrestrial agricultural animals were domesticated long ago, significant increases in productivity are still taking place through breeding programs (Gjedrem 1997).

Table 1 lists the major techniques and practices that are likely to result in genetic changes to captive populations of aquatic organisms. Aquaculture, the ornamental fish industry, and basic research are the main reasons for captive breeding and the intentional genetic changes listed in Table 1. In some cases, the techniques described are used in combination.

Closing the life cycle in captivity

This is likely to have some genetic effects within very few generations. There may be initial founder effects, genetic adaptation to conditions in the hatchery, inbreeding or negative selection due to hatchery management practices. The degree of change from the wild founder population is likely to vary greatly from case to case even within a species, and may be difficult to

Table 1. Genetic changes that can be induced in captive populations of aquatic organisms. For further details and referenced examples, see text.

Culture practice or genetic technique	Effects or outcomes	Current usage
Captive breeding	Adaptation to captive environment (domestication), possibility of inbreeding	Widespread, common. Aquaculture, ornamentals, restocking, research
Selective breeding	Improvement of specific traits, correlated response, with non-selected traits, possibility of reduced variation, production of synthetic strains in some cases.	Several species but small overall impact. Aquaculture, ornamentals.
Interspecific hybridization	Hybrids may combine desirable traits from different groups; possibility of sterility but nonsterile hybrids may lead to introgression and breakdown of genetic distinctiveness.	Widespread in research, limited in aquaculture.
Genetic monosex production	Monosex female or male populations, allowing culture of only the sex with more desirable traits, reduced reproduction, etc.	Moderately common in aquaculture.
Induced polyploidy	Triploids or tetraploids. Triploids show sterility (especially females), may also see increased survival of interspecies hybrids.	Widespread in research, limited in aquaculture except for oysters and salmonids.
Chromosome set manipulations	Gynogenetics or androgenetics: can be used to produce partially or completely inbred lines.	Widespread in research, little direct application in aquaculture.
Nucleus transfer	Nucleocytoplasmic hybrids clonal lines?	Research only.
Gene transfer	Transgenics, modification of traits controlled or strongly influenced by single genes.	Widespread in research, not yet used in commercial aquaculture?

quantify. It may be necessary to use a combination of molecular markers (e.g., allozymes, mtDNA, microsatellite loci), measurement of various traits (e.g., growth rate, behavior) and hatchery records (if appropriate records have been kept) to assess any such differences. Kincaid (1983) described the effects of different levels of inbreeding, achieved by planned crosses, on several traits in the rainbow trout (*Oncorhynchus mykiss*). Many of the traits studied showed significant levels of depression after only one generation of sib mating ($F = 0.25$).

Intentional selective breeding

This should result in significant changes in the selected traits but will probably also result in changes in other traits that are genetically correlated to those being selected. Selection can be enacted upon a captive population established from a locally obtained population, but many larger breeding programs use populations collected from multiple locations and may develop breeding programs from these. Such breeding programs may involve crossbreeding between different stocks if there is evidence of heterosis, or more commonly the development of synthetic strains based on the best performing founder populations. Mixing different wild populations may lead to outbreeding depression in some instances, as described for pink salmon (*Oncorhynchus gorbuscha*) by Gharrett and Smoker (1991).

Although selective breeding has been undertaken to some extent in several species of interest to aquaculture, the overall contribution of selectively bred aquaculture stocks to world aquaculture production is still very low (Gjedrem 1997). It should be possible to increase greatly the productivity of aquaculture stocks through selective breeding.

Interspecific hybridization

This has been carried out experimentally in a wide variety of taxa, most commonly between fairly closely related species. Relatively few interspecific hybrids are used on a large scale in aquaculture today (Bartley et al. 1997). Examples of F_1 hybrids are male *Clarias gariepinus* x female *C. macrocephalus*, which is a major product in freshwater aquaculture in Thailand (Little et al. 1994), hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) in Israel and bass (*Morone saxatilis* x *M. chrysops*) in the USA (Hallerman 1997). In some cases, unintentional hybridization may lead to introgression and the loss of pure species, e.g., in aquaculture stocks of *O. niloticus* in Asia where *O. mossambicus* is present as a feral species (Macaranas et al. 1986). A variety of hybrid red tilapia strains have been developed and are widely used in aquaculture (McAndrew and Wohlfarth, in press). These hybrids generally originate from *O. mossambicus* and one or more other tilapia species (*O. niloticus*, *O. aureus*, *O. urolepis hornorum*).

In macroalgae, interspecific protoplast fusions have been carried out (Notoya 1995). In some of these, the fusion products regenerated and produced plants.

Genetically monosex populations

These are commonly used in aquaculture for species where one sex is of significantly higher value for culture than the other one. Knowledge of the sex determination mechanism of the species concerned is required to develop techniques for producing fish which are genetically monosex. For example, nearly all of the rainbow trout produced in Scotland are genetically female (SOAEFD 1997). The technique involves masculinizing genetically female (XX) fry to produce functional males (sometimes referred to as neomales) which will produce only female offspring when crossed to ordinary XX females (Bye and Lincoln 1986). This system is also fairly widely used for rainbow trout in other countries and in some other salmonids (e.g., chinook salmon *Oncorhynchus tsawytscha*: Hunter et al. 1983; Solar and Donaldson 1991). Genetically male Nile tilapia (*O. niloticus*) have been developed as an alternative to hormonally masculinizing mixed-sex fry of this species (Mair et al. 1997). Here YY males are produced and crossed to XX females to give XY (male) offspring. While the species given above as examples have XX/XY sex determination systems, other species commonly used in aquaculture have different sex determination systems, which would require different approaches to manipulating sex ratios (e.g., the blue tilapia (*O. aureus*) is WZ/ZZ, Mair et al. 1991b; the gilthead seabream (*Sparus aurata*) is a protandrous hermaphrodite, Zohar et al. 1995).

Induced polyploidy

Triploidy is used to suppress reproduction in some species (reviewed by Benfey 1989). In fish, triploidy is effective in suppressing gonad development only in females, so it is often used in combination with genetic techniques for all-female production e.g., in the rainbow trout (Bye and Lincoln 1986). Triploid males of many species show gonad development and develop secondary sexual characteristics, and may even produce gametes, but production of surviving offspring is very rare as the overwhelming majority of the gametes are aneuploid. Triploidy is generally induced by temperature or pressure shocks to fertilized eggs. Triploidy is also used in the culture of oysters, particularly the Pacific oyster, *Crassostrea gigas* (Allen 1987; Allen and Downing 1991).

An alternative method of producing triploids, by crossing diploids with tetraploids, has proved to be feasible in rainbow trout (Thorgaard 1992) and the Pacific oyster (Guo et al. 1996) but may not be feasible in several species of fish due to low viability of induced tetraploids (e.g., Cassani et al. 1990; Cherfas et al. 1993).

Gynogenesis and androgenesis

Gynogenesis and androgenesis have been induced in a wide variety of species of fish and have applications in several areas of research, including the analysis of sex determination, gene mapping (e.g., Lie et al. 1994; Kocher et al. 1998; Young et al. 1998) and the production of inbred lines. Gynogenesis and androgenesis have been used to provide information about sex determination systems in salmonids (e.g., Chourrout and Quillet 1982; Quillet and Gaignon 1990; Quillet et al. 1991), cyprinids (e.g., Stanley 1976; Wu et al. 1990;

Komen et al. 1992; Bongers et al. 1994; Castelli 1994; Pongthana et al. 1995), cichlids (Penman et al. 1987; Avtalion and Don 1990; Mair et al. 1991a, b) and a variety of other species (e.g., *Ictalurus punctatus*, Liu et al. 1996; *Solea solea*, Howell et al. 1995). Fully inbred lines have been produced by gynogenesis or androgenesis, for example in the zebra danio, *Danio rerio* (Streisinger et al. 1981), common carp, *Cyprinus carpio* (Komen et al. 1991; Bongers et al. 1995) and Nile tilapia *O. niloticus* (Hussain et al. 1998; Sarder et al., in press) and have applications in areas such as disease and immunology research, toxicology and estimation of quantitative genetics parameters. As yet, such techniques have found little direct application in aquaculture, although gynogenesis may be a convenient way to produce genetically female progeny at the start of a program to produce monosex female fish in certain species, e.g., silver carp, *Hypophthalmichthys molitrix* (Mirza and Shelton 1988) and silver barb, *Puntius gonionotus* (Pongthana et al., in press).

Nucleus transplantation

This is a technique which has been used mostly to study the interaction between nucleus and cytoplasm in different species during embryo development (e.g., cyprinids, Tung et al. 1973; amphibians, Liepins and Hennen 1977). The technique has the potential to produce clonal replicates of normal outbred individuals (as opposed to the fully inbred lines produced by gynogenesis or androgenesis, or "outbred clones" from F_1 crosses between such lines), although this appears to have been carried out only in laboratory research on amphibians (McKinnel 1978).

Gene transfer

Gene transfer research in fish has a history of about 15 years, reviewed recently by Gong and Hew (1995) and Sin (1997). The original technique used for introducing copies of cloned genes into random chromosomal locations was microinjection of DNA into eggs. This is probably still the most commonly used method, although the process is not very efficient. More controlled introduction of genes has proved to be much more difficult. Some spectacular results have been obtained, such as the significantly enhanced growth rates in salmonids. Devlin et al. (1994) produced coho salmon (*Oncorhynchus kisutch*) transgenic for an "all-salmon" metallothionein promoter–growth hormone gene construct. On average, the transgenic coho salmon were more than 11 times the size of nontransgenic controls. Other potential areas for the application of gene transfer in fish include cold tolerance (Wang et al. 1995), maturation control (Alestrøm et al. 1992) and disease resistance (Sin 1997). Research has also been conducted on gene transfer in other groups of aquatic organisms, e.g., crustaceans (Bachère et al. 1997), microalgae (Matsunaga 1995) and seaweeds (Qin et al. 1994).

Chromosome-mediated gene transfer (CMGT) (Disney et al. 1987, 1988) involves the transfer of chromosome fragments from irradiated sperm of a donor species. The maternal chromosome complement is doubled by inducing gynogenesis and the resultant embryo carries a diploid maternal genome plus some of the fragments from the paternal genome.

One of the major current constraints to what can be achieved through gene transfer is the level of knowledge of the molecular biology, biochemistry and physiology of the traits which it might be possible to modify. Initially, very few cloned fish genes were available and many of the first laboratory experiments used other vertebrate or prokaryotic genes. Recent developments in molecular biology, e.g., Polymerase Chain Reaction, automatic sequencing, genome mapping projects, and the use of *Fugu rubripes* as a model species (Brenner et al. 1993; Elgar et al. 1996) are likely to facilitate further developments in gene transfer in aquatic organisms, although it could be argued that the early interest in gene transfer in the 1980s itself stimulated research into basic molecular genetics of aquatic organisms.

Aquatic "bioprospecting" is likely to lead to the identification of products that could be produced by cloning relevant genes and inserting them into bacteria, etc. Marine bioprospecting is currently lagging behind its terrestrial equivalent (Tangley 1996).

Terminology

Classification of the abovementioned techniques and the resultant organisms has been attempted for a variety of reasons. Concerns about the potential impact of some genetic changes in cultured organisms on humans (e.g., as consumers) and on the environment have been major forces behind the recent intensive consideration of the implications of some of these techniques, particularly gene transfer. Terms that have been used include "genetic manipulation", "genetic management", "products of modern aquatic biotechnology" and "genetic modification". "Genetically modified organism" (GMO) is a term that is currently used with widely varying definitions by different bodies (see Table 2) but for essentially the same purpose, i.e., grouping together a set of techniques that may have effects which should be studied and possibly controlled by policy and regulations. As far as aquatic organisms are concerned, the definition of GMO as used in the EU would probably only include gene transfer out of the techniques commonly used in research on fish today, whereas the definition used by ICLARM and FAO would include the products of all of the practices and techniques listed in Table 1. Discussions on biosafety in relation to the Convention on Biological Diversity use the term "living modified organism" (LMO). The current draft definition of this is "any living organism containing a novel combination of genetic material obtained through the use of modern biotechnology", with modern biotechnology meaning "the application of in vitro nucleic acid techniques/ [and cell fusion techniques] that overcome natural physiological reproductive or recombination barriers, other than traditional breeding or selection" (Working Group on Biosafety 1998).

Without commonly accepted definitions, the term GMO loses value and becomes confusing to those not familiar with the specific techniques concerned. This could easily lead to misunderstandings, for example, a quote from Pullin (1994) "GMOs are also widely used in aquaculture", if taken out of context, could be understood to mean that transgenic organisms are commonly used in aquaculture, while in fact it really states that captive breeding and a few other techniques are widely used.

Implications of Genetic Change

Environmental concerns

Success in producing organisms that have enhanced value for aquaculture or ornamental purposes may also lead to a greater probability that such organisms will be transferred to other locations within and beyond the original distribution of the species concerned. It should be noted that this effect is also true of many other aspects of developing a successful culture practice, e.g., success in breeding a species may lead to interest from other people, who may have had difficulty in breeding a similar species, to introduce that species, even if it is an alien species.

From the environmental impact perspective, most of the practices and techniques listed in Table 1 could result in populations that could have significant effects on wild conspecifics, even if these were the original founder population. For example:

- The effects of transgenic fish on wild populations, through genetic or ecological effects, are largely unknown and are likely to be specific to the modification concerned. Such impacts could vary from zero (e.g., if a noncoding DNA sequence was used as a marker for the effects of restocking using fish from the same population as the wild fish, produced by a well-managed hatchery) to significant (e.g., if expression of the introduced DNA caused a major change in the ecological role of the transgenic fish through a large increase in size or the ability to utilise a new food source). Worries have also been expressed about unanticipated pleiotropic effects in transgenic fish (ABRAC 1995a).
- In the case of conventionally bred organisms, restocking waterbodies with fish from poorly managed hatcheries may be intended to augment wild populations that have been depleted through overfishing or habitat destruction. However, the effect may be to put further pressure on wild populations if the stocked fish compete with the wild fish but either fail to breed or else carry inappropriate genotypes.
- Escapes from aquaculture may impact on wild fish populations through sheer weight of numbers. Skaala (1995) stated that the number of Atlantic salmon (*Salmo salar*) escaping annually from fish farms in Norway exceeded the number of wild salmon harvested in Norway.
- Hybridization in the hatchery may lead to introgression between species in the wild through escapes or releases of hybrids.
- Escaped or released male triploid fish may attempt to breed with wild diploid fish and, if present in sufficient numbers, may disrupt overall spawning success (this can be avoided by using only female triploids, by combining triploidy and monosex female production techniques).

Table 2. Examples of the different definitions and uses of the term 'genetically modified organisms' (GMOs).

A. The European Union (Council of the European Communities 1990) stated that:

"Techniques of genetic modification ..... are inter alia:

(1) recombinant DNA techniques using vector systems as previously covered by Council Recommendation 82/472/EEC;

(2) techniques involving the direct introduction into an organism of heritable material prepared outside the organism including micro-injection, macro-injection and micro-encapsulation;

(3) cell fusion (including protoplast fusion) or hybridisation techniques where live cells with new combinations of heritable genetic material are formed through the fusion of two or more cells by means of methods that do not occur naturally."

The same document also stated that:

"Techniques .... which are not considered to result in genetic modification, on condition that they do not involve the use of recombinant DNA molecules or GMOs, are:

(1) in vitro fertilisation;

(2) conjugation, transduction, transformation or any other natural process;

(3) polyploidy induction"

B. The U.S. Department of Agriculture (ABRAC 1995a, 1995b) gives the following categories of "applicable organisms" and "non-applicable organisms" for assessment under the "Performance standards for safely conducting research with genetically modified fish and shellfish":

Applicable organisms:

(1) Deliberate Gene Changes – including changes in genes, transposable elements, non-coding DNA (including regulatory sequences), synthetic DNA sequences, and mitochondrial DNA;

(2) Deliberate Chromosomal Manipulations – including manipulations of chromosomal numbers and chromosomal fragments; and

(3) Deliberate Interspecific Hybridization (except for non-applicable cases discussed below) – referring to human-induced hybridization between taxonomically distinct species."

Nonapplicable organisms:

"(a) intraspecific selective breeding by natural reproductive processes or intraspecific captive breeding, including use of artificial insemination, embryo splitting or cloning; and

(b) interspecific hybridization provided that (i) the hybrid is known to be widespread because it occurs naturally or has been extensively introduced (e.g. through stocking) in the environments accessible to organisms escaping from the research site, and (ii) there are no indications of adverse ecological effects associated with the specific hybrid in question."

C. GMOs are defined by ICLARM (Pullin 1994) as:

"... organisms whose genetic characteristics are changed, purposefully or otherwise, by any captive breeding, selection and genetic management." "Genetic management includes hybridization, manipulation of ploidy and sex determination, and gene transfers."

Such negative impacts, while potentially significant, need to be assessed in relation to positive impacts (e.g., economic) and other factors with negative impacts on biodiversity (e.g., introductions of alien species, habitat destruction).

The effects of captive breeding and intentional genetic alterations are, in some cases, fairly routine to demonstrate or to detect (e.g., altered sex ratios or ploidy levels, major changes in quantitative traits, the presence of novel DNA). Others (e.g., minor changes in levels of genetic variation or quantitative traits) are much harder to detect. The broadest definition of GMOs (Table 2) thus includes genetic changes that may be effectively undetectable. Skaala (1995), for instance, describing studies on the effects of escaped cultured salmonids, stated that it was not possible to distinguish between cultured and wild Atlantic salmon at the individual level.

Even for those organisms with single, significant genetic changes, such as transgenics, detection (and therefore control over use and movement) may depend on being aware of what to look for. Comparison to species introductions and quarantine regulations suggests that controlling use or movements of transgenic fish is much more like quarantine control than control of species introductions. It should be possible to identify to the species level most animals being transferred (apart from difficulties of distinguishing between very similar species and early life history stages) and therefore to detect most species introductions. However, with potentially infected or carrier organisms and potential transgenic organisms, it is necessary to know for which pathogen or gene construct to test. It is hard to conceive of a screening method for organisms containing unspecified foreign DNA. Moreover, it is now possible to produce a transgenic fish using only DNA from the same species, e.g., by using a DNA construct containing a species' own metallothionein promoter with its growth hormone coding sequence. It has been suggested that such transgenics should be called "autotransgenics" to distinguish them from transgenics produced using a DNA construct that contains, at least in part, DNA from other species, which would be called "allotransgenics" (Beardmore 1997).

Since most of the genetic alterations discussed here take place in the context of aquaculture and associated research, a central consideration is whether or how aquaculture should develop domesticated stocks of organisms, which are equivalent to those already produced by animal and plant breeders and farmers in other agricultural sectors. Such increases in productivity are likely to be necessary to meet future demands for fish and shellfish products (Gjedrem 1997). It can be argued that cultured aquatic organisms often interact strongly with wild populations (via accidental and deliberate releases) and that it is desirable to minimize such effects. Using only wild seed or wild broodstock would minimize the potential genetic impact of aquaculture on wild stocks but to attempt to prevent the development of domesticated stocks for aquaculture would be a radical step and probably impractical. The initial impetus for the development of hatcheries for aquaculture has frequently been a shortage of wild seed. For many species, aquaculture is already well beyond the stage of using wild seed or wild broodstock. Most of the world's aquaculture production (and also the ornamental fish industry) rely on hatchery production and, in many cases, on alien species.

Certain applications of biotechnology may minimize genetic and/or ecological risk, for example, the use of monosex females and/or triploidy to prevent breeding. Deliberate use of such technologies to minimize environmental impact, e.g., with grass carp (*Ctenopharyngodon idella*) in the USA (Allen and Wattendorf 1987; Thomas 1994), have tended to involve alien species. However, induced sterility could be used more generally to limit the effects of cultured organisms on wild conspecifics.

Consumers' attitudes

From the consumer's point of view or to facilitate control of new and relatively poorly understood technologies, it seems likely that gene transfer, among the techniques listed in Table 1, will give rise to most concerns about alterations in the properties of the organisms produced. Currently, several transgenic plants and plant products are already being grown and sold for public consumption on a large scale (Brookes and Coghlan 1998), but this has not happened yet for transgenic animals. There is evidence of a consumer backlash in Europe against transgenic plant foods as a result of the mixing of transgenic glyphosate-resistant soya beans with nontransgenic soya in the USA before sale into European markets (Chown 1998).

Policy and Controls

The intention of most policy with regard to genetic change in cultured aquatic organisms should seldom be to prevent potentially useful developments but rather to attempt to minimize the risk of negative impacts (or to ensure that positive impacts outweigh negative ones–see Kapuscinski et al. this vol.). In order to do this, it is necessary to have appropriate policy and regulations in place to cover research and development from the laboratory phase to trials in outdoor facilities and release. At present, the situation varies between countries. In some (e.g., in the UK), all research and development in specified categories are regulated, e.g., for genetically modified fish (DOE 1997). In the USA, observance of the performance standards for safely conducting research with genetically modified fish and shellfish is voluntary (ABRAC 1995a). UNEP guidelines (UNEP 1996) exist to provide an international technical framework for safety in biotechnology.

While it may be possible to control activities tightly in certain categories (e.g., gene transfer) at least in some countries, it has to be accepted that it is not possible to control all of the activities that would come under the broadest definition of GMOs in Table 2. The role of policy in many areas must therefore be to guide appropriate development. Towards this end, the following actions are suggested:

- creating an atmosphere of awareness of potential negative implications of certain actions, such as release of the products of new techniques onto the market or into the environment without adequate testing;
- appropriate guidance to assist in decisionmaking during research and development of new technologies, e.g., performance standards (ABRAC 1995a, b);
- encouraging codes of practice, which include genetic aspects, for producer organizations; and
- fostering international acceptance of a common definition of terms such as GMO.

For the newest and least understood of the genetic technologies in aquatic organisms (gene transfer), technical difficulties and nontechnical factors (consumer attitudes and worries about environmental impact) have meant that transgenic aquatic organisms have reached the stage of outdoor testing only in highly restricted conditions and for a very limited range of species and DNA constructs, at least in countries that have developed and implemented appropriate policy and regulations. It is hard to predict how this situation will develop. It is, however, possible that in countries without appropriate policy and regulations, techniques such as gene transfer could be introduced without the knowledge of the government and public. It is to be hoped that developments in transgenic aquatic organisms will not follow the patterns observed for many introductions of alien species (a well-known threat to aquatic genetic resources), which have occurred on a fairly haphazard basis in the past, despite the existence of international codes of practice etc. (e.g., Turner 1988).

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Policy Implications for Commercialization of Transgenic Fish

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ABSTRACT

The properly regulated use of genetically modified fish in aquaculture can allow for a rapid increase in the amount of fish protein available for consumption at lower costs than presently possible, while limiting environmental dangers associated with fish farming. Regulations to guide the use of aquatic transgenics must be clear, science-based and not unduly burdensome if they are to accomplish the desired purpose of enhancing food supply and maintaining environmental quality.

Introduction

The recent development of rapidly growing transgenic salmon, trout, tilapia and other finfish has created concern among environmentalists (Kapuscinski and Hallerman 1990, 1991; NASCO 1994; CNI 1995; Zilinskas and Balint 1998; Kapuscinski et al. this vol.). It is feared that genetically modified fish might pose further dangers to the health and safety of wild fish stocks than those posed by commercial aquaculture. Potential commercialization of such fish has also raised fears that their use might result in detrimental social and economic consequences for some groups (Hite and Gutrich 1998). It has been suggested, for example, that dramatic increases in aquaculture productivity, resulting from the application of genetic engineering technologies that are controlled by large corporations, could disadvantage underdeveloped countries relative to industrialized countries and could jeopardize the livelihoods of fishers everywhere (Open-ended Ad Hoc Working Group on Biosafety, Convention on Biological Diversity, 1996). Some special interest groups and countries have suggested, therefore, that the application of genetic engineering to fish farming be highly constrained if not prohibited altogether (CNI 1995; Greenpeace 1997). This paper takes the view that such draconian policies would be a grave mistake, with negative implications for the environment, the world economy and the supply of adequate amounts of fish protein worldwide. Instead, national and international policies that foster the safe development and use of biotechnology should be strongly encouraged and supported in aquaculture to increase utility and productivity.

The foundation of this belief is that harvesting wild fish for consumption, as practiced today in many areas, is not an environmentally sustainable activity, and that expanded, low-cost, environmentally friendly aquaculture would help to feed the world. Indeed, it has been suggested that aquaculture yields will have to increase seven-fold over the coming 25 years simply to maintain current per caput fish consumption worldwide (Claxton 1995), and, according to FAO, the world is likely to see an increase of 300% in aquaculture production over the next 13 years (FAO 1997). Improvements in the economics and environmental soundness of aquaculture are therefore required to ensure greater benefits to consumers and to the environment.

Status of Transgenic Technology

At this time, transgenic technology has shown that the growth rate of farmed fish can be increased by 400% to 600%, (Hew et al. 1992; Devlin et al. 1994) while simultaneously reducing feed input by up to 25% per unit of output, thereby improving food conversion ratios (R.H. Devlin, pers. comm.; Hew and Fletcher 1997). Researchers working with trout, salmon, tilapia, carp and other species have all reported dramatic increases in growth rates based on using a variety of gene promoters linked to growth hormone genes (e.g., Hew et al. 1992; Devlin et al. 1994; Maclean et al. 1995). The result of this biotechnology-derived improvement will be dramatically increased harvests with reduced production costs and with diminished exploitation of scarce feed products. The attendant shift in economics will facilitate the use of more environmentally sound practices in aquaculture, as discussed below.

Environmental Concerns

Environmentalists' fears of transgenic fish can be summarized in the form of two hypothetical and mutually contradictory dangers associated with their escape into the wild:

- transgenic fish will outcompete wild stocks and lead to a loss of genetic diversity;
- transgenic fish will be less fit in the wild, will crossbreed with wild types, and produce offspring with lower survival rates thereby reducing the total population of wild fish.

It is not the intent of this paper to argue the validity of either fear. Those wishing to examine the scientific literature will find a number of articles detailing the potential of adverse consequences resulting from the escape of farm raised fish, including transgenics. Some authors have suggested that these fears are overstated (e.g., Tave 1986; Knibb 1997) whereas others have held that the dangers are quite real, at least in localized areas (e.g., Kapuscinski and Hallerman 1990, 1991; Hindar et al. 1991; Regal 1994). The purpose of this paper is to suggest how the development of transgenics for rapid growth and other valuable traits can increase the economic value of aquaculture, limit its impact on the environment and enhance the well-being of wild fish. The discussion of this issue uses salmon farming as a principal example, because transgenic salmonids are likely to be the first species to be used commercially.

The salmon example

Salmon farming is conducted almost entirely in open seawater cages and has resulted in a number of environmental concerns. The most frequently cited problems include the following:

- impact on wild stocks of large numbers of escapees - numbering in millions of fish in a single growing season (NASCO 1994, 1997);
- impact of particulate, nitrogenous and other chemical wastes on local ecosystems (Gowen and Rosenthal 1993; McLay and Gordon-Rogers 1997; Ellis et al. 1998).
- multiplication of water-borne infectious diseases associated with concentrated biomass (Goldberg and Triplett 1997);
- destruction of natural habitat due to reconfiguration of, or intrusion upon, coastal areas to support farming activity (Phillips et al. 1993; Ellis et al. 1998).

Of continuing concern is that the projected growth of the salmon farming industry over the next 20 to 30 years (FAO 1997) would be expected to increase its environmental impact if present methods of farming remain unchanged. These problems will also apply to the farming of other species, the growth of which may be even more rapid. How then, to square the circle and to grow the larger amounts required for consumption while minimizing environmental impacts?

The use of transgenics

Based on technical progress to date, it seems probable that the application of gene modification techniques, if employed appropriately, offers one of the best opportunities for resolution of this problem.

The advent of transgenic salmon, which can attain market size in one-third to one-half the time historically required, with roughly 20% less feed input (Fletcher et al. 1997), will allow for the commercial introduction of a new farming system based on the use of recycled-water facilities. These facilities have virtually no impact on surrounding waterbodies and can, in fact, be situated many miles from any coastal location. The critical factor allowing for the expanded use of these facilities and for subsequent reduction in deployment of open water cages is the vastly improved economics associated with rapid-growth transgenics (Table 1). Their significantly improved feed conversion also enhances sustainability by requiring less of the world's increasingly scarce feed proteins to support aquaculture.

Table 1. Cost comparisons for transgenic vs. nontransgenic salmon production.

Production criterion	Aquaculture operation Nontransgenic	Transgenic
Harvest size (lb)	1 000	1 000
Harvest cycle (months)	36	18
Total cycles	1	2
Total weight (lb)	1 000	2 000
Food input-cost (lb^{-1})	$0.60	$0.48
Fixed cost (lb^{-1})	$0.90	$0.45
Production cost (lb^{-1})	$1.50	$0.93
Total production cost	$1 500	$1 860
Sales revenue	$1 800	$3 600
Gross profit	$ 300	$1 740
Increased profitability	-	580%

In this *pro forma* analysis, a traditional farming operation is assumed to produce 1 000 lb of salmon per harvest over a 36-month harvest cycle; the transgenic operation has a cycle of 18 months and 20% improvement in food conversion ratios (FCRs). The cost of production (i.e., US $1.50/lb) in the traditional operation is based on the industry average, comprising 40% for feed ($0.60/lb) and 60% for fixed costs ($0.90/lb). Both operations are assumed to be subject to a wholesale price ex-farm of $1.80/lb. Note that, in the event that FCRs were not improved, production cost-per-pound for transgenic salmon would still be lower (i.e., $1.05/lb from $0.60/lb for food and $0.45/lb for fixed costs), resulting in total production cost of $2 100, providing gross profit of $1 500 (500% improvement).

Water recycling facilities have been available for many years, but have been ignored by salmon farmers until very recently due to their large capital investment requirements and high operating costs. The few salmon farmers who operate land-based facilities have generally been unable to compete economically with seawater cage operations and have become hatchery-nursery operations, concentrating on egg and smolt generation for sale to growout farmers.

This state of affairs has begun to change recently, albeit slowly, as a result of several factors. First, there is a growing realization within the industry that increasingly complex environmental regulations present a significant cost to farmers. In many locations, these regulations put a limit on production and require potentially expensive ameliorative efforts, resulting in a less advantageous cost structure for seawater cage systems and severely limit opportunities for growth (Ackefors and Olburs 1996; McLay and Gordon-Rogers 1997).

Second, as the salmon farming industry matures, the size and nature of the producers are changing. What was once an industry of small farmers is rapidly evolving into an aquaculture version of agribusiness: relatively large companies with multinational interests controlling an increasing share of production. These companies are less interested in least cost methods of production in the short term than in the predictability of costs and harvest size in the long run. In any given year, a seawater cage facility may represent the most cost-effective method of production, but may also be subject to the highest degree of risk: storms, disease, predation and changes in water temperature that can severely and unpredictably reduce yields. In the past year, for example, at least 100 000 Atlantic salmon (*Salmo salar*) in British Columbia escaped due to storm damage; a previously unknown infectious disease devastated the salmon harvest in New Brunswick; excessively warm ocean temperatures in Scotland in 1997 resulted in the death of salmon worth £1.3 million (Anon. 1997). For large firms with the available capital, therefore, reliance on indoor systems represents a predictable alternative with greater opportunity for long-range planning and growth at diminished risk.

Third, recent improvements in the design and engineering efficiencies of modern recycled-water plants allow for higher stocking densities, less disease, fewer breakdowns and lower operating costs. The increased number of engineering firms now designing and promo-ting water-recycling systems ensures that improvements to filtering systems, pumping and oxygenation equipment, temperature controls and water flows will continue.

Despite these pressures and incentives to move from open water to indoor growout, the vast majority of salmon are still grown outdoors and the movement towards recirculation systems is slow. The primary reason for this is still the lower costs of growing salmon in open waters compared to growing in a capital intensive, highly engineered plant. The missing component, the single element which can drive the movement towards more environmentally sound land-based salmon farming, is the advent of fish which are significantly less expensive to raise. Rapidly growing transgenics, such as those developed in Canada by Dr. Choy Hew and Dr. Garth Fletcher (Hew et al. 1992) and licensed to A/F Protein under the tradename *AquAdvantage*®, Inc. meet this need (A/F Protein, Inc. 1998).

These transgenic strains of Atlantic salmon, Chinook salmon (*Oncorhynchus tschawytscha*) and rainbow trout (*O. mykiss*), and similar transgenics developed separately by Dr. Robert Devlin (Devlin et al. 1994), grow 400% to 600% faster than their nontransgenic siblings during the early life stages and reach full market size in less than half the time required for nontransgenic fish of the same species. Such transgenic Atlantic salmon reach a weight of 3 kg in 14 months from first feeding (Fig. 1); in the same time period, transgenic rainbow trout routinely reach a weight of 4.5 kg (Sutterlin 1998). The economic impact of these growth rates is enormous: not only is the cost-per-unit weight of production lower as a result of shortening the growout time and reducing the amount of feed required, production is essentially doubled over time because two harvests of transgenic salmon can be produced in the same time that it takes to produce one harvest of nontransgenic salmon. Preliminary economic analyses (Table 1) indicate that if a farmer were to receive the same market price for transgenics as for nontransgenics, profitability could increase by over 400%. Obviously, this will not happen, nor is it desirable. The preferable outcome will be a sharing of economic benefits between consumer and producer: lower costs of production and increased output will lead to lower selling prices and a larger market as people who presently cannot afford the product will find it in their price range (Hite and Gutrich 1998).

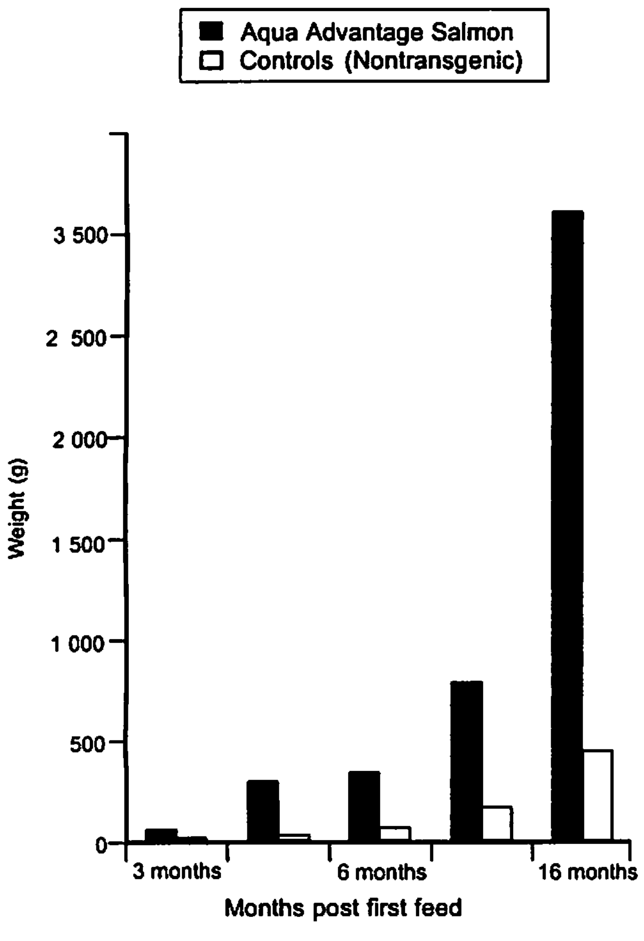

Fig. 1. Growth performance of AquaAdvantage Atlantic salmon (*Salmon salar*).

The production of transgenics removes an important barrier to the widespread use of land-based systems for salmon growers. With transgenics, the anticipated cost of land-based production will be as low (if not lower) than the present cost of seawater cage production. Given the growing disincentives to farming salmon in open seawater, land-based farming is likely to become an extremely attractive alternative. The economic viability of land-based systems will match their environmental advantages.

The pattern of lower cost of production, greater yields and lower consumer prices can be replicated in other species as the technology expands to encompass fish such as tilapia (*Oreochromis niloticus*), flounder (*Pseudopleuronectes americanus*), cod (*Gadus morhua*) and others. Even where the initial capital requirements for high-tech indoor growing systems cannot be met, transgenics will at least reduce input needs and increase output at lower costs–an invaluable benefit in a world where the price of fish makes it prohibitively expensive for many. There may well be places and conditions under which rapid-growth transgenics will have to be controlled to avoid environmental damage to water systems, but these issues are best left to individual countries or regions to regulate and resolve under appropriate policies.

The first commercially available transgenic salmon, A/F Protein's *AquAdvantage®* salmon, are being grown in land-based facilities. The company is also aware, however, that land-based systems may not be feasible in all locations. At such locations, the company permits the licensee to use open water cages, but only for sterile transgenics that are female triploids. A/F Protein believes that this eliminates any direct threat to the wild fish population, even if it does not fully address some of the other environmental concerns cited previously. The policy issue here is, is it not more acceptable to raise sterile, rapidly growing transgenic fish in open water cages than fertile, slow growing nontransgenic fish? If the commercialization of transgenic fish proceeds according to the principles of using environmentally isolated facilities or growing only sterile fish in open areas, this technology will produce a net gain for the ocean's ecosystems by replacing systems with more severe impacts.

Socioeconomic concerns

The other arguments used to try and limit–or eliminate–the use of transgenic technology for aquaculture are based on its perceived disruption of local economies, particularly in underdeveloped countries and regions. The rationale is that the improvements in productivity will be a form of economic imperialism, because the intellectual property will be owned and controlled by large companies, based largely in Europe and North America, and will have the effect of increasing the dependence of poorer regions on wealthier countries. This has been the position of some countries that are Parties to the Convention on Biological Diversity. They fear implementation of transgenic technology will lead to further impoverishment of poorer resource-based economies, particularly those dependent on fishing or traditional aquaculture. Such arguments are false. Opposing technical advances because they emanate from and are controlled by companies in countries with a preponderance of the world's economic resources is an attack on the world's economic system in general, and is not specifically relevant to the use of biotechnology *per se*. Where the goal is to produce more food at a lower price, this socioeconomic argument is particularly misplaced. It is clear that the ability to produce more seafood at lower prices will preferentially benefit those who presently can ill-afford this protein source (Hite and Gutrich 1998). Moreover, it is reasonable to assume that much of the aquaculture industry will remain situated in the same countries where it exists today: including some of the world's less developed countries. In such countries, use of transgenic technology will offer benefits both in the form of less expensive food and economic growth.

The application of transgenic technology does not preclude the legitimate reimbursement of indigenous groups which provide knowledge or genetic resources leading to biotechnological advances and economic benefits. Where benefits are obtained through the assistance of such groups, contractual obligations to share profits or other benefits with the groups is the proper way to proceed.

Conclusion

Recognizing the enormous potential benefit of biotechnology, such as the development of transgenic fish, means also recognizing that while regulatory oversight is necessary, regulations must be used to safely advance its use, not to hamper or eliminate the technology. Further, regulatory oversight should be developed in keeping with the thoughts expressed in the ICLARM-GTZ Bellagio Conference on 'Environment and Aquaculture in Developing Countries' (Pullin 1993), that "environmental conservation and human needs must be balanced." Accomplishing this requires that regulations should be based on economic and scientific assessment of risks and benefits, that they not impose undue burdens and delays on those being regulated, and that regulatory bodies offer a clear, unambiguous path for those being regulated to follow. A sound understanding of the economic, nutritional and environmental advantages which transgenics can offer–through application of cost-benefit analysis–should be employed (Balint et al. 1998; Hite and Gutrich 1998). Examples where these guidelines to the development of policy have not been followed show that the results are negative to producers, consumers, and ultimately, to the environment as well (Ackefors and Olburs 1995).

Aquaculture includes many corporations that are firmly convinced that the use of transgenics will facilitate the use of more environmentally friendly systems of aquaculture and will bring broad economic and social benefits. Such companies also believe that transgenic technology is a vital part of a broader development which is transforming the productivity of aquaculture and creating a more widely available, sustainable food supply to feed the world's growing population. The world may witness a revolution in aquaculture that this author calls the "Blue Revolution":

"Bringing together technology from the biological sciences and engineering to produce an aquaculture industry capable of large scale, low-cost production independent of proximity to the oceans and less invasive to the environment. Increased growth rates, enhanced resistance to disease, better food conversion rates, alteration of breeding cycles, more efficient use of indoor water recycling plants are all aspects of this revolution" (Aqua Bounty Farms 1998).

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Discussion

Neira: There are a lot of transgenic plants already and I have heard a comment that, in 10 years, about 90% of the plants in use will be transgenic. I think that a lot of species used in commercial aquaculture will be transgenic also. So, I accept that what you are proposing for the development and use of transgenic fish is 'normal', in the sense that the gene transferred belongs to the species. What I don't accept so easily are the closed system conditions that you are proposing. I believe that this is being said because of the view that most people are afraid of transgenics. I have asked this question in Chile. For most people, this is an economic question rather than a biological one. If transgenic salmon were introduced into the Chilean production system, of course, some other salmon producing countries might say 'Hey, Chile is producing transgenics, so don't buy them'. Besides, in Chile, we can harvest at 19 months, so the advantage that you describe–14 months–is not so great.

Entis: But that's not 19 months from hatch, is it?

Neira: It is 19-20 months from hatch. My other point is that you are, I believe, a little bit 'out of time' in promoting transgenics. Aquaculture will benefit greatly from the application of selection. Genetic gain per generation from this can be 10-15%. So, selection will catch up fast the advantages of transgenics. I do still believe in transgenics, but you will have to work very hard to keep your advantage.

Entis: I do accept that. Of course you are right that growth rate can be improved each generation by non-transgenic means. However, the transgenic approach not only solves the growth problem for the equivalent of many generations of selection but also allows salmon farmers and others then to work on problems other than growth. For example, one of the biggest problems in aquaculture is that we have sacrificed flesh quality characteristics for growth rates. Most fish are very fatty today–although ours are not; they have a much lower fat content than others of equal size. The real issue is that biotechnology and transgenic have these great potentials. So, we should take a policy decision to examine these–as well as the risks. That's all.

Froese: You made a point about growing transgenics in closed systems rather than open systems. But wouldn't open water systems, for example in Chile, simply use these fish and export them and beat your price for closed system fish all the time? The global market might not allow you to go the route that you've suggested.

Entis: I think that there will always be different niches and positions. For example, an open water product from Chile might not compete in the USA with a locally raised, closed system product, given transportation costs, etc. I don't believe that there is one global market for these products. Also, the costs of closed systems will go down as large companies get involved. Their initial capitalization costs are critical, but their running costs are competitive.

Kapuscinski: Your strategy is well targetted at your socioeconomic situation – developing a luxury food item and trying to minimize hazards. But, to what extent could this approach be used more generally in aquaculture around the world? For example, do you see all of the carp farming in China going in this direction? We need to consider not just the specifics of your situation but also the wider picture and the possible limitations of your approach.

Entis: I accept that. It might be considered 'imperialistic' for us to insist that all those to whom we license our products (on which we have intellectual property rights) must grow these only in closed systems, because in many parts of the world the capital to develop these systems is lacking. However, because of environmental considerations we have a company policy that we will license fish only to those who will grow them in closed systems or in open systems as sterile fish, so that any escapees will be nonfertile. This environmental aspect needs more investigation. For example, if it could be shown that transgenics grown in open water systems did not pose environmental problems, we would think 'that's great!' and these conditions could be changed. At this period of time we are advocating, along with the precautionary principle, that it would be unwise to allow fertile transgenic fish to be grown under all circumstances. This applies to transgenics with any characteristics.

Bartley: I think that we need to congratulate Elliot and his company for focusing on the characteristics of their product. The Precautionary Approach requires us to look at the product and, where there are uncertainties, to move slowly. I do not think that we can expect people to just farm indoors and to recirculate. In this world, where something is cheaper it will be tried. The public will need to be well informed about transgenic fish.

Wang: On the ecolabelling question, I think that a nondamaging product can be distinguished from others and, if more expensive to produce, can have a higher price. For example, most salmon are now farmed in pens. If more salmon were produced in recirculation systems, they would be a different product. Is it difficult for you to get approval for your products?

Entis: It's not difficult. We have presented data to the FDA. The issues are twofold. First, food safety is not a big issue. We have put salmon growth hormone into salmon. The bigger issue is–where can these fish be grown within the USA? The USA does not have a coherent policy on this yet, so we are saying ourselves that the fish will only be grown in recirculation systems or that they will be sterile if grown outdoors. We are conducting studies on the likely fitness of our fish outdoors. There are indications that they would be far less fit than wild fish. They are aggressive feeders and are very stupid in front of predators.

Pullin: I like very much your premise that it doesn't matter by whatever means a domesticated organism is produced, it is still 'modified' by comparison with 'wild(er) types.' This is the basis for the broad definitions of a 'GMO' that we follow in ICLARM (Pullin 1994). If you've already got a 25-30% improvement in FCR (almost as a bonus, because you were just targetting growth), that is very nice. It holds back somewhat the 'crunch' that is coming for farmed aquatic carnivores, like salmon, because of the increasing scarcity and cost of feed ingredients like fishmeal and fish oil. However, your fish are still not decoupled from these marine resources.

Entis: This is a broader question for agriculture and meat sources in general. It cannot be answered only with respect to transgenics.

Pullin: Agreed.

Entis: I can only point out that fish remain the most efficient converters, for those people who want to eat meat. We are encouraging people to eat fish.

Pullin: But, in agriculture, nobody farms a carnivore.

Entis: We are also working on plant sources for fish feeds to address the limitations that you mention.

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Genetic Resources and Fisheries: Policy Aspects

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ABSTRACT

The effects of fisheries on aquatic genetic resources are briefly reviewed. Fisheries impact on genetic resources at different levels and include selective fishing on stocks, genetic change in enhanced stocks, species extinctions, disruptions to ecosystems, and removal of nontarget species. Fishing exerts a selective force on natural populations by removing a restricted size range of individuals, so that traits linked with size and age are likely to be changed by selective fishing. The genetic impacts of fishing have been difficult to demonstrate in wild populations, due to the phenotypic plasticity of many life history traits that respond to both biological and physical parameters as well as selection pressures. Selection is likely to be fishery-specific and dependent upon the interaction between fishing gear and the average size and age at onset of sexual maturity of the target species. Measured genetic impacts in enhanced fisheries range from no detectable change to complete replacement of local stocks. Protocols have been developed that enable hatchery managers to minimize genetic change by careful choice of the origin and number of parents used for seed production.

Species extinctions, and threatened and endangered aquatic species, are most common in freshwater and estuarine environments and are produced by habitat loss and degradation rather than direct impacts of fishing. However, marine fishes with low reproductive rates, large size at onset of sexual maturity, and restricted distributions, such as the coelacanth and some sharks and rays, are vulnerable to exploitation. In addition, industrial fisheries are disrupting ecosystems. Many collapsed stocks have maintained relatively large population sizes and would not be expected to lose genetic diversity. Fishing also impacts on a range of nontarget species, and those with low population sizes and low reproductive rates, including sharks, turtles, albatrosses and marine mammals, are vulnerable to accidental harvesting. In many managed fisheries, measures are being put into place to reduce mortalities on nontarget species through gear restrictions and local closures. The move towards large-scale marine protected areas and seasonal closures will contribute to the conservation of nontarget species. Illegal harvesting of protected species and overfishing of quota species in high seas fisheries urgently require new initiatives in conservation and sustainable management. Most genetic problems relate to overfishing and while biological solutions to problems of overfishing, seem obvious, such as reducing fleet size in industrial fisheries and creating closed areas in artisanal fisheries, the sociopolitical measures to resolve the conflict between long-term conservation goals and short term economic gains will be difficult to implement.

Introduction

Extinctions of freshwater species due to human impacts have been all too common this century (Moyle and Leidy 1992). Marine extinctions because of human impacts are thought to be rare, due in part to the high abundance and wide range of many species, coupled with their potential for extensive larval dispersal. In recent years, however, several species of marine mollusc have become extinct (Culotta 1994); in addition, stocks of abundant fishes have collapsed (Beverton 1990; Myers et al. 1996; Cook et al. 1997) and the genetic composition of some heavily exploited populations has been changed by selective fishing (Stokes et al. 1993; Smith 1994).

This paper outlines the effects of fisheries on aquatic genetic resources. The effects of other anthropogenic activities on genetic resources, such as aquaculture, pollution and reclamation, are discussed by other authors (Abban, M. Gupta, Mires and Neira, this vol.).

Aquatic genetic resources are considered as species diversity and genetic diversity. Fishing removes both target and nontarget species from the ecosystem, and is the major source of adult mortality for many heavily exploited species. Fisheries have been classified into five categories: traditional subsistence, recreational, small-scale artisanal, large-scale industrial, and enhanced fisheries (McNeely et al. 1995). The five categories differ considerably in scale, geography, harvesting methods, management practice and philosophy. Subsistence fisheries carried out by traditional methods for local food or other uses are unlikely to impact on abundant resources. Problems arise in the other categories of fisheries due to the scale of operations and the efficiencies of modern fishing methods. The greatest management problems lie in the small-scale artisanal fisheries that have few management controls over large numbers of fishers, and in the large-scale industrial fisheries with gross catching capacity. Long-term genetic conservation goals are rarely considered in fisheries management (Stokes et al.1993) either through lack of knowledge or low priority. Four scales of genetic loss have been recognized in wild fisheries: loss of within population variation, loss of between population variation, loss of fitness in enhanced populations, and extinction (Currens and Busack 1995). The US Endangered Species Act recognizes the importance of these different scales and affords protection under the Act, to certain populations within species, in order to conserve genetic resources; e.g., specific runs of Pacific salmon (Waples 1995). In enhanced fisheries, which have the potential to change the genetic structure of wild populations, genetic conservation goals have also been considered and implemented (Munro 1993; Waples and Do 1994; Bartley et al. 1995; Blankenship and Leber 1995).

The potential impacts of fishing on genetic resources are outlined, followed by policies and management changes that are being considered to alleviate the negative genetic impacts of fisheries.

Genetic Diversity and Selective Fishing

Fishing is a selective activity, extracting a restricted range of size classes from natural populations. Traits linked with size and growth rate will be changed through differential fishing mortalities. Although it is recognized that fishing is likely to change the genetic structure of heavily exploited stocks (Ryman and Utter 1987), evidence for the selective effects of fisheries has often been equivocal (Table 1), and has to be balanced against nongenetic responses of fish populations to environmental change. Life history traits, such as size and age at maturity, have a genetic base but are phenotypically plastic: at reduced densities, fish grow faster and reach maturity at an earlier age and smaller size. At reduced density, however, growth rate is optimized so that genes coding for growth have maximum effects and hence response to selection (Thompson and Stokes 1996).

Experimental studies have shown that size-based selection can produce significant change in life history traits of aquatic species within a few generations. Selective removal of the largest fish from a population of the tropical freshwater *Oreochromis mossambicus* resulted in reduction in male growth rate after 3-4 generations while control populations remained unchanged (Silliman 1975). Size-specific harvesting of replicate laboratory populations of the water flea (*Daphnia magna*) produced genetic change in life history traits within 10-12 generations. Harvesting small individuals led to an increase in the mean size at age and size at first reproduction, whereas harvesting large individuals produced the reverse with a decline in size at age and decline in size at first reproduction (Edley and Law 1988).

Populations of freshwater guppies (*Poecilia reticulata*) transferred, from river systems with cichlid predators that prey on large guppies, to streams with killifish predators that prey on small guppies, experienced genetic change from this size-specific predation, within 11 years over an average of 18 generations. Descendents of the introduced population had larger offspring and reproduced at a larger size and greater age than in the donor population (Reznick et al. 1990, 1997). Rearing descendents from the two populations under similar laboratory conditions showed that the life history differences had a genetic basis (Reznick et al. 1990).

A common observation in the heavily exploited demersal fisheries in the North Atlantic Ocean has been a decline in mean size and age of fish over long periods of heavy exploitation. Similar observations have been made in Atlantic and Pacific salmon and in lake fisheries (Smith 1994). Declines in age at maturity in cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and plaice (*Hippoglossoides platessoides*) have been attributed to the selective removal of late maturing fish from the population (Beacham 1983a; Borisov 1979; Rowell 1993). Individuals that mature at smaller or younger sizes have a selective advantage under heavy fishing pressure because late maturing individuals are likely to be captured before the onset of sexual maturity (Beacham 1983a).

In coho salmon (*Oncorhynchus kisutch*), life history strategies are maintained by disruptive selection favoring small "sneaky" males or jacks and large "fighting" males or hooknose (Gross 1985). The fishery has selectively harvested the larger fish increasing the rela-

Table 1. Examples of biological responses to selective fishing.

Selected trait	Example	Reference
Early maturity	Cod (*Gadus morhua*)	
	Scotian shelf. Reduction in mean age at maturity from 5 years in 1960 to < 3 years 1978.	Beacham 1983a
	Arcto-Norwegian. Decline in age at maturity from 8/10 years in 1930 to 6 years in 1970s.	Borisov 1979
	Coho salmon (*Oncorhynchus kisutch*)	
	North America. Fishing for large males favored survival of "jacks" that mature at 6 months of age.	Gross 1985,1991
	Cichlid (*Oreochromis niloticus*)	
	Uganda. Decline in size at maturity from 20 to 29 cm to 18 to 24 cm between 1950 and 1970.	Gwahaba 1973
	Protandrous shrimp (*Pandalus borealis*) Fishery selected for small females and individuals that first mature as females.	Jensen 1965,1967; Charnov 1981
Small size	Pacific salmon (*Oncorhynchus* spp.)	
	Three species of salmon showed a decrease in mean size at age after years of size selective fishing.	Ricker 1981
	Disruptive selection in sockeye salmon *Oncorhynchus nerka* gillnet favored small 3-year and large 4-year-old ocean fish.	Ricker 1991
Spawning season	Atlantic herring (*Clupea harengus*)	
	Early spawners overfished and serially replaced by late spawners; spawning season shifted from Sep to Oct around 1900 to Jan in 1950s.	Devold 1963; Mathisen 1989
	Chinook salmon (*Oncorhynchus tschawytscha*)	
	Heavy fishing on spawning peak Jun to Jul in late 1800s lead to smaller spawning peaks in May and Aug by 1938.	Thompson 1951; Mathisen 1989

tive frequency of jacks (Gross 1991). However, anthropogenic changes at other stages of the life cycle also influence the ratio of jack to hooknose males. Stream clearance reduces the available refuges for jacks, favoring hooknose fish on the spawning grounds, whereas eutrophication increases fry growth rate leading to an increase in the proportion of juveniles maturing as jacks (Gross 1991).

Many species have shown a reduction in mean size over the past few decades of heavy fishing, but there is uncertainty as to whether the changes are due to selective removal of larger fish, selective depletion of stocks with large body size, or changes in oceanographic conditions (Ricker et al. 1978; McAllister and Peterman 1992). Some key examples are noted in Table 1. For species with long spawning seasons, unequal fishing pressure over the season may selectively favor fish that spawn in a specific period. Progressive changes in the arrival and spawning of herring (*Clupea harengus*) on the Norwegian coast may be the result of selective harvesting on the first returning subgroups of herring (Devold 1963; Mathisen 1989). However, changes in the spawning time of herring have been explained by changes in environmental conditions. The disappearance of autumn spawning herring in the Baltic Sea has been linked to improved feeding conditions, brought about by eutrophication, providing adults with sufficient food reserves to spawn in the spring (Aneer 1985).

Changes in genetic diversity, measured with allozymes, have been reported in heavily exploited populations (Altukhov 1990,1993; Kirpichnikov et al. 1990; Smith et al. 1991). Allozyme markers provide a rapid method to estimate genetic diversity, and although much of this diversity may be selectively neutral, some studies have shown that allozyme diversity is positively associated with growth rate (e.g., Zouros and Foltz 1987). Kirpichnikov et al. (1990) showed that during the fry stages of sockeye salmon (*Oncorynchus nerka*), slow growing individuals were less heterozygous than fast growing individuals. The fishery selectively favors the survival of fast growing and early maturing fish, so that the genetic diversity of the population, measured with allozymes, has increased as a result of fishing. The reduction in genetic diversity reported with the initial exploitation of orange roughy (*Hoplostethus atlanticus*) around New Zealand (Smith et al. 1991) has not been verified over a longer time period (Smith and Benson 1997).

Modelling provides the quickest method for determining genetic responses to selective fishing and, in the absence of long-term data, provides the only retrospective method for stocks that have been selected. Models are dependent on the use of realistic biological parameters; several models have used a biallelic approach when life history traits are likely to be polygenic, while others have taken a generalist approach (e.g., Bergh and Getz 1989; Kapuscinski and Lannan 1984,1986). The most useful models have been those developed for specific fisheries. An age-specific model used to describe exploitation acting on life history traits of the Arcto-Norwegian cod (*Gadus morhua*) showed that selective fishing lead to changes in life histories that produced changes in yield (Law and Grey 1989). Thompson and Stokes (1996) modelled the trawl fisheries for North Sea cod, that catch fish >20-30 cm, and showed that fishing favored the survival of fast growing fish. Although fast growing fish suffer a higher annual mortality than slow growing fish, they mature earlier and produce more eggs, and consequently leave more offspring for the next generation. Only at a high minimum size does fishing selectively favor slow growing fish.

Increased fishing mortality might be expected to favor the survival of slow growing fish, as shown by experimental studies (Silliman 1975; Edley and Law 1988), but the reverse has been reported from modelling studies of cod trawl fisheries which demonstrated that fishing favored the survival of fast growing fish (Thompson and Stokes 1996). The selection pressures in the two studies were different: in the experimental studies, only the largest fish were removed, whereas in the trawl fishery, with knife edge selection, fish were removed at the onset of sexual maturity. These contrasting results–selection for slow-growing and fast-growing fish–show that it is premature to make general conclusions about the selective effects of fisheries. The genetic consequences of fishing are likely to be dependent upon the size selectivity of different gear types and the size at onset of sexual maturity in the target species.

Policy aspects

- The selective effects of fisheries are complex, and the population traits and response to selection must be well understood before changes to management are considered (Miller and Kapuscinski 1994).

Further research is required on selective fishing. Modelling provides the best option for estimating the genetic effects of selective fishing, but models must be species- and fishery-specific. The size at onset of sexual maturity and the size selectivity of the fishing gear are critical for determining the genetic outcomes of selective fishing. Estimates of the heritability of age or size at onset of sexual maturity are needed, for marine species. Selection will, however, occur even when heritability is low. The time scale of genetic change will be longer than for traits with high heritability and environmental changes or catastrophes may influence events over a long time scale.

- Future management decisions should consider both the evolutionary and ecological implications of harvesting. Law and Grey (1989) suggested that an evolutionary stable harvesting strategy for Arcto-Norwegian cod could produce an increase in yield by reducing effort on the small immature feeding stocks in the Barents Sea, and by focusing effort on larger and older spawning fish off the Norwegian coast. Brown and Parman (1993) extended the concept and suggested that an evolutionary approach to management would choose a lower harvest rate that favors larger fish and preserves yields in evolutionary time, against an ecological approach that favors small fish and maximizes short-term yields.

- While the trend in fisheries management is towards output controls, based in some fisheries around individual transferable quotas, mitigating the selective effects of fishing will require specific input control measures such as gear and area restrictions. Size limits that prevent the capture of immature and small mature fish reduce the risk of size-selective fishing. Size limits might be effective in recreational fisheries where undersized fish can be returned with some chance of survival but, in most marine fisheries, especially industrial and deepwater fisheries, individuals are too badly damaged by the catching process to survive if returned. Thus, size limits can result in overfishing when undersized catch is discarded at sea. Closed areas or gear restrictions that reduce fishing mortality on juvenile fishes should be considered but need to be fishery-specific.

Genetic Diversity and Enhanced Fisheries

Depletion of aquatic resources, especially freshwater fish, led to the development of hatcheries for rearing and releasing juvenile fish at the beginning of the century. Currently the maintenance of some populations of Pacific salmon is dependent upon hatchery seed (Winans 1989) and more than four billion smolt are released annually in the North Pacific Ocean (Hindar et al. 1991). Enhancement of fisheries has been defined as a process whereby the abundance of free living juveniles is supplemented by the release of juveniles reared in hatcheries or captured elsewhere, such as offshore areas (Munro and Bell 1997). Enhancement appears to offer a "quick fix" to fisheries management problems of declining stocks and has considerable appeal to politicians and fishing companies, although scientific support for enhancement programs is sometimes less compelling. Hilborn (1992) has argued that for salmonids "hatchery programmes that attempt to add additional fish to existing healthy wild stocks are ill-advised and highly dangerous". Hatcheries at best address the symptoms and not the causes of declines in fish stocks (Meffe 1992) and enhancement alone will not improve or rebuild fisheries, but must be integrated with management measures for stock conservation (Blankenship and Leber 1995; Munro and Bell 1997).

Stock enhancement of marine teleosts, crustaceans and molluscs has been developed most extensively in Japan in response to declining coastal catches brought about through overfishing, pollution and loss of coastal habitat (Morikawa 1995). Stock enhancement is also being considered in many regions to rebuild depleted stocks from abalone to tuna. Red drum (*Sciaenops ocellatus*) enhancement in Texas has been successful through a comprehensive program that includes not only large-scale stocking (145 million seed in 1993), but also management controls on commercial and sport fishers catches, and habitat protection measures (McEachron and Daniels 1995).

The release of hatchery stocks has ecological and genetic implications for wild genetic resources (Marnell 1986; Thomas and Mathisen 1993). The genetic impacts of large-scale releases are likely to be negative when there are genetic differences between the hatchery stock and the wild population (Skaala et al. 1990; Hindar et al. 1991). A large number of genetic effects of cultured salmonids on native populations have been documented and range from no detectable effect to complete displacement (Hindar et al. 1991). The major potential genetic problems with enhancement programs are the reduction of within and between stock genetic diversity and the replacement of wild stock by released fish.

The high fecundity of many aquatic species allows the production of numerous seed from a few parents and the risk of loss of genetic diversity. Studies of hatchery populations suggest that loss of genetic diversity is common and has been reported in many studies (e.g., for fish, Verspoor 1988; Koljonen 1989, and for invertebrates, Durand et al. 1993; Benzie and Williams 1996). A large number of genetic changes, from morphology to disease resistance, have been recorded in domesticated salmonids (Skaala et al. 1990); and the life history traits of cultured Atlantic salmon (*Salmo salar*) frequently differ from those of wild stocks (Heggberget et al. 1993).

Salmonid species and many marine fishes are composed of genetically differentiated subpopulations that are assumed to be adapted to local conditions (Skaala et al. 1990). When different co-adapted gene complexes evolve in different populations then mating between distantly related individuals in a mixed enhanced population results in outbreeding depression, which is expressed as reduced fitness (Emlen 1991). There is evidence that introduced stocks of chum salmon (*Oncorhynchus keta*) do less well than native stocks and do not contribute to subsequent spawning runs (Altukhov and Salmenkova 1990). Population crosses of pink salmon (*Oncorhynchus gorbuscha*) produced a decrease in survival and an increase in asymmetry in the F2 generation (Gharrett and Smoker 1991). Populations of Atlantic salmon (*Salmo salar*) in Norway are threatened by a monogean parasite (*Gyrodactylus salaris*) introduced with stock from the Baltic Sea, which are resistant to the parasite (Hindar et al. 1991; Heggberget et al. 1993). A reduction of interpopulation variation will have a long-term impact on species survival (Ryman and Stahl 1981; Gharrett and Smoker 1993).

Hatchery released stocks of brown trout (*Salmo trutta*), derived from central Europe, have failed to survive through to sexual maturity and to interbreed with wild stocks in Spanish rivers (Moran et al. 1991), but in Atlantic salmon (*Salmo salar*), escapes from farms interbreed with wild stocks (Crozier 1993). A comparison of wild and farmed Atlantic salmon, both in the hatchery and in the wild, showed that farmed fish had higher growth rates and were more aggressive than wild fish such that releases were a threat to small native populations (Einum and Fleming 1997).

Policy aspects

- The genetic aims of hatcheries producing seed for enhancement are in opposition to hatcheries producing seed for aquaculture. Enhancement programs aim to maintain genetic diversity within and among wild stocks, while aquaculture selects for seed that has specific production traits and which should not be used in enhancement programs. Technical protocols and methods for avoiding genetic problems with enhancement have been reviewed for salmonids (e.g., Thomas and Mathisen 1993) and clams (Munro 1993; Benzie and Williams 1996). General principles and recommendations have been published by FAO (1993), and codes of practice for transfers of stock have been drawn up by ICES (1996), to be applied to all enhancement programs.

- Local broodstock, taken from wild stock, should be used to reduce the risk of introducing foreign alleles into the enhanced population and to reduce the risk of outbreeding depression through mixing of different co-adapted gene complexes. Occasionally, there may be local extinctions, in which case broodstock from geographically neighboring regions should be used. Prior to choosing broodstock, it is necessary to carry out a population genetic survey, using molecular techniques and an assessment of life history traits, to determine the number of stock units for broodstock collection and subsequent seed releases. For example, King et al. (1995) used three broodstock collections from the upper middle and lower Texas coast after finding clinal variation in genetic characters in wild populations of spotted sea trout (*Cynoscion nebulosus*).

- Genetic approaches for use in hatcheries, to avoid inbreeding and loss of diversity due to drift, are well known (e.g., FAO 1981; Munro 1993). The general recommendation, for populations managed for a short-term period, is to use 50 male and 50 female parents to ensure that 99% of genetic variation is retained in the first generation. Lower numbers of parents and unequal sex ratios result in loss of genetic variation. Holding and spawning large numbers of broodstock can present technical difficulties for marine species (e.g., Gervis 1993). Multiple spawnings can be used to overcome the problems of getting large numbers of hatchery broodstock to spawn at the same time period, as used for seabass (*Atractoscion nobilis*) (Bartley et al. 1995). For species with long spawning seasons, it is necessary to use multiple spawnings to avoid selection for spawning period.

- Steps should be taken to avoid obvious selection, such as size grading, within hatcheries. However, some selection is inevitable as hatchery conditions cannot mimic those encountered by wild seed. Therefore prior to release, seed should be tested for potential genetic change, this can be done relatively quickly with molecular methods. Seed should not be ongrown for use as broodstock, to avoid domestication selection; rather, broodstock should be taken from wild stock to maintain genetic diversity.

- Enhancement programs based on collection of wild seed should avoid transfer of stock between different stocks/populations or between regions/sea areas. Hatchery produced seed should only be released into areas from which the broodstock were derived. Evaluation of survival and subsequent reproduction of enhanced seed should be monitored through physical and genetic tagging, provided that the latter can be achieved without compromising genetic goals (Crozier and Moffett 1995).

Species Diversity

Species extinctions

Around 20% of the known freshwater fish species have become extinct this century, for the most part due to habitat loss and degradation through reclamation, forestry, pollution, water extraction and dam construction, rather than to the impact of fishing (Moyle and Leidy 1992). The majority of aquatic organisms on the endangered and threatened lists (IUCN 1996) are freshwater or estuarine (Froese and Torres this vol.), although in the past few years several commercially important marine teleosts, notably bluefin tuna (*Thunnus thunnus*), and haddock (*Melanogrammus aeglefinus*), have been added (Huntsman 1994).

Until recently, it had been assumed that marine species with large population sizes, wide distributions and potential for dispersal through larval drift were not susceptible to human induced extinctions (Culotta 1994; Tegner et al. 1996; Malakoff 1997). However, marine fish species with low reproductive rates are vulnerable to exploitation. The coelacanth (*Latimeria chalumnae*) is thought to be in danger of extinction due to its high value, restricted distribution and very low reproductive rate (Mackenzie 1995). Skates and rays also have low reproductive output and given their large size at first reproduction are vulnerable to overexploitation. The population of skate in the Irish Sea (*Raia batis*) has been severely reduced (Brander 1981), several species of elasmobranch are no longer caught in the Bay of Biscay (Quero and Cendrero 1996), and species of ray have disappeared from the Gulf of Thailand (Pauly et al. 1989). Concern has been expressed over the abundance of oceanic sharks caught in longline fisheries (Manire and Gruber 1990).

Several species of marine mollusc have become extinct in the latter part of this century, mostly due to habitat degradation (Culotta 1994). The white abalone (*Haliotis sorenseni*) has been pushed to near extinction through overfishing. Numbers of adult white abalone have been reduced to such an extent that densities are below those required for successful reproduction, leading to a recruitment failure over many years in spite of very high individual fecundity (Davis et al. 1996). Giant clams (*Tridacna and Hippopus* spp.) have become locally extinct due to uncontrolled harvesting in the Philippines (Juinio et al. 1989), but loss of the clam (*Hippopus hippopus*) in Tongan waters was probably due to mass mortalities as a result of environmental change rather than overexploitation (Loto'Ahea and Sone 1995).

Ecosystem disruptions and species replacements

Large-scale fluctuations in abundance of marine fish stocks are common. Up to six categories of stock have been described from steady state demersal to high variability pelagic stocks (Spencer and Collie 1997), with Pleuronectiformes the most stable and Clupeiformes the most variable (Hilborn 1997). Fluctuations occur over a range of time scales, from annual to centennial. Biomass flips, due to changes in environmental conditions, in particular water temperature, occur when one abundant species drops to a very low level and is replaced by a second species (Sherman 1990). Biomass flips are common in small pelagic stocks, and have been reported between sardine and anchovy in the California current (MacCall 1986), between sardine and jack mackerel off the Iberian coast (Wyatt and Perez-Gandaras 1989), between pilchard and jack mackerel off Namibia (Crawford et al. 1989), and between herring and pilchard in the English Channel (Cushing 1984). Examination of scale records in marine deposits has shown that sardine and anchovy have fluctuated in abundance for at least a thousand years (Soutar and Isaacs 1969).

There is increasing evidence that fishing changes the species composition of fish communities on an ocean wide scale. Fishing has been the major cause of collapse in stocks of small pelagic fishes (Beverton 1990). Nine out of 10 collapsed stocks have shown signs of recovery, but only one has reached its former size. Time might have been insufficient for the other stocks to fully recover. Overfishing is unlikely to drive a marine pelagic species to extinction, but there is a risk that the structure of the community will be changed and that the population might never fully recover, but might be replaced by competing species (Beverton 1990). The rise in gadoid fish stocks in the North Sea during the 1960s and 1970s has been linked with a decline in pelagic fish stocks (Beverton 1990), but also with more favorable conditions for survival of gadoid larvae (Cushing 1984). This highlights the difficulties of determining the impact of fishing in a fluctuating environment. Decline in herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) biomass in the northwest Atlantic, due to overfishing, led to a major increase in sand eels (*Ammodytes* spp.) (Sherman et al. 1981). Similar findings were reported in the North Sea, where subsequent expansion of the sand eel fishery has resulted in declines of seabird populations and reproductive failure during some years (Monaghan et al. 1989). The collapse of the capelin (*Mallotus villosus*) stock off northern Norway led to breeding failure in kittiwakes (*Rissa tridactyla*) (Barrett and Krasnov 1996), and the lack of juvenile herring and capelin led to starvation in seabirds and marine mammals (Hamre 1994). Long-lived species of seabirds can withstand short-term reproductive failures produced by loss of prey species, but will not withstand long-term reductions in prey biomass.

Stocks of cod (*Gadus morhua*) have collapsed over the past few years on both sides of the North Atlantic (Myers et al. 1996; Cook et al. 1997). It is too early to expect a recovery. The species composition on Georges Bank in the northwest Atlantic Ocean has changed from one dominated by gadoid predators to one dominated by dogfish predators over a 20-year period (Sissenwine and Cohen 1993). For the cod stocks that collapsed, the fishing mortality had been underestimated and there had been a large excess in catching capacity. The collapsed stocks have followed a similar pattern with a rise in fishing mortality and reduction in age structure, followed by a rapid increase in fishing mortality coupled with discarding of young fish (Myers et al. 1996). In the North Sea, most cod reach sexual maturity at age 4, but are caught as early as age 2 with only 4% of age 1 fish surviving to age 4; clearly this level of exploitation cannot be sustained (Cook et al. 1997).

In the Yellow Sea, the composition of the fish community has changed over a 30-year period. Trawling for demersal predators (cod, *Gadus macrocephalus*; plaice, *Cleisthenes herensteini*; yellow croaker, *Pseudosciaena crocea*; and hairtail, *Trichiurus haumela*) significantly reduced the biomass leading to an increase in large pelagic species (herring, *Clupea pallasi*; chub mackerel, *Pneumatophorus japonicus*; and Spanish mackerel, *Scomberomorus niphonius*), which were targeted and subsequently declined due to fishing, to be replaced by small pelagic prey species (anchovies, *Engraulis japonicus*; *Setipinn taty*; and scaled sardine, *Harengula zunasi*) (Jin and Tang 1996). One endemic demersal species (seasnail, *Liparis tanakae*), with low commercial value, increased in abundance over the same time period (Jin and Tang 1996). In the Gulf of Thailand, trawling led to the disappearance of demersal rays and teleosts, with replacement by triggerfish (family Balistidae) and an increase in cephalopods due to reduced predation (Pauly et al. 1989).

In the Bering Sea and Gulf of Alaska, there was an explosive growth in fishing during the 1950s and 1960s. Fleets expanded from small coastal vessels to large industrial vessels targeting demersal and pelagic marine fish, invertebrates and salmon (Alverson 1992). In addition, there were major changes in oceanographic conditions leading to large-scale declines in abundance of salmon (*Oncorhynchus* spp.), herring (*Clupea pallasi*), pollock (*Theragra chalcogramma*), king crab (*Paralithodes camtschatica*), tanner crabs (*Chionecetes bairdi* and *C. opiliod*), and pink shrimp (*Pandalus borealis*) which resulted in a series of closures and collapse of the crab fisheries in the 1980s (Marasco and Aron 1991; Alverson 1992). The sea otter was hunted to extinction along much of the west coast of North America last century, which led to an increase in abundance of its prey species. Re-establishment of sea otters has led to significant declines in marine invertebrates preyed on by sea otters (Jamieson 1993).

Destructive fishing practices on coral reef assemblages have had a profound impact on ecosystem structure (Ohman et al. 1997). Overfishing of large predators has led to a increase in herbivorous fish which reduce the standing biomass of algal turfs and macroalgae (Watson et al. 1996). Overfishing of herbivorous teleosts, along with reduction in grazing echinoids from disease, has led to an bloom of macroalgae on Jamaica's coral reefs (Hughes 1996). Changes in abundance of predators can also have impacts in intertidal ecosystems. Excessive harvesting of a gastropod predator (*Concholepas concholepas*) led to an increase in mussels (*Perumytilus purpuratus*); closure of areas for harvesting produced an increase in predator abundance with a decline in mussels and an increase in barnacles (*Jehlius cirratus* and *Chthamalus scabrosus*) (Duran and Castilla 1989).

The long-term effects of large-scale disruptions to fish abundance and fish community structure are unclear. Some species, especially small pelagic species in upwelling systems, show natural large-scale fluctuations in abundance, but the impact of fishing and other anthropogenic changes may lead to larger and longer-term fluctuations. A recent review of the fishing down of marine food webs indicated that present exploitation patterns are unsustainable (Pauly et al. 1998). Experimental studies with terrestrial ecosystems have shown that loss of diversity can impair ecosystem performance (Naeem et al. 1994), and that preservation of biodiversity is essential for maintenance of stable productivity in grassland ecosystems (Tilman and Downing 1994).

Genetic comparisons before and after stock collapses have not been made. Stocks can have collapsed, from a commercial perspective, but might still maintain large population sizes and would not be expected to lose genetic variation due to drift. For example, the Icelandic herring (*Clupea harengus*) collapsed to 1/3 000 of its peak biomass, but its population would have consisted of about one million fish at its lowest size (Beverton 1990). The California sardine (*Sardinops sagax caerula*) fishery collapsed in the late 1950's, and remained below 1/250 of its peak biomass for twenty years before showing signs of recovery (Beverton 1990). This sardine (*S. sagax caerulea*) has low allozyme diversity, relative to other clupeiods (Hedgecock et al. 1989). This is unlikely to be due to the collapse of the fishery because other populations of Pacific sardine in Baja California and the Gulf of California, which were unaffected by the collapse, also have low diversity (Hedgecock et al. 1989), as do other species of sardine (e.g. *Sardinella aurita* and *S. longiceps*) that have not suffered a recent collapse (Kinsey et al. 1994; Menzes 1994). Genetic diversities at allozyme loci in post-collapse stocks of the Japanese sardine (*Sardinops melanosticta*) and the South African pilchard (*Sardinops ocellata*) are similar to other clupeoids (Fujio and Kato 1979; Grant 1985). Samples from the Georges Bank herring (*Clupea harengus*) fishery, which collapsed in the 1970s, were found to be different to neighboring populations in the Gulf of Maine at an enzyme locus and in year class structure, indicating that the stock recovered through resurgence and not recolonization (Stephensen and Kornfield 1990). However, allozymes measure only a small portion of the genome. Ryman et al. (1995) have pointed out that when large populations crash, they lose proportionally more of their alleles than small populations that decline to the same size. Thus, population crashes of pelagic species could have lost alleles that would not have been detected with allozyme methods. Molecular techniques allow the recovery of DNA fragments from dried scales and otoliths, providing an opportunity to measure genetic change in collapsed fisheries, through analysis of archived scale and otolith collections.

Policy aspects

- The problems and limitations of current fisheries management practices and policies are well documented (e.g., Botsford et al. 1997; Hilborn 1997; OECD 1997; Roberts 1997). The complexity of marine ecosystems and the large number of target and nontarget species exploited by fisheries has precluded so far the adoption of an ecosystems approach to management. This might have contributed to overfishing and stock collapses (Botsford et al. 1997). Nearly all artisanal and industrial fisheries target more than one species, yet management, especially of industrial fisheries, has focused on single species, with the aim of maximizing yields over the short-term, measured in years rather than decades. Management of fish stocks will have to consider other species in the food web and to consider environmental changes that may impact on stock sizes. Many of the problems of fishery management in artisanal and industrial fisheries are due to open access total allowable catches and the gross overcatching capacity; there is an urgent need to reduce effort through fleet reduction and closed areas (FAO 1996a).

- Involving fishers in the management of the resource should theoretically encourage a more responsible approach to exploitation; although short-term economic gains may outweigh long-term sustainability issues. Some have argued that the best hope for greater sustainability of ecosystems is to insulate management from the pressures from fishers for greater harvest (Botsford et al. 1997). Rights-based fisheries with individual transferable quotas (ITQs) provide long-term incentives for fishers, but are not popular in all communities due to restrictions on access. ITQs have been relatively simple to introduce in isolated island states such as Iceland and New Zealand, where there are few users, but will be more difficult to implement in artisanal and industrial fisheries with large numbers of fishers, having different political agendas. There is a risk that ITQs encourage high grading and discarding of quota species, leading to overfishing. In some fisheries, the fishers are increasingly involved in the management of the resource and ITQs are evolving into co-management schemes, where ITQs provide the instrument for stakeholders to manage the fishery (OECD 1997).

- The precautionary principle takes account of the uncertainties in aquatic ecosystems and the need to take action with incomplete knowledge. It can be applied to both industrial and artisanal fisheries at all stages of development (FAO 1996b). Taking a precautionary approach to fishery management shifts the burden of proof from managers, showing that fishing is having a negative impact, to fishers showing that fishing has no detrimental effect (see also Bartley and Pullin, this vol.). Similar approaches are used in the management of pesticides and clinical drugs (Peterman 1990).

- High value species with low mobility in the adult stages, such as abalone and clams, require more protection than simple input controls (such as legal size limits) in order to maintain the high densities for successful reproduction (Tegner et al. 1996). Reserves or marine protected areas (MPAs), could maintain a stock at adequate breeding densities in the short term, but even an MPA might not produce a large enough pool of larvae for extractive fisheries or long-term survival for species with extensive larval dispersal.

- Spatial restrictions on harvesting of target species (Carr and Reed 1993) can enhance neighboring fisheries (Watson et al. 1996). Practical demonstrations of the benefits of protected areas on external fisheries are limited, although protective management has resulted in higher yields to fishers outside an MPA in the Philippines (Alcala and Russ 1990). The required number, size and distribution of MPAs depends on species patterns of larval dispersal and recruitment, and on adult movements (Carr and Reed 1993; Watson et al. 1996). Extensive larval dispersal and adult emigration, characteristic of many marine species, create theoretical and practical problems for establishing MPAs, although marine species in general are less likely to suffer inbreeding and loss of genetic diversity through genetic drift than freshwater species. More research is desirable to test the impact of MPAs and to develop genetic conservation models, but the protection of critical resources cannot wait for another 10-20 years for the scientific jury to reach a decision. There is a need to establish more and larger MPAs in many aquatic environments and to monitor their impact. It is has been suggested that up to 20% of reef habitat should be designated as an MPA in the southern Atlantic with the remaining area subject to traditional fishery management policies (Bohnsack 1990). Certainly there is a risk that MPAs can provide a false sense of security, as they will not be sufficient to maintain stocks without management controls on harvest rates outside the MPA (Carr and Reed 1993). Monitoring and evaluation programs both inside and outside MPAs will be necessary to ensure that conservation and sustainable use goals are met. Temporary closures and moratoria should be considered for rebuilding of depleted stocks.

- The establishment of MPAs sometimes excludes fishers from traditional areas and thus requires local acceptance and management to be successful. Fiske (1992) compared the success of establishing marine sanctuaries in Puerto Rico and American Samoa. The critical factors in establishing and maintaining an MPA was the acknowledgment of local cultural and political systems. Success was achieved when local people were involved throughout the process. Beatley (1991), discussed the establishment of MPAs in temperate seas and noted the need for a balance of local and central control.

- Some loss of rare species and species with low population size and reproductive potential may be inevitable in industrial fisheries. Species with localized distributions, such as the coelacanth, may be protected in closed areas (e.g., a coelacanth national park (Bruton and Stobbs 1991) or by restrictions on fishing gear, but these measures will only be successful if displaced fishers find alternative employment. In the short term, international MPAs may have to be established with aid programs.

- There is a need for greater understanding of the interaction and impact of fishing and climate change on abundance of stocks. If quotas are to be adjusted to account for climatic influences, then regulatory methods must be responsive to short-term events to ensure that economic expectations are sound and that large fishing fleets, geared to periods of high stock abundance, are reduced in periods of low productivity to minimize overfishing (Ludwig et al. 1993; Beamish et al. 1997).

- In order to shift from a single species-based to an ecosystems approach to fisheries management, there is a need to define the biological components in the system. Aquatic species, especially salmonids but also marine fishes, are subdivided into regional stocks; yet many management zones in the North Atlantic are based on political rather than biological boundaries (Pawson and Jennings 1996). Molecular analysis of deep sea fish has revealed localized genetic differences among circumglobal species (*Cyclothone alba*) previously assumed to be monotypic (Miya and Nishida 1997).

- Illegal harvesting of protected species and overfishing of quota species can be difficult to detect at sea, but monitoring of fish catches with molecular methods can identify catches even processed into value-added product such as fillets. The US FDA has a regulatory fish encyclopedia (Tenge et al. 1993) and others should be established to address regional issues of illegal fishing.

- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has been successful in limiting trade in endangered species. Few marine fishes and invertebrates are covered by CITES, in part because many species are conceived to be at risk of commercial extinction, but not biological extinction. However, oceanic sharks and tropical reef fishes captured for the aquarium trade might be increasingly listed as threatened or vulnerable (Wells and Barzdo 1991). As with all international agreements, success depends upon member countries' monitoring and enforcing regulations. Currently the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) agreement on toothfish (*Dissostichus eleginoides*) in the Southern Ocean is being blatantly ignored by nonsignatory countries and by fishing companies from signatory countries which have reflagged vessels. Unofficial estimates put the global landings of toothfish at more than five times the recommended annual catch (Isofish 1998).

Impacts of Fishing on Nontarget Biodiversity

Fishing causes mortality on a wide variety of nontarget species of benthos, fish, birds, reptiles and mammals (Dayton et al. 1995; Alverson and Hughes 1996). Many nontarget species are vulnerable to exploitation due to their low reproductive rates and small population sizes relative to those of the target species. Genetic impacts on nontarget species are rarely measured, but these can pose risks of extinction of species and local populations. There is considerable anecdotal information for the negative impacts of trawling on benthic communities but scientific evidence is in part limited as there are few areas of virgin seafloor in the heavily fished coastal regions of the North Atlantic and Pacific Oceans (Jones 1992). Bottom trawling has two effects on the benthos: direct scraping and ploughing of the sediment and indirect effect of attracting predators to feed on damaged and discarded species. Up to 90% of the bivalve *Arctica islandica* that are caught in the beam trawl fishery in the southern North Sea are damaged (Witbaard and Klein 1994). Beam trawling on stable sediments in the Irish Sea has lead to a decrease in abundance and reduction in number of epifaunal and infaunal species (Kaiser and Spencer 1996). For deeper sea demersal fisheries, there is limited information on the number and distribution of invertebrate species, although there is a high species diversity and a high level of endemism in some deep sea environments (Probert et al. 1997). It is likely that these communities are less adapted to disturbance, from storm events, than shallow coastal communities. Furthermore, many species have not been described and no one would know if they were lost (Malakoff 1997). New species of marine invertebrates continue to be discovered, even in the well worked seas around Great Britain and Ireland (Costello et al. 1996). Expansion of fishing activities, coupled with an increase in taxonomic effort, has led to about 30 new species of fish being described annually from the New Zealand 200 mile EEZ, and about half of these are new to science (Roberts and Paulin 1997).

Around 27 million of biomass are discarded each year in marine fisheries, with the greatest discards in the northwest Pacific fisheries, although tropical shrimp trawl fisheries discard more than any other single fishery (Alverson et al. 1994). Small mesh trawls used in shrimp and prawn fisheries catch juveniles of a wide number of nontarget fishes and even adult turtles. Some species of turtle are already in danger of extinction from disturbance at nesting sites. A reduction in fishing mortality on adults is critical for their long-term survival (Anon. 1990). Turtle escapement devices are increasingly employed to reduce bycatch (e.g., Broadhurst et al. 1997; Rogers et al. 1997).

The largest industrial tuna fishery occurs in the western and central Pacific Ocean, where the resource is exploited by a variety of methods. Observer records show that the shark by-catch can be as great as the tuna catch in the long line fishery, but much of this goes unrecorded due to limited observer coverage and poor reporting of the fishery (Bailey et al. 1996). Some fisheries targeting rare or endangered species have been closed, but the target species can be caught in other fisheries, for example sturgeons (*Acipenser brevirostrum* and *Acipenser oxyrynchus*) in the shad gillnet, and prawn trawl fisheries off the southern Atlantic coast of the USA (Collins et al. 1996).

Destructive fishing methods, such as dynamite and poisoning with sodium cyanide, along with anchor damage, have led to localized reductions in both fish and invertebrate diversity on coral reefs. Modelling has indicated that the sum of current practices would continue loss of diversity and coral cover for 25 years before any recovery would be expected (Saila et al. 1993). Coral reefs are also under threat from other impacts such as coral mining, sedimentation and hurricane damage.

The rapid growth of some seabird colonies has been attributed to the amount of offal available from fishing vessels (e.g., Dunnet et al. 1990). The number of seabirds theoretically supported by offal and discards from fishing in the North Sea has been estimated as high as 5.9 million scavengers (Garthe et al. 1996). Increases in large scavenging species can have a detrimental impact on other seabirds through increased nest predation (Daily 1997). In other fisheries, scavenging seabirds are killed and longline fishing is having a detrimental impact on populations of albatrosses and petrels in the southern hemisphere (Murray et al. 1993; Moreno et al. 1996). Gillnet fisheries also kill nonscavenging species, such as auks in the northern hemisphere, which have low reproductive output and are vulnerable to additional mortality due to fishing (ICES 1991).

Porpoises and dolphins are caught in gill nets and pelagic trawls, but often the impact at the population level is unknown due to limited information on the distribution and abundances of these mammals. However, their low reproductive rates make these small cetaceans vulnerable to fishing mortality (Gislason 1994). Several species of porpoise have been reduced to very low numbers by indiscriminate gillnet fisheries (Jefferson and Curry 1994). The Steller's sealion (*Eumetopias jubatus*) population off Alaska collapsed between 1950 and 1990 and this is now a threatened species. Northern fur seals (*Callorhinus ursinus*) have also declined in abundance and are considered a depleted species (Marasco and Aron 1991). This sealion collapse occurred due to a combination of events: overfishing of dominant prey species, indiscriminate shooting, by-catch, and authorized harvest (Alverson 1992).

Policy aspects

- The catch of nontarget species varies considerably from fishery to fishery and area to area (Alverson and Hughes 1996) and requires specific regional measures to mitigate the impact of fishing. Global restrictions on some fishing methods may be effective, such as the ban on high seas drift net fishing in the Pacific Ocean (UN 1989). Some generic management measures have led to successful reductions in catch of nontarget species: for example, documenting the nontarget bycatch in order to identify and to determine the size of the problem through fleetwide observer coverage; the development of new or modified gear and protocols for harvesting; educating fishers about the impact of nontarget mortalities, to gain their support for technical or regulatory change; and public information campaigns through which the consumer can put economic pressure on inefficient fishing fleets.

- There is a need to develop less damaging harvesting methods especially in some recently developed deep sea fisheries, where trawling has been likened to clear felling a forest to harvest a few high value species. Further research is required to determine the impact of trawling on benthic communities but, in the meantime, it would be wise to adopt the precautionary principle, to assume that there is damage from trawling, until proven otherwise, and to restrict trawling in new fisheries. In other fisheries, there is a need to ban specific fishing methods, such as dynamite and poisons on shallow water reefs, and to restrict gill net fisheries that harvest marine mammals and seabirds. Seasonal closures and closed areas around mammal and seabird breeding colonies have been implemented in some fisheries. Other fisheries, such as the New Zealand southern squid trawl fishery, are monitored by observers and are closed when the sealion bycatch reaches a predetermined threshold level (Plan 1997).

- MPAs provide refugia from destructive harvesting methods, as outlined in section 3 above, and are required in the deep sea environment where heavy trawling gear is damaging benthic communities. Reserves range from complete protection, where all types of fishing are banned, to protected areas where some types of harvesting are allowed. Many marine reserves have been established in recent years but most are small scale and focused on coastal and sublittoral zones for scientific or recreational purposes, although a deep water reserve has been declared off Australia (Koslow and Exon 1995).

- Seabird by-catch by longline vessels has been significantly reduced by the use of tori poles and aerial streamer lines to scare birds away from the vessel. Education programs are required for fishers to ensure that tori poles are used on all vessels (Brothers 1994; Moreno et al. 1996). A range of additional mitigation measures, such as night setting, use of weighted hook-lines, thawed baits, restricting offal discharge, and hook size, can reduce the by-catch of albatrosses and petrels in Southern Ocean line fisheries (Murray et al. 1993; Moreno et al. 1996). Specific measures are likely to be required for each line fishery and may include closed areas or seasons around nesting islands. Independent observers are required on vessels to record the mortality of seabirds. In addition, programs are required to monitor breeding colonies so as to assess impacts due to fisheries and environmental change.

Fisheries have impacts on genetic resources at different levels. These impacts include selective fishing on stocks, genetic change in enhanced stocks, species extinctions, disruptions to ecosystems, and removal of non-target species. Most genetic problems relate directly or indirectly to overfishing and while biological solutions to problems of overfishing seem obvious, such as reducing fleet size in industrial fisheries and creating closed areas in artisanal fisheries, the socio-political measures to resolve the conflict between long-term conservation goals and short-term economic gains will be difficult to implement. Many of the pressures on aquatic genetic resources result from a direct pressure to feed the growing global human population. In addition to developing policies on fish harvesting methods and areas, wider policies promoting more efficient utilization of fish resources, and for controlling population growth will contribute to the conservation of aquatic genetic resources.

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Discussion

Harvey: You mentioned ICES-FAO Guidelines for Stock Enhancement. Where can we get copies of these?

Smith: I have a copy here. The reference is ICES 1996 (see also FAO 1993; Munro 1993; Thomas and Mathisen 1993; Benzie and Williams 1996, cited in Smith, this vol.). ICES makes some recommendations, mostly for hatcheries, on choice of broodstock and on the number of viable parents for producing seed.

Kapuscinski: There is a fair amount of debate as to whether 50 males and 50 females are appropriate minimum numbers for all species. There have been suggestions that 100 or even 500 might be more appropriate. A fixed number for all species probably doesn't make sense. It depends upon the life history of the species. This complicates the preparation of general guidelines for hatchery practice. This is not to say that such guidelines are not a good idea. They are very important. But they should not be treated as a 'cookbook'.

Smith: This point is covered in the ICES protocols. Fifty breeding pairs is taken as a rule of thumb. The intention is to raise the awareness of hatchery managers who frequently produce large volumes of seed from relatively few parents caught at sea. Our experience with abalone is that operators often use only 10 males and 10 females and frequently only one of the female spawns. From this, they can produce sufficient seed for a farm or for an enhancement operation. We have measured, just with allozyme data, a 25% loss of genetic diversity in that situation.

Pullin: You use the term 'nontarget' for species that are inadvertently caught. Devin Bartley and I have tended to use this term for the biota in the foodweb that support the target species–like phytoplankton etc. Has your use of the term gained common acceptance? I think that we have to decide on one use or the other.

Smith: I'm not aware that our use of the term has found its way into any legislation but it is used this way in fisheries management when considering bycatch issues. In this case the species might be the same, for example, when large numbers of juveniles are dumped.

Pullin: So, I think we have to let you have the term and we'll look for another.

Smith: Well, we'll have to tighten up our definitions as well.

Welcomme: You referred mainly to marine fisheries, so I'd like to add some comments on inland fisheries. Enhancement of inland fisheries is becoming a major trend, especially in food deficient areas. A large proportion of the world's inland waters is now so damaged that stocking, in order to mitigate the damaged to stocks caused by fisheries and by other users, is now becoming a standard and widespread technology. I suggest that the same trend will occur in coastal fisheries as they and their environments experience the same pressures.

Schei: You mentioned threatened species and threatened stocks. In some countries, there is concern over the criteria used by IUCN and others to define what is a 'threatened species'. For example, it doesn't make sense to list the cod as a threatened species. From the international and political point of view, it is necessary to develop some new criteria for threatened stocks and species of fish. They may be 'economically' threatened rather than threatened as such. On the other hand, there is a need to determine what are the implications of loss of biodiversity for the functioning of ecosystems. We need to find new ways of defining the negative consequences. Do you agree?

Smith: I certainly agree and we'll hear more on this in Rainer Froese's presentation. Regarding description of ecosystems, it will take a long time, longer that our lifetimes, to determine whether these changes are permanent. Fishing, coupled with climate change will have large effects on the abundance of predatory species.

Wang: Can you comment on the recent World Trade Organization ruling on turtle excluder devices and the US Congress debate on ecolabelling.

Smith: I have no practical experience of that fishery.

Kapuscinski: The US National Academy of Science convened a Study Group that produced a book (National Research Council 1990). This concluded that turtle excluder devices were effective and did not reduce the yields for fishermen. On the US East Coast, some fishermen had already begun to develop their own turtle excluder devices and then teamed up with university-based engineers. Congress then passed a bill that required all fishermen in the USA to use turtle excluder devices. These devices are now starting to be used in the Gulf of Mexico, although some fishermen have complained about this.

Wang: My question was about the WTO ruling.

Kapuscinski: Well, the US Congress recognized that it was necessary for fishers to use turtle excluder devices because of the requirements of the US Endangered Species Act. Then other countries tried to sell shrimp from fisheries where the devices were not required. When the US prohibited entry of their products, the countries protested to the WTO that this was an unfair trade barrier, and the WTO agreed with them. This ruling was released last week.

A. Gupta: There was also a WTO ruling about the tuna-dolphin case and many NGO's protested this. The dispute was between Mexico and the US. The ruling was that the US could not apply its laws in water beyond its jurisdiction. For example, Asia-Pacific waters are outside this jurisdiction, so the catching of dolphins by tuna fisheries in these waters was not a matter for the US. Secondly, the WTO ruled that the US position was discriminatory in nature. Dolphins are caught by tuna fishermen in other waters than those in which the US was trying to impose restrictions. These matters should really be considered as environmental issues not trade issues. The WTO will surely review them further.

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Preparation and Implementation of Fisheries Policies in Relation to Aquatic Genetic Resources

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ABSTRACT

In recent decades, intensive urban, industrial and agricultural activities have had a negative impact on natural aquatic habitats. Fisheries and aquaculture activities are sometimes blamed for endangering the sustainability of the genetic diversity of species in aquatic habitats. Such activities include: habitat destruction; pollution of adjacent waters by intensive production; effects of antibiotics and other chemical treatments; intensive collection of wild seed; competition between endemic fauna and escaped alien species, including predation by the latter; introduction of pathogens; and genetic introgression between local fish populations and alien or farmed populations, species and transgenics. Because policymakers are rarely experts on all of the issues within their mandates, they often depend on external sources to: (1) define specific necessities (local, national, international); (2) assess previous experiences; (3) review professional opinions of experts; and (4) acknowledge legislative boundaries. The interactions between aquaculture and aquatic environments have generated a number of different and often controversial attitudes. The introduction of alien species has always been hotly debated. In Israel, where inland aquaculture is well developed, many introductions of alien species have been done nevertheless. To date, no adverse effects have been reported. No solution has been found to the problem of the uncontrollable introductions of ornamental fish. Responsibility for legislation concerning aquatic genetic resources is often partitioned between different governing bodies, which often have a considerable overlap of authority. The codes of conduct formulated by international organizations, such as ICES and FAO, are important contributions, which support administrators in the long and tedious process of the preparation of laws, regulations and policies. Considering the budgetary limitations, organizational problems, political pressure and public opinions that exist in all administrations, advisory bodies should recognize that what might seem to be an optimal solution to a problem is not always the best option.

Introduction

In recent decades, intensive urban, industrial and agricultural activities have had negative impacts on natural aquatic habitats. Fisheries and aquaculture activities such as the construction of farms, introduction of alien species, genetic manipulation and overfishing have been blamed for endangering the genetic diversity of species in aquatic habitats Administrators, whose task is to define laws, regulations and policies, often operate from a different perspective than the bodies that have been established to provide them with advice. They are expected to make decisions on policies and to assume responsibility for their acts. To do so, they have to rely on professional inputs from dependable sources, to decide which avenues to take, and to prepare feasible plans, according to organizational and budgetary limitations. Within this process, they are often exposed to political pressure, economic interests, and administrative overlaps as well as public opinion—which, in some cases, is based on ignorance and hysteria. In this paper, the main factors that affect decisionmaking, in relation to aquatic biodiversity from the viewpoint of fisheries and aquaculture administrations, are reviewed together with some related problems and dilemmas.

Fisheries and Aquaculture: Factors that Affect Aquatic Genetic Resources

Because policymakers are rarely experts on all issues within their mandates, they often depend on external sources to: (1) define specific (local, national, international) necessities; (2) assess previous experiences; (3) review professional opinions of experts; and (4) acknowledge legislative boundaries (Fig. 1). In decisions concerning the conservation of natural environments where a multitude of factors are interrelated and the significance of basic terms such as "biodiversity" is still being discussed (e.g., Beardmore et al. 1997), it is not surprising that expert advice can range from apocalyptic predictions to nonchalant attitudes. In the next section, some examples are presented of how the factors mentioned above can affect the preparation of policies related to aquatic biodiversity.

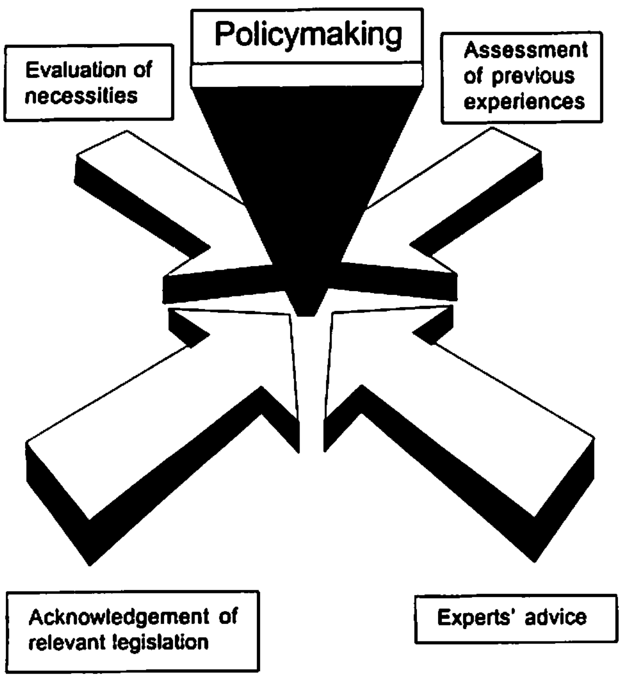

Fig. 1. Inputs affecting the process of policymaking.

Examples of 'Necessities' from the Viewpoint of Fisheries and Aquaculture Administrations

State of global fisheries

According to FAO statistical reports (1996), world fisheries may not be adequate to meet future demands. By 2010, the demand for fish is expected to reach 140-150 million t as opposed to 80 million t in 1995. On the other hand, the world fish supply from marine and inland capture fisheries is expected to follow one of two scenarios. According to the pessimistic one, supplies in year 2010 will reach 107 million t, 33-43 million t short of the expected demand. According to the optimistic one, production will just about meet the expected demand of 140 t. To fulfill these expectations, aquaculture production is required to grow from 21.6 million t in 1995 to 39 million t in 2010: an increase of 80.5% (FAO 1995). This situation undoubtedly increases the incentives for governments and private entrepreneurs to develop aquaculture wherever possible and whenever it seems profitable do so (Fig. 2). It also emphasizes the need to develop aquaculture as a means to alleviate the pressure of human activities on aquatic genetic resources (AGR).

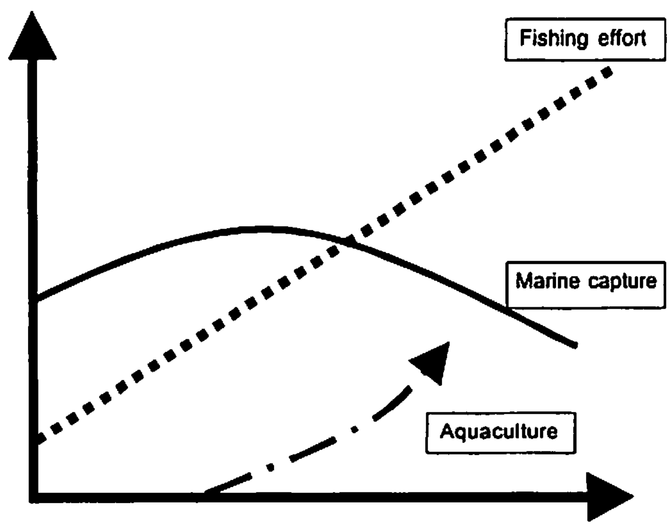

Fig. 2. The expected mutual impacts and tendencies among the global fishing effort, marine catches and their effect on aquaculture production.

Conservation of aquatic genetic resources

The dramatic increase of the rate of extinction of species in certain environments, as compared to pre-human times (Beardmore et al. 1997), is arousing concern among international agencies, governments and conservationists as well as among fisheries administrations. These concerns have generated the necessity to try to safeguard natural resources for the generations to come. Most fisheries and/or aquaculture activities inevitably take a toll on the environment. Beardmore et al. (1997) enumerated seven impacts of the development of aquaculture and described their potential effects on AGR. These impacts can be summarized as: (1) habitat destruction; (2) pollution of adjacent waters by intensive aquaculture; (3) pollution from antibiotics and other chemical treatments; (4) depletion of stocks from intensive collection of wild seed; (5) competition between endemic fauna and escaped alien species, including predation by the latter; (6) increased disease from introduction of pathogens; and (7) loss of genetic diversity through introgression with local fauna by introduction of alien populations, species and transgenics.

Administrators need to assess previous experiences for each of the possibilities mentioned above and to draw upon expert advice, so as to reach conclusions on how potential impacts can be integrated in the decisionmaking process.

Assessment of Previous Experiences

Habitat destruction

All aquaculture developments utilize resources and cause environmental changes. Some of them might also have destructive effects on aquatic habitats (GESAMP 1991), yet the impact of these factors has rarely been quantified and the "potential adverse effects of aquaculture are still of speculative nature" (Barg 1992). Coastal areas, on the other hand, seem to be very susceptible to environmental changes. For example, mangroves host and support multitudes of AGR. Their destruction, in favor of economic developments, including aquaculture, can cause severe damage to coastal environments (e.g., Phillips et al. 1993).

Whether these negative experiences are taken into account in the process of policymaking depends heavily on available legislative measures, the power of governments to enforce them, public opinion, business opportunities and political interests.

Pollution of adjacent waters by intensive aquaculture

The experience gathered on interactions between aquaculture and aquatic environments has generated a number of different and often controversial attitudes. Mires (1995) described four categories of aquaculture systems and showed how each interacted differently with their adjacent environments. Retention of runoff water in fishponds contributes to purification and therefore has a beneficial effect on the environment. Closed water systems, which by definition release little water, do not affect aquatic environments and their biodiversity and cannot be put in the same category as open water systems or cage culture, in which all farm outputs are directly released to receiving waterbodies. In a comprehensive bibliographical study, prepared for the Commission of the European Communities Directorate General for Fisheries (Munday et al. 1992), the editors concluded "... it can be said that quantification of the outputs generated by aquaculture does not match the public perception of the severity such outputs will have on the environment".

Effects of antibiotics and other chemical treatments

The development of drug-resistant microbial communities is the main danger related to the use of antibiotics in aquaculture and other industries. A correlation has been found between the quantity of antibacterial compounds used in cage farms and the number of resistant bacterial populations in their vicinity (Herwig et al. 1997). Although experimental work in the laboratory has suggested that the cessation of treatment can lead to a rapid decline in the levels of antibiotic-resistant organisms, it has also been found, under laboratory conditions, that some antibacterial compounds persist in sediments after three months (Samuelson et al. 1994). In experimental tanks, which simulated fish and shellfish farms in salt-marsh conditions, the disappearance of oxytetracycline occurred in two phases: with average half lives of 30.2 and 318 hours, respectively (Pouliquen et al. 1993). In marine cages, oxytetracycline was detectable within an area only twice as big as the cages themselves (Coyne et al. 1994). Spanggaard et al. (1993) compared the antibiotic resistance in bacteria sampled from Danish trout farms, their adjacent streams and unpolluted streams and concluded that microflora did not seem to be affected by intensive fish farming and the use of antimicrobials. The use of antibiotics in aqua-culture is sometimes used as an example of the selfish irresponsibility of the aquaculture industry towards the environment. However, these allegations are often exaggerated. It is in the economic interest of aquaculturists to use such drugs as rarely as possible.

The long-term effects of specific chemicals, especially pesticides and other bioactive agents have not been well studied (Munday et al. 1992). Nevertheless, some applications, even if short term, might have a negative influence on AGR. Sublethal effects are difficult to detect (Wester and Roghair 1994); for example, impairment of reproductive function which undermines the ability of aquatic organisms their chances to compete with others over territory or nutritional resources. On the other hand, failure to use appropriate drugs to treat disease condition can lead to disastrous economic and environmental results.

Intensive collection of wild seed

The overexploitation of fish stocks can also be discussed in the same context as the intensive collection of wild seed. Both activities have the potential to be detrimental to biodiversity. The estimated mass collection of glass eel in Portugal averages 210 t·year^{-1} (Moriarty 1997) and millions of elvers are used directly for human consumption. This is an example of how natural resources are wasted. Had they been used for the recruitment of fishponds or left to grow in their traditional habitats, the same amount of seed could probably have produced thousands of tons of eel. In fact, the recruitment and catch of glass, yellow and silver eel have declined considerably throughout Europe since the late 1970s. However, there appears to be no single proven cause for declining recruitment and there are few data available for natural mortality between immigrant glass eel and emigrant silver eel (Moriarty and Dekker 1997).

Technologies for induced reproduction of fish and other aquatic organisms developed so far have shown that, in the long run, aquaculture will not have to depend on the intensive collection of wild seed. By supporting research in this field and by enforcing fishing regulations, governments can help limit negative impacts on the genetic diversity of wild stocks.

There are several approaches to the replenishment of overexploited fish stocks in natural environments: (1) mass release of nursed fry; (2) the declaration of spawning areas as permanent or *ad hoc* nature reserves; (3) the closing of fisheries during certain periods of the year; and (4) habitat restoration. The first seems to be effective in lakes and rivers but its effectiveness in oceans still needs to be proved. The second and third options are elegant solutions, based on natural recovery, when human intervention is suppressed, and the fourth depends upon resources managers helping natural processes to recover.

Possible effects of introduced alien species on natural fauna

The Group of Experts on Scientific Aspects of Marine Pollution (GESAMP 1991) has published a bibliography with specific information on the contamination of wild stocks by alien species via aquaculture. Based on Israel's experience, it can be said that one of the most important sources of introduction and transfer of pathogens is the ornamental fish industry. This trade in fish and other aquatic organisms, that are packed alive in millions of oxygenated plastic bags, and flown from one part of the globe to another together with water from their origin, is extremely difficult to control. Veterinary services at airports cannot cope with inspecting such large quantities, and rely on health certificates issued in the countries of origin even when, in many cases, these documents are not reliable. Legislation does not require the use of quarantine for these fish, mainly because of the high construction and running costs of such installations and the reluctance of government authorities to assume responsibility for any damage caused to the fish while held by them.

Capture fisheries are comprised of many species. If aquaculture is to contribute a similar choice of species for consumers, aquaculturists might have to enhance their efforts to diversify the fish species that are farmed. Diversification implies the introduction of alien species and/or the transfer of native ones or creating new types through genetic manipulation, with the possibility of their inadvertent or intentional introduction into natural aquatic environments.

The introduction of alien species has always been a controversial issue. Conservationists have traditionally opposed introductions while most aquaculturists have encouraged them. Israel, where inland aquaculture is well developed, has introduced about 20 alien species and hybrids (18 finfish and two crustaceans) for aquaculture or stocking purposes. Unfortunately, some introductions were not accurately recorded. Until 1991, introductions of alien species or genetically modified ones to Israel were not submitted to any legal formalities or debates. In spite of these numerous introductions to Israel, there have been no indications or formal complaints of any adverse effects on biodiversity. It must be noted, however, that apart from Lake Kinneret and the upper Jordan River, whose ecological balance is of vital importance, Israel lacks other extensive inland aquatic ecosystems and fauna that could be damaged by alien species. Moreover, the introduction of alien tilapias to Israel did eventually contaminate wild stocks of *Oreochromis aureus* in Israel.

The water quality of Lake Kinneret, which supplies 30% of the water used for human consumption in Israel, is strongly dependent on the maintenance of an ecological balance among its aquatic species. In spite of the numerous introductions of alien species, the quality of this water has remained good. This indicates that detrimental effects to water quality and ecosystem functioning have been negligible. Had policymakers followed the advice of those groups opposing introductions, a loss of commercial opportunities would have ensued.

In contrast, the introduction of a large predator such as the Nile perch (*Lates niloticus*) in Lake Victoria is a clear demonstration of the catastrophic effects that certain interventions can have on the genetic biodiversity of some lakes (Wooton 1990).

Review of Experts' Opinions

There are three forms of expert contribution to the process of policymaking: (1) literature; (2) targetted research and/or surveys aimed to provide answers to specific questions; and (3) verbal and written opinions.

Literature

Existing technical and other relevant literature describe previous experiences. Because of lack of time or professional limitations on certain issues, policymakers do not usually study lengthy papers. Even if they do, they are often faced with diverse opinions that leave them to decide on their own which option to choose. For example, in Israel, in discussions held in the Ministry of the Environment, some experts claimed that further development of cage culture in the eastern part of the Gulf of Eilat (Gulf of Akaba) will cause irreparable damage to the coral reefs located on the west and that this activity should be stopped or reduced. Others claimed that since no noticeable damage in the environment has been noted beyond the close periphery of the cages, there is no reason for governing agencies to interfere. The Minister in charge chose to compromise and solve this dilemma arbitrarily by allowing farms to add another 1 000 t of feed with which 500 t more (+33%) of fish can be produced. He also ordered the continuation of monitoring.

Targetted research and surveys

Targetted research and surveys have advantages as well as some limitations. In the case of overfishing, statistical surveys by experts, before and after restrictive measures are taken, can supply important information on the validity of these steps. On issues such as the introduction and transfer of alien species or of genetically manipulated organisms to natural aquatic environments, it is not always possible to appease doubts concerning the possible impact of these introductions, by means of experimentation or simulation. The latter can supply information on issues concerning the biology of the organisms and their commercial potential but not on their chances of substituting or coexisting with the fauna and flora of natural environments. Once all possible information about the behavior of introduced alien species in controlled environments has been studied it is up to decisionmakers to decide whether there is sufficient evidence to support the assumption that their distribution out of experimental facilities will not cause irreparable environmental damage to AGR. In Lake Kinneret in Israel, for example, where no endemic predatory fish exist, the introduction of alien predators is limited to fish that in controlled experimental conditions have shown that they cannot reproduce in freshwater. Thus, eventual damage to the environment is limited by the life span of the introduced organisms and stopping further introductions can reverse negative trends. Oppositionist groups could have claimed that the inhibited maturation of these fishes in experimental ponds does not necessarily indicate that in nature they will not reproduce but in this case they chose not do so.

Verbal and written opinions

Solicited verbal and written opinions require the input of the expertise of knowledgeable persons in fields relevant to the debated issues. These persons are asked to pronounce their views about what they believe will happen if certain administrative steps are taken. A consensus among a number of experts on debated issues is always more dependable and more appreciated than opinions obtained by a majority of votes or on one expert alone and should therefore be preferred.

Acknowledgement of Legislative Boundaries

In many cases, responsibility for the enforcement of laws and regulations concerning the conservation of AGR is partitioned *ad hoc* among different administrations. In Israel, for example, responsibility for the introduction and transfer of aquatic organisms is in the hands of the Department of Fisheries and Aquaculture (DFA) in the Ministry of Agriculture and Rural Development. The Authority of Nature Conservation (ANC), which functions within the Ministry of Infrastructures, is responsible for safeguarding all nature reserves, national parks and monuments, as well all organisms which are on the list of endangered species. Opinions are that the introduction of alien species for aquaculture enhances the possibility of their accidental entry into protected areas and endangers their flora and fauna. Nevertheless, because fish farms are not within the jurisdiction of the ANC, the possibility of any legal intervention on its part is very limited.

Regulations concerning the treatment of diseased fish can be dealt with under two jurisdictions. According to the Fisheries Law, aquaculturists are obliged to inform the DFA about any outbreaks of disease in fish and the Director of the DFA has the authority to take action relevant to the situation. In parallel, the law concerning animal sanitation falls under the authority of the Veterinary Services (VS). However, since this law was decreed, the VS has not added any operational regulations to it and the only link that it has with aquaculture relies on the word "fish" which appears in the long list of animals under VS jurisdiction. Indeed, the legal authority given to the veterinary profession to treat aquatic organisms, to prescribe drugs and supply sanitary certificates, is unclear in many countries.

Similar legal conflicts on the potential ecological impacts of farms on the environment exist between the Ministry of the Environment (ME) and the DFA. Here again, legislation does not always provide standards with which farms must comply. Thus, important issues are often discussed between farmers and the relevant government officers, but are not always resolved.

The following are some examples of how the kind of inputs presented above have been integrated into applicable policies in Israel.

- Fish farms in Israel must be licensed to operate. Through this measure the DFA plans to regulate the operation of farms and to minimize any negative impacts on the environment. The policy of the DFA is to minimize any detrimental effects caused by farm effluents on the environment and to biodiversity. Hence, the development of closed and recirculatory water systems has been given high priority in research programs.
- A compromise has been reached between the DFA and the VS over environmental safeguards concerning the use of antibiotics. The VS formulates policies and is responsible for enforcing legislation and regulations for drug use, sanitation in fish packing and processing plants, and the implementation of relevant international sanitary regulations in the agricultural sector. The DFA, via the Central Laboratory of Fish Diseases, controls the prescription of legal drugs and antibiotics and supplies advisory services to farmers on fish pathology and sanitation.
- Wherever possible, the establishment of aquatic nature reserves is considered one of the most efficient tools for (AGR) conservation. In some cases, the contribution of these reserves to biodiversity conservation exceeds by far that of other approaches, such

as the establishment of genebanks. Moreover, the maintenance of nature reserves may be cheap. The role of fish farms here can be ambivalent. It is recognized, nevertheless, that nature reserves are not a complete solution to the problems of conserving AGR *in situ* and undisturbed.

Inland aquaculture has added new environments in and around which multitudes of new aquatic species have emerged. This development has also enhanced dramatically the proliferation of migratory aquatic birds, especially pelicans and cormorants that thrive on ponds but that endanger profitability. By unilateral decision, and in spite of protests, the DFA supports legal actions taken by farmers to destroy bird habitats within farm premises and harass the birds with the intention of shortening their stay in farms.

Policymaking

In situations similar to those described above, harmonization between aquaculture development projects and the conservation of AGR requires the adoption of decisionmaking strategies, often under uncertain and somewhat chaotic conditions. Natural aquatic environments are exploited by a number of users. Some, for example capture fisheries, have a direct impact on its populations while others may affect them indirectly by dumping their wastes in them. Some exploit aquatic environments and compete heavily with AGR while others can be more environmentally friendly. Some human activities in and around natural aquatic environments will function within legal boundaries while others will not. All these factors create mutual impact zones that require the adoption of different policies, that are or should be governed by laws.

A model describing the evolution of policymaking is presented in Fig. 3. Identification of necessities and definition of general and specific aims begin the process. These are listed by order of priority. Thereafter, the interests of affected parties and stakeholders are identified and assessed, areas of conflict are recognized and information gaps are identified. A study of relevant previous experiences is done through consultation with experts and legislators, and literature reviews. Four options for actions emerge: (1) do nothing; (2) act unilaterally; (3) compromise; and (4) remedy information gaps by means of experimentation and/or simulation. Often, in spite of efforts, some information gaps persist. In such cases, policymakers can either decide to take risks and act or not to do anything. Following the choice and implementation of any of these paths, an evaluation is done to assess results and new priorities are set as findings emerge.

Conclusion

Regulatory measures concerning fisheries and aquaculture and their effect on AGR are taken at government and/or ministerial levels. In this respect, international codes, such as ICES (1994) and the FAO (1995), are important contributions that assist administrators in the long and tedious process of the preparation of laws, regulations and policies. Considering the budgetary limitations, organizational problems, political pressures and public opinions that exist in all administrations, advisory bodies should consider that what may seem to be an optimal solution to a problem is not always the best option. When a cost-benefit evaluation of a proposed solution is not clear, policymakers often reject it altogether. For example, regulatory policies favoring the conservation of AGR at

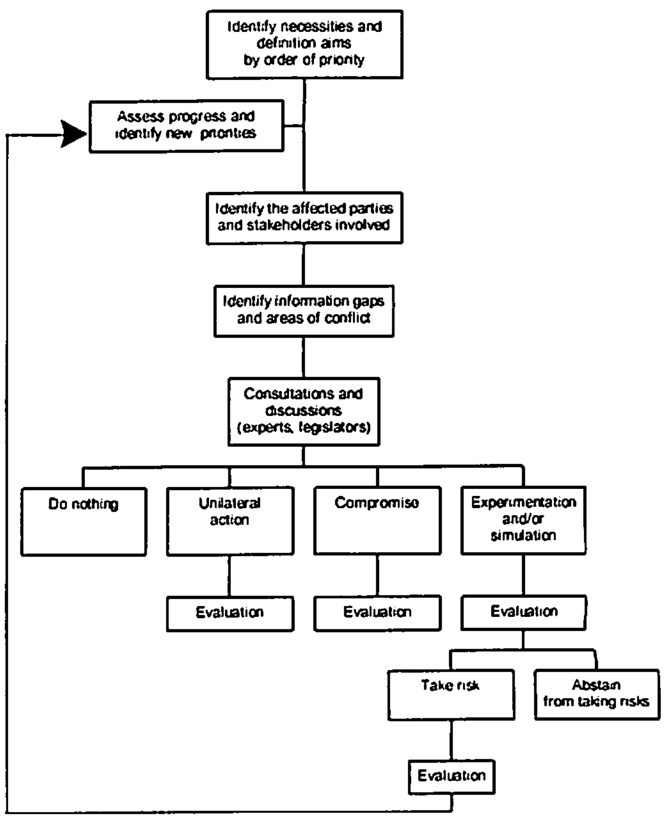

Fig. 3. A model of a process of policymaking.

the expense of high-income industries such as tourism may be rejected under the pretext that the price to be paid for their implementation does not match the benefit obtained. On the other hand, modest but effective suggestions can still make important contributions to the solution of problems. For example, measures such as the establishment of nature reserves, control of fishing efforts, restrictions on drug use and farm licensing are examples of policies that can be relatively easy to accept and implement, depending upon local circumstances. Suggestions such as the establishment of fish genebanks and worldwide databases on aquatic species may seem ambitious to national administrators, less relevant to local necessities and of doubtful benefit.

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Discussion

Pullin: I like your analysis very much, but in your schema about 'demand' should you not include sectors other than fish? Their products interact with the demand for fish. For example, economists compare the relative prices and availability of chicken and fish. As far as I know, they don't yet compare the economic implications of the environmental impacts of chicken and fish production systems. But I think that we all need to consider, whether we are aquaculture enthusiasts or not, that to fill the widening gap between fish supply and demand entirely with farmed fish might not be environmentally a good idea. The fish supply-demand gap can also be filled, in part, by people eating other things.

Mires: I agree, but my point of view comes from the position that I hold. I cannot do anything without legislative backing and I cannot do things for others in other positions.

Pullin: I appreciate that. The way in which ministries are organized, have their budgets set, and have their performance assessed is very often unisectoral.

Mires: I agree with that also. That is why I would like to compromise with other administrations in order to have a policy. That is why meetings like this are very important. If there could be a code of conduct through which different administrations could pursue the same aims, they could get better results. However, when the fisheries sector faces very conservative views from environmentalists who leave absolutely no gap for the further development of an industry that is required to feed the population, then you have to take unilateral decisions and all the conflicts come after that. There is a need for flexibility on both sides. Again, that is why I say that these meetings are so important.

Pullin: I also have a comment about alien species introductions. When Israel introduces alien species, it seems that these are sometimes not only for use within its borders but for use in extending Israeli technology and those species to other countries.

Mires: Not any more.

Pullin: Well, I was once criticized for not supporting, without prior appraisal of environmental impacts, the widespread introduction across Africa of Chinese black carp that were supposed to be going to eat enough snails to solve the bilharzia problem. I suggested thorough prior appraisal and was accused of wanting to keep Africa as a museum and of not caring about the health of Africans. Incidentally, I'm pretty sure that snail eating fish alone would not dent the bilharzia problem very much. My point is that a country that imports alien species needs to be careful about appearing as a kind of springboard for their further introduction to other countries.

Mires: Well, that is not the aim. I am only looking at lists of aquaculture species for use within Israel. But the aquatic environments there are very important. Israel has only one lake and that lake produces over 30% of the water needed for the human population. Any disruption of that aquatic environment would very dangerous. That is why we have not allowed the introduction of predators. Nevertheless you will find bass on our list. These are found at locations south of the lake and we are hoping to contain them there – and so far we have been able to do so. There are measures to be taken against people who break that regulation. This law is applied.

Froese: I enjoyed very much your talk as you are a policymaker. We scientists can usually say anything that we want, whereas I appreciate that policymakers cannot always do that. Concerning introduced species, we have a database on species that have caused problems, and so are best avoided or eradicated. I think that I saw some on your list. For example, *Oreochromis mossambicus* is considered a pest in some countries.

Mires: Like carp for example?

Froese: Yes, carp is considered a pest in Australia. Mosquito fish are now considered pests in some countries because they compete for feeding with local fish and they do not really do their job well of feeding on mosquito larvae. Do you have any comments?

Mires: Yes. There is a lot of luck involved in what happens with introductions. For example, carp could have reproduced in the only lake that we have, Lake Tiberias, but they don't. The lake has no predatory fish, so why don't the carp reproduce there? I don't know. They have reached some kind of balance. Some exotic strains of tilapia also entered the lake, but they have not taken over. Today, we are much more careful. My feeling is that omnivores are better candidates for introduction, not large predators.

Raymond: Could you expand a bit on your comments concerning the effects of public or political pressure?

Mires: Well, in Israel there are always many points of view and it is virtually impossible to bridge them all. For example, the issue of introductions is very widely debated. The nature reserve authorities would like to interfere and usually oppose introductions. However, the law has given that authority to the Director of the Fisheries Department. The nature reserve authorities fear that introduced species will eventually reach the reserves, which are under their authority. If we could have a dialogue, then we could work out better solutions and policies.

Kapuscinski: I was interested to hear your comments about the lake and introduced species. You said that you were essentially 'lucky'.

Mires: There are other examples.

Kapuscinski: The 'take home' message is probably that we need to take very seriously the variability of ecosystems around the world. There is a big challenge for science here. We have to be very careful about generalizations. We need to learn the lessons about what has happened in different places, but to realize that a case-specific approach is usually needed. I'll present further information on this tomorrow.

Mires: I agree. We have adapted our policies in recent years. There is, for example, a Committee of Experts for the introduction of species – and no introductions are allowed unless they have been approved by that committee. Predators can only be introduced if they will not reproduce in inland waters. For example, lately we have authorized the introduction and dispersion of the red drum (*Sciaenops ocellatus*) because it will not reproduce. So, if it happens to be a pest or causes any damage, this is reversible. We use our station on the coast for receiving introductions and all its effluents go to the sea. So, any escapees can only reach the sea, not inland waters. I also believe that if aquaculture is going to substitute for a lot of marine fisheries, it has also to come close to the diversity that marine fisheries provide. We could cover our whole country with carps, but there would not be a market for them. This is why introductions are for us a necessity.

Kooiman: We have been working on the situation in the North Sea and we have found that, for many issues, legislation is not a very good instrument. There need to be other options. For example, there is now a lot of interaction between environmentalists, fish processors, and the supermarkets on the question of replacing fish with chicken, etc. It is very difficult to influence these situations with legislation. In general, regulations, legislation and other traditional instruments work only in very selective areas. People tend to think 'Well, let's have some legislation and then the problem is solved.' Usually, this is when more problems start.

Mires: The market will decide to what extent chicken takes over from fish. I cannot change that by applying any policy as long as there is fair competition. The fact is that the demand for fish is increasing. If there are constraints placed on the further development of fisheries, then there will be imports of fish from countries where they have less environmental problems.

Schei: The missing element, nationally and internationally is 'liability.' There are very few agreements or regulations on how to apply liability.

Mires: By that do you mean assigning responsibility?

Kapuscinski: If something goes wrong?

Schei: Yes. Who is going to clean up the problem? This provision is also lacking in the Convention on Biological Diversity. Do you have any legislation or rules in Israel as to who is 'liable' if they, for example, introduce a species that turns out to be detrimental? And do you have rules that make it possible for private persons to sue the government if the government is responsible? In Norway, 20 years ago, we introduced *Mysis relicta* as a food for fish, but it turned out to be the wrong type of fish that ate this crustacean. The introduction was made on the best scientific advice available at the time but still a judge decided that the government had to pay compensation to those affected. Do you have anything like that?

Mires: Not in legislation. Of course, theoretically, persons are responsible for their decisions and can be sacked if things go wrong. But it is a good point that you have there. People can of course go to courts and complain, but there are no rules on this. It would also be quite difficult to present damages vs. advantages in some cases.

Utilization of Genetic Resources in Aquaculture: A Farmer's View for Sustainable Development

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ABSTRACT

Aquaculture, as practiced today, uses many species and relies significantly on wild genetic resources. One of the most economically important aquaculture industries, shrimp farming, is discussed in this paper as an example. There are aspects of shrimp farming that may have strong influences on natural biodiversity, such as the introduction of alien species, movement of diseased stock, and farming practices, which use materials that may have impacts on the environment. It is important to formulate policies and to make recommendations to encourage the development of suitable technologies that properly address the needs of both aquaculture and the conservation of aquatic genetic resources. The domestication of aquaculture species, increasing utilization of recirculating or low exchange systems, and sensible utilization of genetic resources are some of the most critical areas for consideration in shrimp farming. The future growth of aquaculture and the potential impacts that it might have on aquatic genetic resources will depend greatly on the formulation of correct and sensible policies. Such policies must consider both the future development of aquaculture and the protection of nature, biodiversity and the environment. Policies which encourage responsible action, such as reduction in dependency on natural genetic material, and the thoughtful and careful introduction and movement of farm stocks, will achieve far greater results toward this goal. The possible positive impacts that aquaculture might have on the conservation of aquatic genetic resources through relieving pressure from fisheries cannot be overlooked.

Introduction

In the history of human development, it has never been more apparent that human activities are having a tremendous and potentially irreversible impact on the planet. The rapid pace of technology development and the increase in human population during the last century have placed great pressure on natural resources. In many cases, humans have caused irreversible damage to the natural state of the planet without fully understanding the consequences of their actions. There has been an increasing escalation of human activities bringing changes to aquatic environments. Humans are increasingly using the world's precious waters for direct consumption, to irrigate fields, for generation of power, for use in industry and to carry away wastes. Humans use living aquatic organisms for food, recreation, medicine and many other uses. The use of water resources and aquatic organisms has had and will continue to have profound impacts on aquatic genetic resources.

The purpose of this paper is to examine how aquaculture, with shrimp farming as an example, can develop responsibility in the future by introducing appropriate aquaculture. The hope is that, with thoughtful encouragement and sensible policies, aquaculture can co-exist with the natural aquatic biodiversity of this planet. The future of aquaculture might never be fully separated from natural biodiversity, but the utilization of natural genetic resources will probably decrease through technology advancement. Indeed, aquaculture products might, to some extent, relieve some of the environmental pressures of capture fisheries and thereby have a positive impact on the world's limited fishery resources.

Aquaculture employs millions of people, directly or indirectly. Although precise numbers are difficult, FAO reports that 28 million people were involved with fishing or fish farming at the beginning of the decade, and that incomplete reporting revealed 5.7 million were involved in aquaculture in 1996. Ecuador, whose major farmed product is shrimp, reported 152 000 people involved in 1996, whereas Indonesia, a country that produces more fish, but still produces more shrimp than Ecuador, reported 2.1 million involved in some type of fish farming. Thailand, the world's leading shrimp producer, did not report information on number of people involved in fisheries or aquaculture to FAO (FAO 1999b). The majority of fish farmers live in developing countries. Their awareness of the issues discussed here, and their chances to voice their position on issues which will directly influence their livelihood are very limited or non-existent. This places a great burden of responsibility on those who are attempting to formulate policies that will affect greatly the lives of these farmers.

Aquaculture and Wild Genetic Resources

In terrestrial animal and crop production, farmers have been working with species and breeds that have been bred in captivity for thousands of years. Many of the breeds used in terrestrial farms are genetically distinct from their wild relatives, many of which no longer exist in the wild. A major distinction between aquatic farming and terrestrial farming has always been the lack of true domestication in many farmed aquatic species.

The relationships between humans and domesticated animals developed through mutual dependence. It has been said that such relationships were possible due to genetic predisposition such as diet (herbivore/omnivore), disposition, or ease in breeding (Diamond 1998), as well as artificial selection (Pullin et al. 1998). Domestication has occurred with only a handful of aquatic species, some carps, tilapias, catfishes and salmonids; and the majority of aquatic animals and plants cultured today remain genetically similar to their wild forms.

Not all of the aquatic species cultured today, or that might be farmed in the future, are suitable for domestication and farm production. Species are often tried simply because of their economic value and market demand as a fishery product (such as lobsters, *Homarus* spp.).

The fact that aquaculture has not been able to wean itself from returning to nature to obtain wild broodstock or seed, demonstrates its inseparable relationship with natural genetic resources. This makes a strong case for the active participation of aquaculturists in the development and evaluation of policies for the use and conservation of aquatic genetic resources.

Fish meal and fish oil remain major ingredients for the feeds used to grow many species of aquaculture and agriculture. The consumption of fish meal and fish oil by aquaculture may increase, although there are some efforts to reduce its use, such as farming herbivores or finding replacements such as soybean.

Due to the diverse nature of aquaculture, it is difficult to generalize about existing global practices. Here shrimp farming is taken as an example, to demonstrate the relationship of aquaculture with natural genetic resources.

Shrimp Farming and Genetic Resources

Use of wild genetic resources in shrimp farming

Shrimp farming is very important in aquaculture today. In 1997, more than 941 000 t of farmed shrimp valued at over US$6.07 billion were produced (data from FAO Fishery Information, Data and Statistics Unit). Shrimp farming is a large foreign exchange earner. The developing countries engaged in this activity market most of their products in the developed world. This, together with supporting activities such as feed manufacture, shrimp processing and equipment manufacturing, plays a substantial economic role in countries such as Ecuador, Indonesia and Thailand.

Shrimp farming today relies heavily on natural genetic resources. Farmers in South and Central America (such as those in Ecuador, Guatemala and parts of Mexico) continue to use captured postlarvae to stock their production ponds. The collection of postlarvae has certainly impacted wild populations of both the targeted species and species that are caught incidentally. With respect to the collection of shrimp postlarvae, aquaculture differs little from those traditional fisheries that have no size regulations. Larvae of other crustaceans, fishes and other animals of a wide diversity are caught and discarded as by-catch. However, wild shrimp postlarvae continue to be utilized because of their apparent hardiness and economical price. Depending on the method and location of the collection, the by-catch can, at times, be kept to a minimum, e.g., in open sea collection of single species, schooling postlarvae (pers. obs.).

Viable shrimp hatcheries coexist in many of the shrimp farming regions of the Americas where collection of wild larvae occurs. However, these hatcheries also source their broodstock from the wild. Asia, which produces about 80% of the world's farmed shrimp (data from FAO Fishery Information, Data and Statistics Unit), relies primarily on wild-caught broodstock. The hatcheries, which produce hundreds of billions of postlarvae per year, capture small numbers of large adults or gravid female shrimp in order to produce postlarvae. Asian shrimp farming depends upon wild shrimp populations to provide all of its genetic resources. It is just as susceptible to fluctuations in the availability of wild resources as any capture fishery activity. Therefore, the conservation of wild genetic resources is invaluable to shrimp farming.

The utilization of wild genetic resources in shrimp farming differs from other capture fisheries. It includes situations unique to farming. One of the most important issues in the use of wild stock, either for breeding or direct culture, is their uncontrolled movement by farmers. Besides the hazards of introduction of alien species, either directly as shrimp or as incidental non-shrimp species when moving wild-caught postlarvae, there are the dangers of introducing diseases. Wild broodstock of Pacific white shrimp (*Penaeus vannamei*) infected with Taura Syndrome Virus (TSV), and black tiger shrimp (*P. monodon*) infected with white spot disease (SEMBV) have been moved to previously disease-free regions (pers. obs.). Such introductions can rapidly affect wide geographical areas beyond the native ranges of shrimp species and of their diseases. This can have devastating consequences for both natural and cultured populations.

Examples of shrimp farming practices and their possible impacts

Shrimp farming, as practiced today, places farms right in the midst of natural environments. It is often difficult to distinguish where the farm ends and the wild ecosystem begins. The water, which is essential for shrimp production, is often introduced from external natural sources such as estuaries, rivers or the open sea. It is then utilized in farm ponds and the effluent is again returned to the natural environment. During the time that the water spends in the farms, its physical, chemical and biological properties are altered. This can be the result of routine farm practices or the natural consequences of interactions between the farm environment and organisms that live in its artificial conditions. When discharged, the water, in its altered state, enters the natural environment and continues to interact with and have impacts on it.

This close relationship between the shrimp culture system and the natural environment tends to lead to the introduction of farmed shrimp to the natural environment through accidental escapes. Alien penaeid shrimps have reportedly become established in Fiji, Italy and Spain (DIAS 1999) and perhaps in the USA (AFS 1997). The impacts of such incidents may not be immediately observable but may take years to be realized. There are documented cases where the impact of aquaculture escapes on biodiversity are known; resulting from competition, predation, ecosystem modification and interbreeding (e.g., Arthington and Bluhdorn 1998). Munday et al. (1992) found that up to 28% of salmon in southern Norwegian rivers may be of farm origin, and Liao and Liu (1989) reported that the exotic catfish *Clarias batrachus*, through interbreeding with the native *C. fuscus*, has highly contaminated the gene pool and endangered the pure form of *C. fuscus*.

Another problem associated with introduction of alien species or non-indigenous populations, is the non-native diseases that they may carry. This threatens aquaculture, the natural environment and local populations. The movement of diseases and parasites through introduction of the host has been examined in, for example, common carp, rainbow trout, barramundi (*Lates calcarifer*), oysters and others (Arthington and Bluhdorn 1998). The movement of TSV through the shrimp culture regions of Latin America may have been the result of transfer of diseased postlarvae and broodstock. Such introductions have been found, not only in farms in the native ranges of the *P. vannamei*, but in areas where this shrimp was introduced as an alien species. The impact of the disease on the *P. vannamei* in farms is well known, but the impact of this introduced virus on its recipient environment is still relatively unknown (Boyd and Clay 1998; Flegel 1998).

Another example of possible effects on the natural environment from farming practices stems from the use of chemicals, drugs and other additives by farmers. The potential dangers to the biodiversity of areas that receive discharges from treated facilities have not been fully studied. However, there has been a positive move in the industry away from heavy applications of man-made chemicals and toward lower stocking densities and the use of probiotics (Boyd and Clay 1998). Such microbes can be in the form of bacteria, yeasts or others. Usually a combination of these artificially grown microorganisms is applied as a routine method for water treatment and disease prevention. Their use is an important part of the overall effort to increase stability in the culture environment. However, there is still much to be learned about their effectiveness in commercial culture (Jory 1996). Today, there exists little or no information concerning the effect of discharging these organisms into the natural environment, and the theory has been that these naturally occuring organisms will have little or no effect on the environment. Given the alternative of using chemicals or probiotics, the holistic approach of "treating the system and not only the symptoms" seems to make far greater sense both from the farming and the environmental points of view (Moriarty 1996).

Towards Sustainable Utilization of Genetic Resources in Aquaculture

Many aquatic species, such as shrimp, eel, groupers, sea bass and others, are raised in a similar manner: larvae, juveniles or broodstock are captured in order to grow them for the market. The survival of this type of aquaculture will depend, for some time to come, on access to wild genetic resources. The domestication of aquatic species would separate the industry from having to obtain genetic material every time that an animal is needed. Moreover, fully domesticated organisms could be less likely to survive in the wild or to impact wild species adversely through interbreeding. This requires the development of technology to reduce or eliminate the reliance of aquaculture on the natural aquatic environment and its biota. This could be achieved by means of a sustainable, artificial culture environment, which would move away from dependency on natural aquatic resources, either as a source or as a place for discharge, and thereby limit the possible genetic impacts from farm escapees and minimize any possible impact that the artificially altered water may have on the biodiversity of the discharge region.

There exist a few examples of aquaculture done in such fashion. Tilapia, catfish and hybrid striped bass have been successfully cultured in recirculating systems in the California desert. In general, however, aquaculture as commonly practiced is far from achieving such separation of artificial and natural environments, and is unlikely to do so in the near future. Even in highly developed animal husbandry, ranchers continue to rely on nature or managed grazing land for the production of cattle and sheep. In the shrimp farms of Asia today, there is a trend toward reduction of water exchange and an increase in water reuse. The trend started as a measure against the introduction of diseases through incoming water, and farmers find it effective. Technology has since been developed to manage the reduced water resources. Besides the reduction of impact on the environment, another advantage of such a system is nutrient recycling in the pond, as nutrients are no longer flushed out on a daily basis. This may reduce the protein level required in shrimp feed. Such changes may reduce fish meal inclusion into the diets (pers. obs.). However, there are costs and practical aspects that must be considered in such closed systems to make them economically viable. Examples like this demonstrate that changes in the fundamental practices of farmers are possible and that the potential to address concerns of both production and the environment is very real.

Towards the Development of Intelligent and Sensible Policies

Aquaculture has become increasingly important in the world today in its role as a provider of currency (often foreign exchange), products, employment opportunities and protein to meet the consumption demands of the general population. From a farmer's perspective, policies must reflect the needs associated with the conservation of genetic resources and the growth of a healthy and viable aquaculture sector. Policies should support the domestication of aquatic species to lessen the need for aquaculture farmers to obtain genetic resources from nature. Meanwhile, aquaculture will continue to require wild genetic material for breeding and stocking purposes. The removal of such natural resources should be monitored, and fishing methods should be improved to reduce their impact on both the targeted species and by-catch (Boyd and Clay 1998).

Policies should address the basic needs of aquaculture and encourage minimum impacts on natural genetic resources. They should also promote sustainable farming technology, with the objective of increasing the separation of the farming environment from nature, so as to minimize the impact of farms on natural biodiversity. Policies and guidelines are also needed to regulate emergent new technologies for genetic modification. The application of such technologies will reduce the time and increase the accuracy of genetic improvement for aquaculture when domesticating animals or plants for the farmers of the future. Of course, there are dangers and risks in many new technologies, so the biosafety of products developed by these methods must be ensured. Special emphasis on producing genetically modified, sterile populations for farm use would reduce the threat of contaminating or altering natural gene pools.

Policymakers must also realize that aquaculture, to be sustainable, must place more importance on separating the farm from the natural environment. Activities that put farm animals or plants in artificial surroundings away from natural waterbodies will have far less impact on natural genetic resources. The development of recirculating systems in some specialized aquaculture industries has gained credibility. However, these are often high technology input systems providing products to a small or developing market (Costa-Pierce and Rakocy 1997). On the other hand, pioneer low exchange systems do exist in semi-intensive and intensive shrimp farms today (see articles in McVey 1993). Policymakers should understand that the development of such technology involves a diverse field of disciplines that may include water quality management, nutrient input, feed formulation, microbiological manipulation, engineering, breeding and genetics, and others. However, complete separation of farm and natural environments is difficult to achieve and indeed sometimes is undesirable due to economic implications. Some of the most successful aquaculture activities put animals directly in the natural environment, as in cage or pen culture of fishes in lakes, rivers or the sea. If physical separation cannot be achieved, policies should at least promote biological separation of farms from nature by using sterile production stock. Quarantine and disease management policies must also be formulated to prevent disease introductions. Overall, the development of policies to promote sustainable and low environmental impact farming practices is a cross-disciplinary task involving a wide range of activities. Policies with clear final goals must reflect this complexity.

The existing dependence of shrimp farmers on natural genetic resources can and should be minimized. Shrimp farmers of Asia have moved away from using wild postlarvae, as hatcheries provide more uniform seed of good quality and can respond more conveniently to demand. Farmers no longer have to wait for the right season or the right tide to capture wild postlarvae to stock their ponds. This is also occurring in industries such as milkfish (*Chanos chanos*) and yellowtail (*Seriola lalandi*) farming. The capture and use of wild broodstock is often a precise activity that requires only a small number of organisms and therefore has less impact on wild populations than the collection of larvae. Policies which promote activities that allow the industry to develop with little or no effect on natural genetic resources should be considered and implemented. At the same time, longer-range policy developed today should place utmost importance on domestication and selective breeding in aquaculture. With success in this field, the impact of aquaculture on natural genetic resources will be greatly reduced.

Conclusion

Some aquaculture operations will rely on wild genetic material for many years to come. That is a fact which policymakers must realize and accept. In many developing countries, policies and regulations on this issue and on other concerns such as alien species introductions, genetic conservation and biosafety, are inadequate. Shrimp farming has developed far more rapidly than the creation of sensible policies.

Shrimp farms have always had a very close relationship with natural genetic resources because of their heavy dependence on broodstock and larvae. The impact of removing these natural resources for farms has not been well documented. The introduction of alien shrimp species and their associated diseases has potential for profound effects on both the natural environment and farms. Policies on quarantine and disease prevention are not yet in place or enforced in many shrimp farming regions of the world. Though viewed as restrictive by many farmers, such policies are actually good for the industry as a whole, and their development and implementation should be supported by all.

From a producer's point of view, policies to promote conservation of aquatic genetic resources must be developed with aquaculture in mind. If policies are detrimental to profitable business, they will likely be circumvented or ignored.

Farmers today are becoming increasingly aware of the impacts of their activities on the environment. There are many aquaculturists in developed and developing countries, who see that aquaculture must coexist with other users of aquatic resources and must give due regard to environmental protection. In order to widen this awareness, education must be intensified among all the groups involved.

The author is hopeful that aquaculture will not cause significant decline in the earth's genetic resources and biodiversity. Indeed, if correctly done, aquaculture can contribute positively to sustaining wild aquatic genetic resources.

PostScript: a Futuristic Scenario of Shrimp Farming

The author leaves the reader with a vision of what may lie ahead for aquaculture. On a sunny morning, farmer Eko heads to the local supplier of shrimp postlarvae. After some small talk, he comes to the point. He is looking for shrimp suitable for his 0.5 ha pond. The woman at the shop writes down the information about Eko's land and his pond as well as the water quality parameters. She tells Eko that it is not a problem if the pond has low salinity when the rain comes next month; she will recommend a genetic line just for that condition. The woman shows Eko a catalog of different shrimp selected to perform well in the type of pond that Eko has. These disease-resistant, hybrid shrimp are sterile and will grow twice as fast as their wild cousins. Eko arranges a date for delivery of the shrimp and heads off to put water into his pond. It is the same water he has been using for the past five crops, and it is now stored in a deep reservoir next to the production pond. On the way home he checks the future delivery prices of shrimp for two months from the date that he plans to stock. The prices look good, but not nearly as good as they were some 10 years ago when shrimp farming was a big gamble and no one knew if there was going to be a harvest when you stocked a pond. Ah! how things have changed.

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Discussion

Neira: I read in a paper by Gjedrem (1997) that it is impossible to have a sustainable production system without controlling all parts of the production cycle–and I agree with that. We cannot separate agriculture from the natural systems if the whole production cycle is not controlled. I have been saying, in Chile, that the responsibility for this is on the producers–they need to control the whole of their production systems. What is your position on this? Are you trying to control the whole of your production system, or are you just waiting for technology to come, or do you believe that the natural system is not suffering because you are doing this or that?

Wang: We and others are developing technology. We are trying to close the life cycle. A lot of animals are grown in aquaculture not because people are good at growing them but because there is commercial demand. We are not terribly good at growing shrimp but we can sell every shrimp that we grow. A lot of people, myself included, believe in the domestication of a few species for aquaculture, instead of having a lot of different species. We aim for a handful of species that we can grow very well and for which we can close the life cycle. These can be the backbone of the industry. We have to close the life cycle in order to domesticate species and then we have to move the growing of those species away from the natural environment – a parallel situation to terrestrial animals.

Harvey: In my experience, 'policy' is something that anyone or any organization can create; e.g., individuals, companies etc. For example, Elliot Entis referred to his company's policy on growing transgenics, whereas I referred to 'agency policy'. Is it cynical to say that 'policy' can be created by a body but then ignored by that body if it wants to; whereas 'legislation' presumably puts the onus on all members of society to abide by it? Do the conference organizers have a clear definition as to what 'policy' is?

Bartley: Well, the definition in our paper (Bartley and Pullin, this vol.) is that policy is your overall plan of action that has instruments to help its implementation.' I see 'legislation' as one of those instruments.

Kooiman: 'Legislation' is usually public–although there is 'private' legislation, for example, codes of conduct for professionals. 'Policy' can be public–e.g., policy made by governments or other formal authorities. This can be called 'public policy.' When, for example, a firm has a policy, this can be called 'private policy.'

Kapuscinski: Even when people talk only about public policy they do this for different scales, for example, the public policy of a whole nation or something as focused as the policy of the Minnesota Department of Natural Resources to avoid overfishing in sport fisheries. But they will also talk about the policy of using certain fishing regulations as opposed to other regulations and they will call that 'policy'. So, policy can be broad or narrow in scope. It can also be overarching and higher than legislation or more focused and used to implement legislation.

Welcomme: It's crucial that we discuss this further. Time scales are also important. Policies can shift much faster than legislation. A question for Yuan Wang–how do you make your voice heard in a structure such as that described earlier by Dan Mires?

Wang: We've done pretty much what we wanted to do because, in the geographical areas that I've worked in, there've been no policies or legislation. I'm here as a farmer. For me, a policy is like a guide to the next steps in the development of aquaculture. As producers, we haven't had to answer to many.

Welcomme: But you are paying the price for that now!

Wang: Yes.

Welcomme: As to the next steps, one government (India) has clamped down on all coastal aquaculture on the basis of the problems caused by this pursuit of self-interest. So, how do you see the next steps? What sort of consultation mechanism do you foresee?

Wang: I think that there is an educational process within the industry. Aquaculture can be divided into two groups: (1) those who are interested in producing economically significant species such as salmon or shrimp, and their operations are very sensitive to the demands of the special interest groups that you refer to; and (2) those who are producing for local consumption (e.g., some carp and tilapia farmers). The second group still do pretty much whatever they want to do. For example, local catfish breeders source their broodstock from wherever they choose, crossbreed them and do whatever they want to do. Shrimp farming has become more sophisticated in dealing with different interest groups and this has been an educational process for us. We know that we do not exist in a vacuum and that we must consider the interests of other groups.

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Intellectual Property Rights and Aquatic Genetic Resources

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ABSTRACT

Aquatic genetic resources offer a still largely unexploited potential. Although R&D activity in this field is at a relatively lower level than in other biotech areas (such as pharmaceuticals and agriculture), a vast range of possible applications of aquatic genetic resources is emerging. The protection of such developments by intellectual property rights (namely patents) becomes an issue of growing relevance for public and private institutions alike. This paper reviews the main directions in the patenting of biological materials in industrialized countries. It points out the current trend towards the protection of natural substances, including genes, and describes the international standards set forth by the Trade Related Aspects of Intellectual Property Rights (TRIPs) Agreement. The room left by that Agreement for maneuver at the national level is discussed. Several aspects are dealt with, such as the concept of 'invention', the scope of claims, and the exceptions to exclusive rights related to the patenting of genetic materials. Because the TRIPs Agreement does not constitute a uniform law, significant differences with regard to the patenting of aquatic and other genetic resources exist. Finally, the rules on access to and sharing of benefits are briefly presented, including the provisions contained in the United Nations Convention on the Law of the Sea.

Introduction

Aquatic organisms often possess unique structures, metabolic pathways, reproductive systems, and sensory and defense mechanisms. Given their genetic and physiological diversity, they may be the source of unique genetic information for new classes of chemicals and processes in a variety of fields. Marine bacteria are emerging as a significant chemical resource; genes found in marine organisms may be transferred to non-marine organisms to produce food additives; some marine substances may have important uses for the treatment of human diseases, as in the case of the compound monoalide, from a Pacific sponge, which has been tested as anti-inflammatory (NSTC 1995). However, the vast majority of the genetic resources of aquatic organisms (including most marine microorganisms) have yet to be characterized.

Aquatic biotechnology, and particularly the research required on marine organisms, have received uneven attention in developed countries. In the United States, for instance, only 1 or 2% of the total federal investment on biotechnology has been devoted to marine biotechnology and aquaculture. In 1992, federal investments in this area reached $44 million, while industry spent an estimated $25 million. In contrast, Japan has made major investments in marine biotechnology: $70 to $100 million annually by the government and $280 to $400 million by industry (CLSH 1993; NSTC 1995).

Research on living aquatic resources has an enormous potential in developing countries. However, their research and development (R&D) budgets are very limited and most, including many with vast aquatic resource systems, have paid little attention to R&D in this field. In general, developing countries account for only around 6% of world R&D expenditures (Hagedoorn and Schakenraad 1994)

Given the broad opportunities offered by aquatic genetic resources and the significant R&D costs, issues relating to the appropriation of research results and the related genetic materials are likely to become increasingly significant for governments, academia and industry.

This paper describes first trends in the patentability of genetic resources in industrialized countries. It then provides an overview on international standards for intellectual property rights, as set forth by the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), and examines the room for maneuver left by this Agreement to legislate at the national level, particularly with regard to biological (including living aquatic) resources. The TRIPs Agreement and other conventions cited in this paper have been published by the World Intellectual Property Organization (Geneva). Specific comments follow on the patentability of aquatic genetic resources. The interface between intellectual property rights and the issues of access and sharing of benefits, as regulated under the Convention on Biological Diversity (CBD), and the provisions of the United Nations Convention on the Law of the Sea (UNCLOS) are then explored, before a statement of main conclusions. Some of the issues covered in this paper are also discussed by Leria (this vol.).

Trends in the Patentability of Genetic Resources

Patents are granted for technical solutions applicable in any field, as far as they are novel and not evident for a person normally skilled in the respective technical field. Patent rights are generally conferred for twenty years counted from the date of filing of the application. The patent owner has the legal power (subject to some exceptions) to exclude third parties from the use of the protected invention without his/her consent.

The U.S. Supreme Court, in its decision re Chakrabarty, 1980, accepted for the first time a patent on a genetically altered microorganism *per se*. The patent, filed in 1972, asserted 36 claims related to the invention of "a bacterium from the genus *Pseudomonas* containing therein at least two stable energy-generating plasmids, each of these plasmids providing a separate hydrocarbon degradative pathway". The patentability of living material has broadened since this decision. Its scope has been enlarged from microorganisms as such to include: (1) cells and subcellular parts; (2) multicellular organisms; and (3) biological materials pre-existing in nature. In industrialized countries, the dominant trend is towards admitting the protection, by intellectual property rights, of any biotechnology-related invention. An accepted principle is that the fact that an invention consists of, is based on or employs living matter, is not a valid ground to exclude protection. Despite recent efforts towards harmonization, particularly in the framework of the TRIPs Agreement, national laws may opt for a variety of solutions with regard to the patentability of genetic resources, or of certain categories thereof. Thus, some developing countries have followed a less expansive approach with respect to patentability of living organisms than have the United States and other industrialized countries. The following paragraphs illustrate the main trends in legislation.

From microorganisms to cells and DNA

While, as mentioned above, the first patent on a living matter *per se* related to a "microorganism", which in the history of science has usually meant a bacterium, the concept of "microorganism" applied in patent cases has now been broadened so as to include cells and any subcellular part, including DNA molecules and genes. In the United States, for instance, genes that have been engineered by mutagenesis or genetic engineering techniques, or even that had not been known previously to exist in nature, have been deemed patentable. For instance, US patent 4.703.008 protected the DNA sequence encoding human erythropoietin. In Amgen Inc. v. Chugai Pharmaceutical Co., a US court affirmed that isolation and purification can form the basis for patentability and, hence, such sequence was not a natural phenomenon but patentable subject matter (O'Shaughnessy 1994).

Claims in the case of genetic engineered organisms normally refer to an isolated DNA sequence, DNA constructs and new transformed organisms derived from them. Claims often include natural DNA sequences without limitations. No major differences seem to exist today amongst industrialized countries with respect to the patentability of microorganisms, cells and subcellular components. The TRIPs Agreement has obliged, as discussed below, all World Trade Organization (WTO) member countries to grant patents with respect to "microorganisms". Developing countries are not bound to comply with the TRIPs Agreement obligation until 1 January 2000. Therefore, though divergences may still exist in national laws with respect to the subject matter and scope of protection, after the year 2000 the patentability of microorganisms as such, and possibly of cells and subcellular parts of all kinds of organisms (including aquatic), shall become common features of patent laws throughout the world.

From microorganisms to animals and plants

Patentability has also been extended from microorganisms to more complex organisms, including plants and animals of all types. Interestingly, the first case in which the patentability of a multicellular organism was judged, related to marine organisms. In *Ex parte* Allen, the U.S Patent and Trademark Office (PTO) was required to consider the patentability of polyploid oysters. The patent claim included:

> "a method of inducing polyploidy in oysters, comprising: (a) separating oysters from one another such that male oysters are isolated from female oysters; (b) inducing said oysters to spawn; (c) controlling the temperature of eggs from said oysters; (d) fertilizing said eggs with sperm to form zygotes; (e) applying hydrostatic pressure to said zygotes at a predetermined intensity for a predetermined duration after a predetermined time following formation of said zygotes to induce polyploidy; and (f) cultivating said ployploid zygotes."

While the examiner rejected the idea of patenting a living organism as such, since the animal produced by the method claimed was "controlled by laws of nature" and was not "a manufacture by man", the Office finally rejected the claim on a very different ground. It did not deny the patentability of the oysters, but held that in this particular case the requirement of non-obviousness had not been met.

The patentability of multicellular organisms has now been confirmed by the granting of numerous patents on plants and animals in many developed countries. In the case of the United States, 69 patents on animals had been granted as of July 1997. The granting of this kind of patents dramatically accelerated in 1996-1997, after some hesitancy of the U.S. PTO. During those two years, the number of patents granted on animals exceeded those issued during 1988-1995. Most patents have been issued on genetically engineered animals to be employed in laboratories. While the majority of patents cover rodents, modified to mimic human conditions or diseases, patents were also granted on a nematode, two avian species, a rabbit, a sheep, a Guinea pig and a fish. US patent 5.545.808 protects a method of increasing the growth rate of a salmonid fish and a transgenic salmonid containing in its germline a salmonid hormone gene that increases the rate of growth at least four times.

In Europe, patents have been granted with respect to plants and animals, but animal "races" and plant "varieties" are not patentable. Plant varieties, excluded from patent protection in Europe and some other countries are protected by "breeders' rights", i.e., a "sui generis" form of IPR protection that specifically applies to plant varieties. The rights conferred by "breeders' rights" are similar to patents, but the former generally include broader exceptions than the latter, notably the right of farmers to re-use protected seed (the so called "farmers' privilege") and the right of any person to use a protected variety for further research and breeding (the "breeders' exception"). The scope of the exclusion from patentability of plant varieties, however, has been limited by the Directive on Biotechnological Inventions (No. 98/44/EC of 6 July 1998) adopted in the European Union which states that: "Inventions which concern plants or animals shall be patentable if the technical feasibility of the invention is not confined to a particular plant or animal variety".

Many developing countries have followed the European approach–as applied before the referred Directive–and exclude the protection by patents of plant varieties and animal races. In Brazil, for instance, breeders' rights are the only modality of protection admissible for plants and parts thereof (Article 2 of the 1997 Brazilian Law on Plant Variety Protection).

From genetically modified to naturally occurring materials

While patentability of living organisms was first granted with respect to a genetically modified microorganism, the protection of any biological material, claimed to be not exactly as found in nature, but isolated and eventually purified, is permitted. For example, in countries that are members to the European Patent Convention, a patent may be granted when a substance found in nature can be characterized by its structure, by its process of obtention or by other criteria, if it is new in the sense that it was not previously available to the public. The European Patent Office states the following, with respect to the patentability of naturally occurring substances:

> "To find a substance freely occurring in nature is also mere discovery and therefore unpatentable. However, if a substance found in nature has first to be isolated from its surroundings and a process for obtaining it is developed, that process is patentable. Moreover, if the substance can be properly characterized either by its structure, by the process by which it is obtained or by other parameters... and it is 'new' in the absolute sense of having no previously recognized existence, then the substance per se may be patentable..."

An example of such a case is that of a new substance which is discovered as being produced by a "microorganism" (EPO Guidelines, Part C (IV), 2.1). In the 1998 European Directive on the matter, it is clarified that:

> "Biological material which is isolated from its natural environment or processed by means of a technical process may be the subject of an invention even if it already occurred in nature."

In the United States, an isolated and purified form of a natural product is also patentable. The concept of "new" under the novelty requirement does not mean "preexisting" but "novel" in a prior art sense, "so that the unknown but natural existence of a product cannot preclude the product from the category of statutory subject matter" (Bent et al. 1991). Similarly, in Japan, the Enforcement Standards for Substance Patents stipulate that patents can be granted on chemical substances artificially isolated from natural materials, when the presence of the substance could not be detected without prior isolation with the aid of physical or chemical methods.

Patents covering genes are not generally confined to the sequence of a gene. The patent application typically claims first, a gene or protein, standing alone, corresponding to that sequence; second, a vector or plasmid incorporating that sequence; and, possibly, third, an organism (e.g., a plant) that has been transformed by means of such a vector. Thus, the patent holder gains effective control over use of the specified gene in genetic engineering (Barton 1993).

Some developing countries have however, refused to go so far with regard to the patentability of existing biological materials. For example, Mexican law excludes the patentability of all genetic materials. This has not prevented Mexico from adhering to and being accepted as a member of the North American Free Trade Association (NAFTA), which contains standards of protection even higher than those of the TRIPs Agreement. Argentina's patent law and the Andean Group Decision 344, do not allow the patentability of materials existing in nature. Brazilian patent law (1996) further clarifies that no patents shall be granted with respect to living beings or "biological materials found in nature", even if isolated, including the "genome or germplasm" of any life form.

In summary, patent law has adapted quite rapidly to the demands created by modern biotechnology in industrialized countries. The process of adaptation has advanced in different directions, but consistently expanding the scope of patentability in the biological field. Certainly, these trends would apply to aquatic genetic resources, which may be subject to patent rights in a manner similar to what is already the norm in other biotechnology fields.

What are the International Standards?

The preceding section indicates the prevailing trends in the patentability of living materials. It is relevant to question, however, the extent to which national laws might adopt different approaches with regard to the patentability of living organisms. To answer this question, it is necessary to refer to the TRIPs Agreement, which contains the minimum standards to be observed by WTO members for the protection of intellectual property rights. The areas covered by the Agreement are copyright and "related rights", trademarks, geographical indications, industrial designs, patents, layout-designs (topographies) of integrated circuits and undisclosed information. International standards need to be implemented through national laws, under the terms provided for by the Agreements. Developing countries can, as noted earlier, delay until 1 January 2000 the implementation of the Agreement (except for obligations concerning national treatment and most-favored-nation treatment). In addition, a further period of five years is contemplated for developing countries that did not grant product patent protection in certain areas of technology on the general date of application of the Agreement for those countries (i.e., 1 January 2000). Countries failing to respect the agreed levels of protection may be subjected to a dispute settlement procedure within the WTO and, eventually, suffer trade sanctions in other areas (cross-retaliations). In exchange, and as a result of the adoption of the TRIPs Agreement, unilateral retaliations become objectionable under the rules of the General Agreement on Tariff and Trade (GATT) and members cannot be obliged to provide any broader protection than is required under the TRIPs Agreement.

Some provisions of the TRIPs Agreement provide the framework for its implementation and interpretation. Its Preamble expressly recognizes "the underlying public policy objectives of national systems for the protection of intellectual property, including developmental and technological objectives". Its various Articles also have provisions in this respect, as follows:

- Article 7 ("Objectives"), states that:

  "the protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to the balance of rights and obligations."

- Article 8.1, on the other hand, provides that:

  "Members may, in formulating or amending their national laws and regulations, adopt measures necessary to protect public health and nutrition, and to promote the public interest in sectors of vital importance to their socio-economic and technological development, provided that such measures are consistent with the provisions of this Agreement."

- Article 8.2 states that appropriate measures:

  "may be needed to prevent the abuse of intellectual property rights by right holders or resort to practices which unreasonably restrain trade or adversely affect the international transfer of technology."

- Article 27.1 stipulates that:

  "patents shall be available for any inventions, whether products or processes, in all fields of technology."

Thus, patents should be granted, inter alia, for pharmaceuticals and food products, two areas excluded from patentability in many countries until recently.

- According to Article 27.2, WTO members may exclude from patentability:

  "inventions, the prevention within their territory of the commercial exploitation of which is necessary to protect public order or morality, including to protect human, animal or plant life or health or to avoid serious prejudice to the environment, provided that such exclusion is not made merely because the exploitation is prohibited by domestic law."

- The Agreement (Article 27.3.b) expressly requires the patentability of microorganisms and microbiological processes.

Article 27.3.a states that Members may exclude from patentability "diagnostic, therapeutic and surgical methods for the treatment of humans or animals". In addition, it allows excluding from patentability "plants and animals other than microorganisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes". However, members "shall provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof". "Sui generis" means, in this context, a breeders' rights system or another regime that provides protection to those that develop new plant varieties. This provision shall, in any case, be reviewed in 1999.

The new international standards, in summary, follow the above mentioned trends on patentability as reflected in industrialized countries, but leave a considerable degree of flexibility. Hence, national laws on the matter may differ significantly, ranging from full protection to any biotechnological invention to a situation where certain types of inventions may be excluded from protection. As discussed below, this would permit national policies to be devised according to the perceived domestic interests, provided that they did not conflict with the standards set forth.

Room for Maneuver under the TRIPs Agreement

Despite the fact that the TRIPs Agreement aims at a certain degree of worldwide harmonization of intellectual property rights, it does not constitute a uniform law. It leaves room for maneuver in different areas, particularly with respect to biological resources, as follows:

The concept of "invention"

The TRIPs Agreement does not contain a definition of what an "invention" is. Under patent law "discoveries", as opposed to "inventions", are not patentable. Thus, there is no obligation under the TRIPs Agreement to adopt an expansive concept of "invention", as currently done by many developed countries. In particular, nothing in the Agreement obliges legislators to consider that substances existing in nature, biological or not, are patentable, even if isolated and claimed in a purified form. Hence, countries may legitimately consider as outside the scope of the concept of "invention" any naturally occurring substance and process as well as isolated DNA sequences, even if transferred to different organisms. This applies, in particular, to any living aquatic resource found in nature.

Consequently, the obligation imposed by the TRIPs Agreement to grant patents on microorganisms (Article 27.3.b) may be interpreted as applicable only to genetically modified microorganisms, and not to those existing in nature. As mentioned above, the concept of "microorganism" has, in some jurisdictions, been interpreted extensively so as to embrace any cell and sub-cellular element. However, according to the scientific concept that may be adopted by national legislation, "microorganism" may be deemed to include only a member of any of the following classes: bacteria, fungi, algae, protozoa or viruses (Coombs 1986). Moreover, the nonpatentability of naturally occurring substances and, in particular, of genetic resources has been declared in some Latin American countries, as indicated above.

In October 1991, the Consultative Group on International Agricultural Research (CGIAR) formulated its "Suggested principles for a CGIAR policy on intellectual property rights". These recommended that patents should never be sought by the CGIAR Centers for "naturally occurring genes". In view of applications by two Australian companies for patents involving chickpea varieties obtained from a germplasm bank located in Hyderabad, the CGIAR called for a moratorium on the granting of intellectual property rights on plant germplasm held in collections of CGIAR centers.

Exclusion of plants and animals

As mentioned, there is no obligation under current international standards to protect plants and animals, with the exception of "plant varieties".

Therefore, the exclusion of the protection of plants and animals may be broadly defined, and encompass the animals and plants as such, any part thereof and plant and animal species, including all types of aquatic resources.

Exclusions based on ethical concerns

Patentability may be also excluded on the basis of "morality" grounds. WTO member countries have flexibility to define which cases would be covered under this exception, depending upon their own ethical values. What is moral or not is relative to the values prevailing in a society at a given time. The patentability of living organisms and, particularly, of animals has been strongly questioned on various moral and religious grounds in many countries, particularly because patenting would stimulate animal experimentation, reduce them to industrial machines and increase their suffering. These issues were considered, for instance, in the case of the Harvard "oncomouse" (Pollaud-Dulian 1997). The examiner of the European Patent Office (EPO) had rejected the application on moral grounds. This decision was reversed, however, by the EPO Technical Board of Appeal, which balanced the benefits and costs of the invention and found that the former outweighed the latter. The conclusion was that the provision of a test animal in cancer research, which may lead to an overall reduction of animal testing together with a low risk connected with the handling of the animals, was important enough for humans to justify patentability (Decision 19/90).

The morality issue has also been considered in relation to the patentability of a herbicide-resistant plant: Greenpeace c. Plant Genetic Systems, published in the Official Journal of the European Patent Office 8-1995/545. The opponent argued that risks in connection with release of the plants into the environment were impossible to predict accurately and therefore a potential risk to mankind existed. "This argument was rejected", explained the Director of the European Patent Office, "because it was not considered appropriate to carry out the balancing exercise of the Harvard Oncomouse decision." The reasons given for this were manifold, but were primarily the lack of consensus in society on "objective morality" and the inability not only of the opponents but of all experts to prove the "extent of the risks" (Gugerell 1996). According to the Opposition Division:

> "The present invention does not belong to that extreme category of inventions which could be regarded as so abhorrent to the vast majority of the public as to render the granting of a patent inconceivable and thus excluded under Art. 53(a) EPC. Apart from such clear-cut cases, the European Patent Office has no mandate to grant or refuse patents on the basis of abstract ethical or moral arguments."

Such moral arguments have been incorporated in the 1998 European Directive on biotechnological inventions, which allow excluding the patentability of processes for modifying the genetic identity of animals which are likely to cause them suffering or physical handicaps without any substantial benefit to man or animal, and also animals resulting from such processes (Article 6.d). This provision would not allow, for instance, the patenting of animals genetically altered to test cosmetics and other cases in which costs (in terms of animal suffering or handicaps) exceed benefits.

Access to patented materials

In order to comply with the disclosure requirement of patent law, the description of a biotechnological invention generally needs to be supported by the deposit of samples of the material that contains the relevant information. Legal systems vary considerably on this topic. Under U.S. law, access can take place only after the granting of the patent. Under European law, samples may be obtained after publication of the application, through an independent expert and only for experimental purposes: any commercial use of the sample will amount to an infringement of the patent, but experimental uses are allowed.

National laws may determine how to deal with the conditions of access to the deposited samples and, particularly, when and under which circumstances samples may be obtained by third parties. The Budapest Treaty (WIPO 1998) which entered into force in 1980, established an international system for the deposit of biological materials, is based on the assumption that access to the sample will be granted after publication of the relevant application (Rule 11.3 (a) of the Regulations of the Treaty). Access to samples after such publication may accelerate innovation, based on improvements of the protected invention or the development of new inventions.

Novelty

Absolute (or "universal") novelty is a typical requirement of patent laws. Novelty is generally destroyed by any prior disclosure, written or not, of the invention in any part of the world. A rule of this type prevents, in particular, the patenting of knowledge or materials developed by and diffused within local or indigenous communities. The cases of the patent applications relating to the Indian neem tree (*Azadirachta indica*) and to turmeric are examples of the possible consequences of a less stringent rule, as adopted in the United States. U.S. law, unlike the law in force in most countries, does not consider that "novelty" is lost when an invention has been divulged outside USA by a non-written means, such as public use and sale. Only *publications* made abroad are deemed to destroy novelty under U.S. law.

Thus, the properties of neem products have been known for centuries in India. Since 1985, over a dozen U.S. patents have been taken out by U.S. and Japanese firms on formulae for stable neem-based solutions and emulsions, including a neem-based toothpaste (Shiva and Holla-Bhar 1996). In the case of turmeric, however, on 14 August 1997, the U.S. PTO declared invalid a patent issued to the University of Mississippi Medical Centre in December 1993. The patent had been challenged by India's Council for Scientific and Industrial Research (SUNS 1997).

Broad claims

In addition to the problems posed by the possible patentability of substances that exist in nature, a number of other important issues arise in relation to biotechnological patents. One relates to the breadth of the patent claims. Some Patent Offices accept claims drafted in functional or informational rather than in structural terms. Hence, the patents granted may cover all ways of solving a technical problem. Examples of this have been an Agracetus patent referring to any genetic manipulation of cotton, regardless of the germplasm in use; a patent granted to Plant Genetic Systems covering the introduction of Bt into most field crops (US Patent No. 5.254.799), and a patent obtained by Lubrizol covering sunflower seed with a high oleic acid content and a low linoeic acid content (US Patent No. 4.627.192).

Exceptions to exclusive rights

Another area in which WTO members enjoy a certain degree of flexibility relates to the exceptions that the law may allow with regard to the exclusive rights conferred by a patent. Such exceptions may include acts made for research and teaching as well as the experimentation (even for commercial purposes) on the invention.

Compulsory licenses

Article 31 of the TRIPs Agreement on "Other use without the authorization of the right holder" contains a detailed set of conditions for the granting of compulsory licenses. Although the TRIPs Agreement refers to five specific grounds for the granting of such licenses (refusal to deal; emergency and extreme urgency; anticompetitive practices; non-commercial use; dependent patents), member countries can grant compulsory licenses on other grounds, such as for environmental reasons. Many recent patent laws (e.g., China, Brazil, Argentina, Andean Pact Group), have provided for different types of compulsory licenses.

Patents on Aquatic Genetic Resources

Aquatic genetic resources have not escaped the trends described above with respect to the patentability of biological materials. A considerable number of patents have been granted with respect to such resources, including at least one on a transgenic fish in the United States. Many patents relate to substances extracted from algae or to the processes to obtain pharmaceutical compositions, cosmetics or food based or containing algae. Table 1 provides examples.

The use of living aquatic resources has a significant potential in a number of fields, such as pharmaceuticals, diagnostic and analytical reagents, cosmetics and food (from fisheries and aquaculture). In pharmaceuticals, recent developments in molecular biotechnology

Table 1. Some examples of patents relating to algae: "WO" is the international publication number of an international application under the Patent Cooperation Treaty.

French Patent No. 2384446	A method to produce algae containing germanium, which allows incorporation of this element in lifeforms to improve their health.
French Patent No. 2059567	Composition of green and blue algae used for medical and dietetic purposes.
European Patent No. 0175268	A potentiator conferring resistance to infection based on a substance extracted from the alga *Chlorella*, using an aqueous solvent.
French Patent No. 2657012	Preparation of compositions for medical use, food, etc. based on several types of microscopic algae.
Patent WO 91/0137	A preparation of zeolites and brown algae for purification of preferentially hydrophilic liquids contaminated with heavy metals that may be radioactive.

have expanded the opportunities for identifying and using living aquatic resources. In particular, new assay technologies that facilitate the testing of the pharmaceutical activity of new compounds permit a rapid and cost-effective exploration of large amounts of compounds. The use of combinatorial chemistry, coupled with high tech computing and analytical methods, reduces costs and the time neccesary to identify new effective active ingredients (Raggett 1996).

Possible industrial applications include methods to induce marine algae to produce specific enzymes (such as superoxide dismutase), and the isolation of enzymes (e.g., from hyperthermophilic bacteria associated with thermal). Other uses include the production of bioceramics and biofilms, fouling control, cloning genes from marine bacteria that produce bioluminescence, biopesticides (such as a product "Padan" (TM) developed from a bait worm's toxin, bioremediation and bioprocessing (such as producing unusual chemical structures by using marine bacteria and fungi). Biotechnology may also be used to enhance reproduction and early development of cultivated aquatic organisms (NSTC 1995).

Many of these developments, if they meet patentability requirements, may give rise to patents relating to:

- new processes of manufacture including microbiological methods (e.g., for the extraction and purification of compounds);
- new uses of substances;
- new products (e.g., pharmaceuticals, food additives, agrochemicals, etc.) based on living aquatic resources; and
- transgenic organisms.

In some countries (Australia, Austria, U.S.A.), medical methods that use living aquatic or any other resources may also be patented, independently from the substances that they employ.

In summary, the patenting of living aquatic resources (or parts thereof), including genetic material in different forms, may increase in the future, given the vast and still largely unexplored potential of utilization of such resources, and the expansive approach on biotechnological patents prevailing in the industrialized countries, as described above.

Access and Sharing of Benefits

The Convention on Biological Diversity (CBD) includes, for the first time in an international binding agreement, provisions on access to genetic resources and the sharing of benefits derived from their exploitation. Access, where granted, shall be on mutually agreed terms and subject to prior informed consent of the Contracting Party providing genetic resources, unless otherwise determined by that Party (Articles 15.4 and 15.5). An important element of the CBD is that all types of genetic resources are subject to the sovereign rights of the country where they are located.

In addition, Article 15 provides that each Contracting Party shall take legislative, administrative or policy measures, as appropriate, and in accordance with Articles 16 and 19 and, where necessary, through the financial mechanisms established by Articles 20 and 21 of the CBD, with the aim of sharing in a fair and equitable way the results of research and development and the benefits arising from the commercial and other utilization of genetic resources with the Contracting Party providing such resources. Such sharing shall be upon mutually agreed terms (Article 15.7).

One important issue is how to coordinate the application of these rules with those conferring intellectual property rights. If a genetic resource is appropriated via intellectual property rights, a conflict may arise between the right-holder(s) and the State(s) that exercise sovereign rights over such resources. In order to address this issue, national laws may require, for instance, that the applicants of intellectual property rights (notably patents and breeders' rights) disclose the origin of any resource involved in an invention and demonstrate that they had obtained the required consent from the source country. A proposal of this kind was introduced by the European Parliament–but rejected by the European Council–during the treatment of the European Directive on biotechnological inventions. Decision 391 of the Andean Group stipulates in this regard that a patent or other intellectual property right may be cancelled, if the title-holder has not complied with the provisions on access.

Finally, it should be recalled that the United Nations Law of the Sea Convention (UNCLOS)–which was adopted in 1981 and entered into force in 1994–contains a number of provisions that are relevant to the analysis of the issues of access and sharing of benefits, as regulated in Article 15 of the CBD (see also Leria this vol.). Under UNCLOS, the rights of coastal States with respect to access to marine resources for the purpose of scientific research vary according to the geographical delimitation of maritime zones.

In their jurisdictions, coastal States have the right to regulate, to authorize and to conduct marine scientific research in their territorial sea. Marine scientific research in the territorial sea shall be conducted only with the express consent of and under the conditions set forth by the coastal State (Article 245). The same right applies for research in the exclusive economic zone (EEZ). Powers of the coastal States are narrower for these than in the case of territorial sea. The EEZ is an area beyond and adjacent to the territorial sea, subject to a specific legal regime (Article 55). According to Article 56, in the EEZ, the coastal State has:

> "sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the sea-bed and of the sea-bed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and ..."

The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance (Article 76). The coastal State exercises over the continental shelf sovereign rights for the purpose of exploring it and exploiting its natural resources. These rights are exclusive in the sense that if the coastal State does not explore the continental shelf or exploit its natural resources, no one can undertake these activities without the express consent of the coastal State (Article 77). The consent of the coastal States is also required for research in the EEZ or on the continental shelf (Article 246.2) but subject to conditions specified in Article 246.3 to 6. These conditions state that coastal States shall, "in normal circumstances", grant their consent for marine scientific research projects to be carried out for peaceful purposes and in order to increase scientific knowledge of the marine environment for the benefit of all mankind. To this end, "coastal States shall establish rules and procedures ensuring that such consent will not be delayed or denied unreasonably" (Article 246.3). Coastal States may, however, withhold their consent if that project is of direct significance for the exploration and exploitation of natural resources, whether living or nonliving.

The UNCLOS also contains some rules on the participation in research by the coastal States. This participation may be a component of a system of benefit sharing as required by the CBD. The UNCLOS provisions on scientific research (Article 249) are that:

> "States undertaking marine scientific research in the exclusive economic zone or on the continental shelf of a coastal State shall", *inter alia*:
>
> (a) ensure the right of the coastal State to participate in the marine scientific research project, without payment of any remuneration to the scientists of the coastal State and without obligation to contribute towards the costs of the project;
> (b) provide the coastal State, at its request, with preliminary reports, as soon as practicable, and with the final results and conclusions after the completion of the research;
> (c) undertake to provide access for the coastal State, at its request, to all data and samples derived from the marine scientific research project and likewise to furnish it with data which may be copied and samples which may be divided without detriment to their scientific value;
> (d) if requested, provide the coastal State with an assessment of such data, samples and research results or provide assistance in their assessment or interpretation;
> (e) ensure, subject to paragraph 2, that the research results are made internationally available through appropriate national or international channels, as soon as practicable."

The provisions of the UNCLOS, as stated, subject applied research activities by foreign states in the EEZ to conditions that may be more stringent than those under the Convention on Biological Diversity (Conde

Pérez 1998). It seems necessary to examine how to make compatible the provisions on access of both conventions in a manner that facilitates research on and use of such resources with due respect of the sovereign rights of the coastal State.

Conclusions and Policy Implications

On the basis of the above discussion, a few main conclusions can be drawn.

First, the patentability of organisms, including living aquatic resources, has progressed since 1980, in the direction of a wide coverage of biological materials, including plants and animals. However, divergences exist in national laws, particularly with regard to the patentability of plant varieties and animal races and, in the case of some developing countries, with regard to substances merely isolated from nature.

Second, the TRIPs Agreement has established international standards for the protection of inventions. Despite its goal to harmonize intellectual property rights on a global scale, it leaves WTO member countries certain flexibility margins to determine the extent of patent protection of biotechnological inventions, as well as the scope of the rights to be conferred to title-holders. In particular, such countries may not confer patents on animals and plants, and on materials pre-existing in nature. Likewise, patentability may be excluded by moral grounds, particularly relevant in the case of animal patents.

Third, given the large and still unexplored potential of aquatic genetic resources in various industrial fields, and the above described trends in patenting, such genetic resources are likely to become increasingly the subjects of patent protection, at least in industrialized countries.

Fourth, though there exist international rules on the access to and sharing of benefits resulting from the exploitation of aquatic resources (particularly marine resources), those provisions need to be implemented at the national level in a manner that ensure an effective exercise of State sovereign rights over such resources while encouraging their sustainable use to the benefit of all peoples.

Finally, the exploitation of aquatic resources in different industries, as indicated above, exhibits a great, still largely untapped potential.In terms of policymaking, the particular characteristics of the aquatic genetic resources–vis-à-vis other areas of biodiversity–should be borne in mind when adopting legislation and developing practices on access and intellectual property rights.

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Discussion

Schei: Have you studied whether there are any results from the patenting of live organisms that are contrary to the objectives of the Convention on Biological Diversity (CBD), particularly its Article 16.5?

Correa: The purpose of the CBD is to facilitate the sustainable use of genetic resources in general. The aim of the patenting system is to restrict the use of any material that has been protected. There is a contradiction here in principle because the owner of a patent has exclusive rights to use of the patented resource, at least in the countries where the patent is recognized. The first contradiction that you may find is that the existence of a patent limits access to the resources. Second, there has been the possibility of getting materials from anywhere in the world and patenting them in, for example, the USA without any provision for sharing benefits with the countries of origin of those resources. So, there is an important issue here and so far there has not been any significant effort to make these two systems compatible; if indeed that is possible. In my view, to the extent that naturally occuring materials are patented, it will not be possible to make both systems compatible.

Leria: Why did you say that the issues are very different for aquatic genetic resources? For example, patents have been given to algae.

Correa: There is no reason why the same regimes for access, sharing of benefits, etc., should be applied to different areas of biodiversity. In my opinion, there are some unique features in each area of biodiversity. For instance, plant biodiversity has its own logic and certain needs, including to exchange materials for the continuous development of agriculture. That is why the FAO Commission is now renegotiating the International Undertaking in accordance with the provisions of the CBD. The extent to which different areas of biodiversity need different legal regimes should be examined. Animal biodiversity may have quite different needs from plant biodiversity in this respect. Aquatic genetic resources might also have their own logic in terms of generation, use and exchange, and might therefore need a different legal regime. The CBD should not be seen as a unique framework to be applied in the same way to different types of biodiversity.

A. Gupta: Products of nature, as the TRIPS Agreement says, indeed have not been patented. So what has been patented? Whenever any biological material is patented, the argument that the biotech companies give (and that is at present accepted by patenting authorities) is that these microbial resources do not exist as such in nature, at least not in pure form. So if you purify a culture, it is no longer a natural product. The argument is that the human contribution in purifying the product must be rewarded. So in the strict sense of the term, such products do not exist in nature.

Second, one of the first genes found was discovered in the University of California, Davis, for blast resistance in rice. It was licensed to certain companies. The scientist who made the discovery was upset about charges of "biopiracy", and explored with Prof. John Barton of Stanford University the ethical ways to deal with the dilemma: how to handle the income from this particular technology, which was not entirely one scientist's achievement because others in the community had made contributions. After consultation with the University Vice-Chancellor, it was agreed to set up a fund from the advance royalties received from certain companies to which this gene was licensed. The fund was used to provide scholarships to two particular groups of people: from Mali, from where the germplasm was obtained, and from the Philippines where the germplasm was collected and characterized (at IRRI). There were many other suggestions. This was the first example of benefit sharing with 'bioscholars'. We need more examples of this kind.

For IPR on aquatic organisms, there is the issue of the fugitive nature of the resources. This makes them less suitable for the property rights that are demanded on fixed terrestrial resources. When communities claim rights over certain waterbodies and spawning grounds, it will be difficult for them to show that those species are conserved only because of those waterbodies or spawning grounds. Also, seasonal floods enable the transfer of aquatic genetic resources from one waterbody to another. So aquatic genetic resources move a great deal. It is difficult to think of linking specific communities with specific aquatic genetic resources, unless they have lived with these resources for a long time; as, for example, in the Arctic Circle. Finally, the issue of knowledge systems is much more crucial, and some access laws are being drafted in different parts of the world. Brazilian law, for example, has a Traditional Reference File where communities can register their knowledge–although lack of registration will not deprive them of their rights. Similarly, Indian law, which we are debating and lobbying for at present, will cover indigenous innovations and community knowledge. Some other countries are considering how to protect knowledge systems. The case for this is strong because knowledge can indeed be characterized, whereas characterizing which communities are the conservers of particular aquatic biodiversity is difficult.

Considerations for the Conservation of African Fish Genetic Resources for Their Sustainable Exploitation

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ABSTRACT

There is great concern for fish and other aquatic genetic resources in various regions of the world, including Africa. The range of aquatic ecosystems in Africa, which are located approximately between latitudes 30°N and 30°S, is as wide and complex as are the ecological conditions between these latitudes. The fish fauna of Africa, compared to other aquatic organisms, is fairly well known at conventional taxonomic levels down to species and is considered rich and complex. However, the aquatic genetic resources of Africa at the population and gene levels have not been extensively studied and documented. Concern for African fish genetic resources has come about mainly due to declines in fish catches. This paper links the activities that threaten African aquatic genetic resources (e.g., overfishing, changing of the biophysical features of aquatic environments, habitat degradation and destruction, and transfers and introductions of alien species and genotypes) to genetic resource erosion and catch declines. It is suggested that policies must provide for the enhancement of conservation of fish and other aquatic genetic resources, for their sustainable use in Africa. This will require the study and documentation of these genetic resources, a gradual but sustained ecosystem-based approach to the use and management of natural resources, and support for development and sustainability of community-based management.

Introduction

Africa is the second largest continent and spans approximately latitudes 30°N and 30°S. Its climatic conditions range from temperate to tropical deserts. This is reflected by the great diversity of flora and fauna on the continent. Africa has a number of large river systems including the Congo, Limpopo, Niger, Nile, Orange and Zambezi. Together with the great lakes and other lesser known water systems (e.g., the rivers Sénégal, Volta and Benue) the major basins constitute a complex array of aquatic habitats whose fish fauna is rich and complex. The general richness and complexity of the African fish fauna, which should be reflected in the genetic resources within a species or a gene pool, result from the following:

- River systems traverse a variety of ecological areas.
- The majority of African river systems do not lend themselves to the established longitudinal zonation characteristics of temperate rivers.
- An appreciable number of African fish species are widely distributed over different ecological areas.

Status of Fish Genetic Resources Information

It could be expected that the genetic variability of fish, which are widely distributed in varying habitats, would be relatively high, reflecting the heterogeneity of those habitats (Nevo et al. 1984). This is, however, yet to be established. There are, at present, concerns for the conservation of African fish genetic resources with diverse perceptions of 'genetic resources' by stakeholders. At conventional taxonomic levels down to species, the fish fauna of Africa may be considered fairly well known. However, the genetic diversity and thus the genetic resources of species or gene pools has hardly been studied. Even for the tilapias, the genetic resources of which have been studied to some extent, the information available on genetic resources covers less than 40% of the about 70 species known.

This situation implies that historic and current actions and concerns for the conservation of African fish genetic resources are not based on documented information showing declines in available resources at the gene level. They are rather based on counter measures to declining fisheries. During the last decade, most attempts at enforcing sustainable fish exploitation methods and thus contributing to fish biodiversity conservation in Africa have been brought about by obvious declines in fish catches. Unfortunately, initial declines in catches usually instigate the rampant use of unauthorized fishing gear and methods to make up for catches. This contributes further to the erosion of available genetic resources and at a faster rate. The crisis was noted by FAO as a global problem, when it reported that nearly 70% of the world's major fisheries are in urgent need of management (FAO 1995). Moreover, until very recently, fish genetic resources conservation in Africa was championed largely by government and academic working groups or agencies which often operate ahead of the general population.

Factors Influencing Fish Genetic Resources

Ordinarily, factors which have contributed to catch declines and the near collapse of several marine and inland fisheries and the concomitant erosion of genetic resources in Africa are similar to factors that pertain in other parts of the world. Perhaps the difference, if any, between the situation in Africa and the developed parts of the world is that the scenario in Africa is unfolding later and at a faster rate. The major factors or causes include overfishing, biophysical changes in habitat, fish habitat degradation and destruction, transfers and introductions of alien species and genotypes, fish culture and its technology 'improvements' and, apparently, unprecedented climatic changes. These various factors are also interactive. Biophysical diversity in aquatic habitats influences the genetic diversity of fish (Nevo et al. 1984). The range of human activities which have effected and continue to effect changes in fish environments are wide and widespread. In Africa, the major actions that have recently contributed to changes in fish environments include deforestation, domestic and industrial pollution, urbanization and 'water development' schemes. Examples of these follow. These factors affect fish in several ways, including elimination of whole populations, changes in the relative abundance of species and thus community structures; changes in habitat and reductions in aquatic habitable space for fish. They result in reduction in the diversity of fish communities and, through competition and other selective pressures, they influence the genetic resources at population or gene level.

Fishing

The effects of fishing practices on fish communities and populations have not been a direct subject of studies in Africa as often as in some other parts of the world. For example, Beacham (1983), Pauly et al. (1989), Myers et al. (1996) and Cook et al. (1997) described some effects of overfishing on stocks outside Africa. For African fishes, an assessment of fisheries on the Niger (Malvestuto and Meredith 1989) may be one of very few direct documented studies of the effects of overfishing on a stock or community. Yet, overfishing abounds in Africa. For example, monitoring fish catches in several river basins in West Africa during the past two decades has provided evidence of declines in catches attributable to overfishing coupled, perhaps, with climatic changes (Lévêque et al. 1988; Abban et al. 1997).

Deforestation

In most parts of Africa, where sustainable exploitation of renewable natural resources has not been established, watercourses have rapidly lost significant amounts of their surrounding vegetation. While international actions to limit deforestation have been concerned with the depletion of forests for timber and wood products, local demand for fuel wood has been a major cause of depleting the vegetation cover of fish habitats. Unfortunately, it is difficult for many to recognize the contribution of fuel wood gathering to this situation.

The predictable response being given to deforested areas, where any remedial action is being taken, is reafforestation of river banks and lake catchments, e.g., current activities within the catchment of the Volta basin in Ghana. Perhaps reafforestation programs will help to reduce damage to aquatic biodiversity, but the newly planted forests are not likely to perform exactly as the natural forests did.

Pollution

Domestic and industrial pollutants are well known factors that cause major changes to aquatic habitats in Africa. Industrial pollutants are widespread because treatment of effluent, prior to discharge to water systems, is minimal or lacking. Domestic pollutants also constitute a major problem because many communities in Africa are sited close to waterbodies, and domestic waste disposal facilities, even in the urban centers, still need a lot of improvement. There are limited documented data on the chemical pollution states of aquatic environments in Africa. Biney et al. (1994) provided a review of information available on heavy metal pollution, including heavy metal concentrations in shellfish and finfish. In their conclusions, they indicated relatively higher concentrations of some heavy metals in African inland waters compared to coastal waters except at some 'hot-spots'. They also concluded that metal concentrations in aquatic organisms, including fish, were generally below WHO safe limits for human consumption, with indications that concentrations in shellfish were generally higher compared to finfish. In spite of the relatively lower concentration of pollutants in coastal waters compared to inland waters, there are historic causes and evidence for higher concentrations of pollutants in coastal waters, including lagoons, estuarine and mangrove environments, compared to those in more inland waters. This is attributed to the sedimentation of many contaminants.

Results of an assessment of persistent pollutants in Lake Kariba by Berg and Kautsky (1997) showed that the use of agrochemicals (specifically DDT) for the control of malarial mosquitos and of tsetse flies in the lake's catchment had impacts on the aquatic environment. They and other workers quoted in their study drew attention to the impacts of various chemical products on the fisheries of the lake.

In a review of information on genetic effects of pollutants on marine and estuarine organisms, including shellfish, Hummel and Patarnello (1994) made two distinct conclusions. First, they indicated that estuarine invertebrates had higher levels of pollutants compared to those in more inland water systems. Second, they provided direct and indirect evidence that pollutants could influence aquatic genetic resources in two ways: (1) by directly damaging DNA in individual cell nuclei, leading to mutations; and (2) by modification of the chemical environment of organisms, thereby exerting selective pressure on individual genotypes.

Considering that estuarine, lagoon and mangrove ecosystems, in addition to their other functions, serve as nursery grounds for both marine brackishwater and freshwater fishes, it is apparent that mutations occurring in and selection to these nursery environments could be significant factors changing fish genetic resources.

Water development schemes

Water development schemes are widespread in Africa, usually in connection with provision of potable water, water for irrigation or the generation of hydroelectric power. Many such activities involve the erection of dams, leading to drastic changes in the original biophysical structure of aquatic ecosystems. Other development efforts which often change water systems include road networks and general urbanization. By their magnitude and often in connection with displacement of human communities, such projects can and have produced pre-implementation impact assessment study reports. It is perhaps unlikely in the imaginable future that impacts on fish genetic resources will be included in assessment studies in connection with water development efforts. However, over 40% of African populations depend on fish for over 50% of the animal protein in their diets, and fisheries is a major socioeconomic activity in most African country economies.

Alien species and genotypes

Issues related to introduction and transfers of alien aquatic species and genotypes have been reviewed by Satia and Bartley (1998). For the majority of significant transfers or introductions to Africa, the original main objectives have been met and the impacts have been positive. For example, many introductions and transfers between the 1920s and 1970s were aimed at increasing fish protein availability, generating income, providing employment, or controlling a disease vector. Irrespective of their measure of success, such introductions and transfers have affected aquatic biodiversity in Africa.

Towards Genetic Resource Conservation in Africa

Adverse effects on fish genetic resources in Africa derive in large measure from everyday life and from accepted development efforts on the continent. Therefore, policies towards conservation of fish genetic resources on the continent must consider public attitudes and perceptions. This is not an easy task. The fundamental situation is that information on the genetic resources of African fish and other aquatic life is very limited. Moreover, the long-term effects of local actions on aquatic genetic resources are not greatly appreciated. However, the most effective groups who can protect these resources are those whose livelihoods directly depend on them.

Therefore, policies should be put in place to assist and to support the following:

- accelerated programs for the characterization and documentation of aquatic genetic resources in Africa, using various approaches;
- formal and informal education on the interrelationships among natural resources and the need for their integrated management; community-based management of fish and other living aquatic resources;
- alternative income-generating activities at local levels, especially to limit habitat degradation;
- incentives for protection of fish genetic resources.

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Discussion

Harvey: I'd like to thank Eddie Abban for emphasizing one aspect of public policy. Like him, as a conservationist I've been advocating that, where we know that a stock is disappearing, let's go out and genebank. There has been a lot of criticism of that approach. The main criticism was that more studies are needed first, and I bridled at that because it could take forever. However, I totally agree that governments and others should continue funding research in this area. My own organization has been brought into the research arena. We are now DNA fingerprinting salmon stocks and doing similar work in South America. It's becoming possible to define conservation units and to understand the delineation among stocks. Conservation efforts can be wasted unless this is known.

Kapuscinski: Supplementary to that, it is virtually impossible to do biosafety and risk assessment work unless you have this information base. 'Capacity building' to do this has become a feature of the biosafety protocols now being negotiated under the CBD. This has to be approached strategically; for example, starting with biodiversity 'hotspots'. I don't see anyway that biosafety assessments can be done unless it is known what is there to begin with.

Abban: That's the problem. You cannot make choices unless you know what you have – and to know what you have takes time. There has to be some prioritization of what needs to be done and how to do it.

Mires: I thank Eddie Abban for pointing out the need for education to apply strategies. For example, in Israel, many wild flowers were on the verge of extinction. Education of children about this brought about a dramatic change of attitude in their parents. Parents are now afraid to pick flowers lest their children say 'no, don't do things like that!'

Welcomme: Lake Victoria is the quintessential example of the problems that are to be faced here. Nobody knows exactly what species were in that lake before they disappeared. Some species are coming back now – this might also be the rapid speciation of cichlids. The 'genebanking' of fish from this lake has been carried out largely by individual aquarists operating, mostly within the USA, on a private basis. This initiative has been taken entirely outside the kinds of official mechanisms that we have been discussing.

I also have a comment about co-management. I was recently at a meeting in which a film on Lake Mweru was shown. It was an excellent example of the incapacity of the fishermen to view the situation of their own fishery. The fishers perceived the fishery as being in decline, whereas it had tripled its total output. The point here is that each of the interested parties in a fishery judges it from their own viewpoint and has no vision of what is going on in the fishery as a whole. This means that co-management and conservation by local peoples is difficult and needs an independent party to integrate the viewpoints and to judge what is actually going on in the fishery. As we progress we may be able to educate stakeholders an all aspects of the fishery so they can take a more rounded view. This, in fact, may be a precondition to get good participatory conservation and management to work.

Some of the African lakes have several hundreds of species, undescribed. Taxonomy is in decline. Most of the large museums are used as centers of entertainment. The very people who are supposed to be describing species are becoming as extinct as the species themselves! Where is the basic information to conserve these stocks going to come from? How is the work going to be funded?

A. Gupta Dr. Abban made the useful point about how these issues are part of everyday life. Scientists often miss this in their research.

Kooiman: The point is made in this paper that only those people whose livelihoods depend on resources can properly conserve them. This is a strong statement. Perhaps it is something to strive for. But we are considering policymakers for whom the resources are not exactly their source of livelihood.

Abban: My experience in Africa is that the policymakers, legislators, etc., are all operating at different levels compared to those who sit by the river, who cut firewood everyday and make the riverbank 'naked'. These are the people who depend on the river daily. Enforcement with police, etc. does not last long. That is why I refer to co-management. There is always some resistance to starting it. But the message does get through to those who depend on the resource everyday.

Pullin: Robin Welcomme mentioned the example of Lake Victoria. Lake Malaŵi is another important example. There are probably between 500 and 1 000 endemic cichlid species in Lake Malaŵi–many with unknown potentials. How can the source countries of such aquatic genetic resources in Africa share benefits with others who are using them or who will use them in the future? At present, some of these species are being used by aquarists around the world. This is a large example. A smaller example is the start-up of a commercial farm in Côte d'Ivoire that uses a fast-growing subspecies of *Sarotherodon melanotheron* from Sénégal. How does the source country benefit? I don't see how the patenting or other instruments described by Carlos Correa can work in these situations, at least for the foreseeable future. The CBD has provisions for benefit sharing – but what are the mechanisms?

Froese: I want to support Eddie Abban on one point in particular. In our database, I have been looking at how much is known about species that could be applied to co-management. The amount of information varies from very little (for example, only one reference just giving the species name) to 260 references (for the cod). The median number for available references is three–that is a very low number. So for many species, we know little more than their names.

Perspectives on Aquatic Genetic Resources in Asia and the Pacific[1]

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ABSTRACT

The Asia-Pacific region has probably the most diverse aquatic biodiversity in the world. In addition to playing an important role in the livelihood of the people in the region, these resources contribute significantly to global fish production, which emphasizes the need for their conservation and sustainable use. While many countries have been signatories to the Convention on Biological Diversity, few countries have national biodiversity conservation plans. Where these exist, either aquatic resources do not receive attention or the plans are not implemented due to lack of resources. Details of legislation/regulations developed by India and the Philippines for bioprospecting, introduction of alien species and genetically modified organisms and protection of rights of local communities over resources and knowledge are discussed. Details of species introduced and established in the wild and of the finfish species extinct or endangered in the region are given. Treaties, to which countries in the Asia-Pacific region are signatories, are listed. The paper emphasizes the urgent need for development and implementation of policies/regulations at national and regional levels, before it becomes too late to conserve the resources.

Introduction

Living aquatic resources are of crucial importance to the livelihood of the peoples of Asia and the Pacific. Marine, brackish and freshwaters in the Asia-Pacific region probably support the most diverse aquatic flora and fauna in the world. Dependence on aquatic products for animal protein is very high, nearly 100% in some coastal villages. For example, fish provides some 70% of the animal protein and 30% of the total protein intake of humans in the Philippines, and the Maldives have the highest annual fish supply in the world at 126 kg per person per annum (FAO 1997a). Approximately a quarter of the population in China's coastal provinces is employed in fisheries and related activities, while about 1 million (5% of labor force) earn their livelihood from fisheries in the Philippines (ADB 1993).

Humans have been a significant evolutionary force in every ecosystem that they inhabit and have been responsible for many changes in both domestic and wild species (Lester 1992). Overexploitation of resources, environmental degradation and habitat loss are resulting in loss of valuable aquatic populations and threatening the extinction of some species. Since aquatic systems are poorly understood, relatively unmanageable and highly vulnerable to human interventions, conservation is not an easy task. Increase in fishing pressure is resulting in reductions in genetic and species diversity. Many of the major fish stocks have been overexploited. Of the fished stocks that account for world marine fish landings, 5% are depleted, 11% are overexploited, 1% are recovering, 36% are fully exploited, 16% are moderately exploited, 5% are underexploited, and 26% of the stocks have not been assessed (FAO 1997b).

[1]ICLARM Contribution No. 1553

Most of the inland and coastal resources in the Asia-Pacific region are under threat from pollution, siltation, habitat alteration, introduction of alien species and overexploitation. Aquatic biodiversity is being lost at an alarming rate. Sixty percent of coral reefs in Southeast Asia have been either destroyed or severely damaged (Wilkinson et al. 1993). In the Philippines, rays are threatened due to hazardous and destructive harvesting practices (Lundin and Lindsay 1993). An estimated 10-15 million coral heads are sprayed with sodium cyanide every year by fishers engaged in the live-fish trade in the Philippines. Overexploitation of sea urchins in the Philippines has caused the fishery to collapse, and two species of giant clams have been hunted to local extinction (Barber and La Viña 1997). On the southern and western coasts of Sri Lanka, coral reefs are disappearing at an estimated rate of 10% annually (Rajasuriya 1993). Globally, at least 20% of freshwater fish species are already extinct or in serious decline due to environmental degradation and management (Moyle and Leidy 1992). The IUCN Red Book lists 53 species as either extinct or threatened in the Asia-Pacific region (Baille and Groombridge 1996; Table 1). This probably is an underestimate of the severity of the problem, because there is no comprehensive assessment of freshwater fish fauna and hence there is a possibility of more species being either extinct or threatened (see also Froese and Torres this vol.) There is a need to conserve genetic stocks of wild and cultured species in order to maintain their genetic diversity that has been developed through thousands of years of evolution. At the ecosystem level, biodiversity attains importance since with increased diversity comes the increased efficiency of resource use. Within an ecosystem, functionally similar species will have different environmental tolerances to perturbations. Thus, the stability and resilience of the system will be increased with increased diversity (Chapin et al. 1997). In the past, conservation, management and utilization of aquatic resources have received very little attention with the result that not much is known of the aquatic genetic resources and their sustainable use. When compared with genetic resources for agriculture, aquatic genetic resources are poorly documented and their ownership and arrangements for access are not well defined (Pullin 1997).

Conservation of Aquatic Genetic Resources

Technological changes are increasing the economic value of genetic resources as a whole, as the potential use of material has expanded considerably, e.g., increased salinity and/or cold tolerance of freshwater species through selective breeding/selection is resulting in extending the use and geographic distribution of the species. Thus, this potential for the use of aquatic genetic resources to develop products of nutritional and other economic value is as great as for the genetic resources of terrestrial plants and animals. However, unlike terrestrial plants and animals, only a few species of aquatic organisms have been domesticated and the major portion of production comes from wild organisms.

The Convention on Biological Diversity (CBD) (UNCED 1992a), Agenda 21 (UNCED 1992b), and the United Nations Convention on the Law of the Sea (UNCLOS 1992) recognize that living aquatic resources are essential for humankind, that nations have sovereign rights over these resources and that some shared by nations (see also Leria, this vol.). The CBD commits its Contracting Parties to take substantive action in many areas, including the development of national plans for the conservation and sustainable use of biodiversity and the integration of these into relevant programs and policies. The FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO 1995a) also emphasizes the need for establishing principles and criteria for the elaboration and implementation of national policies for responsible conservation of fisheries resources and fisheries management and development. Forty-six countries in Asia and the Pacific are signatories to the CBD and to a number of other conventions, codes and protocols, including the CCRF (Table 2) (FishBase 1997), but little attention has yet been paid to developing and implementing policies for the conservation and use of aquatic genetic resources. Some existing conventions on natural resources do not even make mention of aquatic genetic resources. Governments rarely develop policies and regulations in such areas until confronted with crisis situations.

Governments in the Asia-Pacific region are, however, concerned about the loss of biodiversity and are in the process of developing biodiversity conservation strategies and action plans. At the national level, many

Table 1: Extinct and endangered finfish in Asia-Pacific region.[a]

Family	Genus	Species	IUCN Status Code	FAO Area Code
Acipenseridae	*Acipenser*	*gueldenstaedtii*	EN	4
Acipenseridae	*Acipenser*	*mikadoi*	EN	4, 61
Acipenseridae	*Acipenser*	*nudiventris*	EN	4
Acipenseridae	*Acipenser*	*persicus*	EN	4
Acipenseridae	*Acipenser*	*schrenckii*	EN	4, 61
Acipenseridae	*Acipenser*	*sinensis*	EN	4, 61
Acipenseridae	*Acipenser*	*stellatus*	EN	4
Acipenseridae	*Huso*	*dauricus*	EN	4
Acipenseridae	*Huso*	*huso*	EN	4
Adrianichthyidae	*Oryzias*	*orthognathus*	EN	4
Adrianichthyidae	*Xenopoecilus*	*oophorus*	EN	4
Adrianichthyidae	*Xenopoecilus*	*sarasinorum*	EN	4
Amblycipitidae	*Liobagrus*	*nigricauda*	EN	4
Atherinidae	*Craterocephalus*	*fluviatilis*	EN	6
Balitoridae	*Yunnanilus*	*nigromaculatus*	EN	4
Carcharhinidae	*Carcharhinus*	*obscurus*	EN	81, 71, 61
Clupeidae	*Tenualosa*	*thibaudeaui*	EN	4
Cobitidae	*Lepidocephalichthys*	*jonklaasi*	EN	4
Cyprinidae	*Acanthobrama*	*hulensis*	EX	4
Cyprinidae	*Acheilognathus*	*elongatus*	EN	4
Cyprinidae	*Anabarilius*	*polylepis*	EN	4
Cyprinidae	*Balantiocheilos*	*melanopterus*	EN	4
Cyprinidae	*Cyprinus*	*micristius*	EN	4
Cyprinidae	*Epalzeorhynchos*	*bicolor*	EW	4
Cyprinidae	*Labeo*	*fisheri*	EN	4
Cyprinidae	*Onychostoma*	*alticorpus*	EN	4
Cyprinidae	*Ospatulus*	*palaemophagus*	EN	4
Cyprinidae	*Phoxinellus*	*anatolicus*	EN	4
Cyprinidae	*Probarbus*	*jullieni*	EN	4
Cyprinidae	*Puntius*	*asoka*	EN	4
Cyprinidae	*Puntius*	*martenstyni*	EN	4
Cyprinidae	*Rasbora*	*wilpita*	EN	4
Cyprinidae	*Schizothorax*	*lepidothorax*	EN	4
Cyprinidae	*Tor*	*yunnanensis*	EN	4
Cyprinodontidae	*Aphanius*	*anatoliae*	EN	4
Cyprinodontidae	*Aphanius*	*burduricus*	EN	4
Dasyatidae	*Himantura*	*chaophraya*	EN	6, 4
Melanotaeniidae	*Melanotaenia*	*boesemani*	EN	4
Odontaspididae	*Carcharias*	*taurus*	EN	71, 81, 61
Osteoglossidae	*Scleropages*	*formosus*	EN	4
Pangasiidae	*Pangasius*	*gigas*	EN	4
Percichthyidae	*Maccullochella*	*ikei*	EN	6
Percichthyidae	*Maccullochella*	*macquariensis*	EN	6
Percichthyidae	*Nannoperca*	*oxleyana*	EN	6
Plecoglossidae	*Plecoglossus*	*altivelis ryukyuensis*	EN	61, 4
Pristidae	*Pristis*	*microdon*	EN	6, 61, 71, 4
Pristidae	*Pristis*	*pectinata*	EN	71, 4
Pristidae	*Pristis*	*pristis*	EN	71, 6
Pseudomugilidae	*Pseudomugil*	*mellis*	EN	6
Retropinnidae	*Prototroctes*	*oxyrhynchus*	EX	6
Salmonidae	*Oncorhynchus*	*ishikawai*	EN	4
Salmonidae	*Salvelinus*	*japonicus*	EN	4
Siluridae	*Silurus*	*mento*	EN	4

[a]IUCN Status Codes, EN = endangered, EW = extinct in wild, EX = extinct, FAO Area Codes: 4 = Asia (inland), 6 = Oceania (inland), 61 = Northwestern Pacific, 71 = Western Central Pacific, 81 = Southwestern Pacific

Source: Baille and Groombridge (1996).

Table 2. List of treaties, conventions and protocols that concern natural resources and the countries in Asia and the Pacific that are signatories.

Treaty	Signatories
Agreed measures for the Conservation of Antarctic Fauna and Flora Amendment to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Art. XI)	China, India, Japan, Australia, New Zealand India, Indonesia, Japan, Nepal, Pakistan, Saudi Arabia, Australia, New Zealand, Vanuatu
ASEAN Agreement on the Conservation of Nature and Natural Resources	Indonesia, Malaysia, Philippines, Singapore, Thailand
Convention for a North Pacific Marine Science Organization (PICES)	China, Japan
Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (SPREP)	Australia, Cook Islands, Fiji, Kiribati, Micronesia, Nauru, New Zealand, Palau, Papua New Guinea, Samoa, Tuvalu
Convention on Conservation of Nature in the South Pacific	Australia
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	Afghanistan, Bangladesh, Cambodia, China, India, Indonesia, Nepal, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Japan, Korea (Rep. of), Kuwait, Malaysia, Mongolia, Myanmar, Taiwan, Thailand, Turkey, United Arab Emirates, Yemen, Australia, New Zealand, Papua New Guinea, Vanuatu
Convention on Biological Diversity (CBD)	Afghanistan, Bahrain, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Japan, Kazakhstan, Korea (Rep. of), Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Qatar, Singapore, Sri Lanka, Syria, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Yemen, Australia, Cook Islands, Fiji, Kiribati, Micronesia, Nauru, New Zealand, Niue, Papua New Guinea, Samoa, Tuvalu, Vanuatu
Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR)	India, Japan, Korea (Rep. of), Australia, New Zealand
Convention on the Conservation of Migratory Species of Wild Animals (CMS)	India, Pakistan, Philippines, Saudi Arabia, Sri Lanka, Australia
Convention on the Conservation of the Living Resources of the Southeast Atlantic	Japan
Convention on the Continental Shelf	Afghanistan, Cambodia, Indonesia, Malaysia, Nepal, Pakistan, Sri Lanka, Thailand, Australia, Fiji, New Zealand, Tonga
Convention on the High Seas	Afghanistan, Cambodia, Cyprus, Indonesia, Japan, Lebanon, Malaysia, Mongolia, Nepal, Pakistan, Sri Lanka, Thailand, Australia, Fiji, New Zealand, Tonga
Convention on the International Maritime Organization	Bahrain, Bangladesh, Cambodia, China, India, Indonesia, Iraq, Japan, Kazakhstan, Korea (Rep. of), Kuwait, Malaysia, Maldives, Myanmar, Nepal
Convention on the Territorial Sea and the Contiguous Zone	Afghanistan, Australia, Cambodia, Fiji, Japan, Malaysia, Nepal, New Zealand, Pakistan, Sri Lanka, Thailand, Tonga
Convention Relative to the Preservation of Fauna and Flora in Their Natural State	Fiji, Kiribati, Papua New Guinea, Samoa, Tonga, Tuvalu, Vanuatu
Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution	Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates
Protocol Concerning Marine Pollution Resulting from Exploration and Exploitation of the Continental Shelf	Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia
United Nations Convention on the Law of the Sea (UNCLOS)	Afghanistan, Bahrain, Bangladesh, Bhutan, Cambodia, China, India

countries have had, for some time, laws and institutions in place concerned with nature conservation. They have long acknowledged the importance of conserving resources through the establishment of parks and protected areas. However, even where aquatic protected areas exist, they are rarely integrated into a landscape-scale approach. The *de facto* open access nature of most coastal habitats, due to the assertion of State ownership, further complicates the picture (Barber 1997). However, conservation policies must take into account that aquatic species are the only remaining nondomesticated living animal resources of major significance (Ryman et al. 1993) that have not received attention in the past for their conservation and sustainable use. While specific policies do not exist in some countries for the sustainable use and conservation of aquatic genetic resources, in others, where they do exist, implementation is a problem mainly due to lack of resources.

While governments have now realized the importance of living aquatic resources, only in recent years have some governments initiated the process for developing national plans and policies for conservation of biodiversity, use and access, and other countries (e.g., India) are in the process of developing these (details available at the CBD website, http://www.biodiv.org).

Access to and Use of Aquatic Genetic Resources

Access

For billions of people in developing countries who depend directly on living aquatic resources for their livelihood, the biodiversity issue is often not its loss or its utility, but the concern for erosion of their access to its components and benefits. Disputes involving access to and exchange of genetic resources have been at the center of international policy and law for some time now. Access rights are being applied to many capture fisheries that were traditionally under common property, open-access regimes (FAO 1995b). The entry into force of the UNCLOS (1992) restricted foreign access to State Exclusive Economic Zones (EEZs). With increasing awareness of the inequities of current international trade in biological material, exploitation by private companies, and rising unrest among local communities because of benefits not accruing to them, there is greater public pressure on the governments to take steps to regulate access to biological material, to generate returns for its use, and to ensure equitable benefit sharing with local communities.

The CBD calls upon Parties to establish conditions that facilitate access to genetic resources for environmentally sound uses and to promote the sharing of benefits arising from their use. For establishing a legal regime on access to genetic resources, the approaches taken by different countries reflect their unique legal, institutional, economic and cultural conditions. Developing legally-binding, prior informed consent (PIC) procedures and mechanisms to carry them out should be the highest priority for countries wishing to share the benefits of use of genetic resources. No country in the Asia-Pacific region has yet adopted a comprehensive legislation governing access to genetic resources. While comprehensive legislation with the approval of the highest authority in the country is needed, it would be better to have more flexible alternatives in the absence of working legislation. This is the course that the Philippines took in 1995 in the, issuing of Presidential Executive Order (EO 247) which regulates biodiversity prospecting and access to genetic resources (La Viña et al. 1997). This EO establishes a framework to regulate biodiversity prospecting with four basic elements: (1) a system of mandatory research agreements between collectors and the government, containing minimum terms concerning provision of information and samples, technology cooperation and benefit sharing; (2) interagency committees to consider, grant, monitor and enforce compliance with research agreements as well as to coordinate further institutional, policy and technology development; (3) a requirement and minimum process standards for obtaining prior informed consent from local and indigenous communities where collection of materials is carried out; and (4) minimum requirements to conform with environmental protection laws and regulations.

A major followup to CBD's provisions for national sovereignty, prior informed consent and mutually agreed terms will be promulgation of national laws and administrative arrangements that regulate international transfer of biological material, like the Philippines' EO. India is in the process of issuing an order under its Foreign Trade Act of 1992 that requires agencies/ individuals, who wish to collect or to transfer biological materials, to seek permission from the following:

(1) Zoological Survey of India for wild animals; (2) National Bureau of Fish Genetic Resources for economically important freshwater fish; (3) Central Marine Fisheries Research Institute for economically important marine fishes; and (4) Central Institute of Brackishwater Aquaculture for economically important brackishwater fishes. The applicant has to declare that the materials will not be used for anything other than for the purpose specified in the application. However, these agencies do not have guidelines or criteria for decisions while screening applications for transfers of living material.

Article 8 of the CBD requires governments to respect, preserve and maintain the knowledge, innovations and practices of indigenous and local communities for the conservation and sustainable use of biodiversity, and an equal sharing of benefits arising from such knowledge, innovations and practices. This provision is qualified by the phrase "subject to its national legislation", which probably implies that it is not binding on the governments if they have laws contrary to this. India has drafted National Biodiversity Legislation (NBL), following a review of 40 national enactments that have a bearing on biodiversity, and these documents have pointed out major gaps in the legal coverage of various aspects of conservation, sustainable use and benefit sharing. The principles covering the NBL are: (1) sovereign rights over Indian biological resources through controls on international access; (2) local community rights over resources and related knowledge; (3) generating greater equity and public participation in conservation and use of bioresources; and (4) availability of technological choices to conserve and use resources ensuring human and ecological safety.

The Philippines EO 247 makes PIC of communities a prerequisite for collecting biological resources. The National Biodiversity Action Plan (NBAP) and the draft National Biodiversity Legislation of India contain provisions ensuring the PIC of local communities. In India, there is a cautious move toward devolving control over resources to local communities. Recent constitutional amendments have given greater powers to local village bodies such as panchayats: a panchayat is a village management organization, representatives to which are elected by the people. The relationship between local, state and central authority is not clear. Preparation of community registers at the local level is proposed under the NBAP, to document traditional knowledge and practices (see also A. Gupta this vol.). A number of organizations and activists in India are suggesting that the law should recognize some form of community intellectual property rights (IPR). The proposed NBAP, while acknowledging the need to recognize community rights, does not give any details on the nature of these rights. Coordination and sustainable exploitation of resources often becomes difficult due to multiple jurisdictions (state, federal, different ministries). It has been proposed that the National Biodiversity Legislation should make suitable amendments under existing IPR enactment and legislation, by framing separate rules under the legislation and to provide mechanisms for intellectual property protection to local communities/individuals.

The Philippines Executive Order 247 clearly states that any agreement for bioprospecting should include a provision for payment of royalties to the national government, local or indigenous cultural community and individual person or beneficiary. It also states that if the collector of genetic material is a foreign person or entity, it must be stipulated that Philippine scientists be involved in collection and research. In case of endemic species, the technology must be made available to a designated Philippine institution in which it can be used commercially without paying royalty.

In some countries, significant powers over natural resources are vested in states or provinces, and national legislation may be limited to creating or amending one or more framework laws with followup assistance to state/provincial governments to develop more detailed rules. Legal experts in Malaysia have concluded that incorporation of relevant access and benefit sharing provisions, under an all encompassing federal act, would exceed the constitutional powers of the federal government. Incorporation of such provisions in existing sectoral framework laws on forestry, fisheries and wildlife is constitutionally sound (Mugabe et al. 1996).

While most developing countries have created institutions to manage and to regulate access to natural resources, most of these institutions are poorly funded, understaffed, and lack administrative capacities to regulate access to genetic resources. To take advantage of new opportunities arising out of the CBD, countries need to invest in strengthening these institutions.

Use

Aquaculture

Ninety-one percent of global aquaculture production is from the Asia-Pacific region, indicating the importance of the aquatic resources not only to the region, but also for global food security. In spite of the importance, arrangements for access to these genetic resources and their use are poorly defined. Studies undertaken in recent years for the genetic improvement of finfish for aquaculture have resulted in improved strains (e.g., GIFT Nile tilapia). However, arrangements for their access and use are poorly documented. ICLARM's policy on IPR on aquatic genetic resources states that it will not normally seek intellectual property protection on any material in its collections of aquatic resources or on cells, organelles, genes or molecular constructs isolated therefrom or from ICLARM's own breeding activities (ICLARM, unpubl.).

Thirteen member countries of INGA, of which nine are from Asia, have been sharing finfish germplasm (including genetically improved strains) for aquaculture, with prior informed consent and on mutually agreed terms, following strict quarantine protocols and material transfer agreements (The INGA Planning Meeting 1997; Gupta and Acosta 1999). However, with the entry of the private sector in to the arena of genetic improvement of aquaculture species, it remains to be seen whether the free exchange of germplasm will continue or the access will be regulated.

Capture fisheries

Asia is a global center for biodiversity (fishes, mangroves, seagrasses, corals and other invertebrates) and home to several large diverse river catchment systems of global significance. All these systems are facing threats from overfishing, construction of dams, pollution and species introductions, among others, resulting in extinction of species and loss of biodiversity. It has been recognized that policies are needed for fisheries resource use, access rights, security of tenure and regulation, especially for inland and coastal fisheries (Ahmed et al. 1997). Wetlands and low-lying floodplains, which are home to a number of important aquatic species, are being reduced or lost due to agricultural developments. Access to these resources, which were for open access in the past, are being regulated, affecting the livelihood of people in rural areas.

Enhanced fisheries

Enhanced fisheries, cultured-based fisheries or ranching for increasing productivity from natural waters is being undertaken in a number of countries in the Asia-Pacific region, e.g., Australia (Petr 1998), Bangladesh (Payne and Cowan 1998), China (Lu 1992), India (Sugunan 1995), Japan (Welcomme and Bartley 1998), and the Philippines (Cruz 1998). However, the utility and purpose of this approach are being questioned because of the fear of the loss of natural genetic diversity through interaction of 'hatchery' fish with native populations (Philipp et al. 1993). Analysis of *Barbodes gonionotus* sampled from the rivers in Thailand indicated that 75% to 96% are from hatchery populations, indicating the possibility of losing or altering the genetic integrity of wild populations (Pongthana 1998). Guidelines and regulations for releasing hatchery stocks into open waters are lacking and this needs to be addressed. Bartley (1996) has provided some protocols for conservation of biodiversity in aquatic ranching. These are applicable in the Asia-Pacific region, as elsewhere.

Movement of Aquatic Germplasm

Movement of species across their natural boundaries for aquaculture or enhancing fisheries or for ornamental purposes can have effects on biodiversity and on the ecosystem into which they are introduced, causing imbalance in predator-prey relations, introduction of diseases, etc. Introduction of aquatic species are considered to be one of the main threats to natural aquatic populations (Williams et al. 1989). The classic example is the introduction of Nile perch *(Lates niloticus)* to Lake Victoria, which has resulted in a multimillion dollar fishery (for export), but perhaps at the cost of hundreds of endemic species that have formed the diet of the local population for ages.

There has been a debate on the limited use of existing advisory codes of practice for introductions and transfers of aquatic organisms (Turner 1988) and on the need for research and development organizations to formulate and implement policies that will minimize environmental risk (Pullin 1994). Based on various consultations and workshops, FAO has developed a draft framework for the responsible use of introduced species (Bartley et al. 1996).

A number of species have been introduced into various countries in the Asia-Pacific region. Sometimes the same species has been introduced to a particular country from different sources/countries, for purposes of aquaculture, angling, enhanced fisheries, control of mosquitoes, ornamental purpose, phytoplankton and weed control. Some species have been introduced accidentally (Table 3). A considerable number of these introductions have reached open waters and have become established in the wild. Introductions are still being made into countries in the region sometimes, by individuals and by the private sector, without the knowledge of the government or without making any assessment of their impact on the environment and on biodiversity. For example, silver carp (*Hypophthalmichthys molitrix*) , which is alien to India, accidentally got entry into a reservoir and replaced an indigenous carp, *Catla catla* (Dubey and Ahmad 1995). Similarly, *Oreochromis mossambicus* replaced almost all other species in Vaigai reservoir in India to form 99% of the total catch (Anon. 1992). In Taiwan, *O. mossambicus*, which was first introduced in 1944, has become the dominant fish surviving in rivers, reservoirs, drainage systems, estuaries and saline lagoons, endangering endemic fresh and marine fish species (Liao et al. 1993). Movement of alien species within the Philippines completely changed the fish fauna of Lake Lanao, Mindanao (Villwock 1972). Despite severe penalties for the introduction of exotic fishes in Australia, tilapias are reported to be spreading widely after being introduced by the ornamental aquarium fish trade (Mather and Arthington 1991). Trade in ornamental fish has grown considerably in the last two decades. Although, many ornamental fish are bred in hatcheries, a significant number still find their way into natural waters, potentially posing a threat to wild stocks.

Escapes from aquaculture can sometimes affect hatchery and wild populations. In the Philippines, *O. mossambicus* has become established in open waters and has hybridized with farmed stocks of *O. niloticus* (Macaranas et al. 1986). The golden snail (*Pomacea* sp.), introduced into the Philippines for farming, has infested over 400 000 ha of ricefields (Acosta and Pullin 1991).

It is almost impossible to reverse the negative impacts of introductions, especially those made into marine and riverine environments. Hence, strict evaluation of impacts and decisions prior to introduction of alien species is essential. Decisionmaking on the use of alien species is essentially a political process that requires realistic assessment of risk, not only environmental but also socioeconomic. Good assessment tools for this are lacking. While governments recognize the need to formulate and to implement policies that will regulate introduction of alien species and minimize the environmental risks of such introductions, very few countries have legal instruments to do so, and where they do have them, are not able to implement them due to lack of resources.

The proposed NBL in India envisages that introduction of alien species and genetically modified organisms and species shall be subject to risk assessment and risk management prescribed in the relevant rules and quarantine procedures when such species are imported. The National Committee on Biosafety of the Philippines has drafted guidelines for securing permission for release of potentially harmful alien species and genetically modified organisms (Anon. 1997a). While these and some other countries in the region have developed or are in the process of developing policies and guidelines, very little has been done when it comes to implementation, due to lack of facilities and resources (financial and human).

Nine member countries of the International Network on Genetics in Aquaculture (INGA) from Asia and the Pacific, have discussed and agreed on protocols for introduction of exotic species (Gupta and Acosta unpubl.). A country planning to import alien species and genotypes has to sign a Material Transfer Agreement which states that it agrees to:

"(a) abide by the provisions of the Convention on Biological Diversity;

(b) preclude further distribution of germplasm to locations at which it could have adverse environmental impact;

(c) not claim ownership over the material received, nor seek intellectual property right rewards over that germplasm or related information;

(d) ensure that any subsequent person or institution to whom they make samples of

Table 3. Number of finfish introduced and established in the wild in Asia and the Pacific.[a]

Country or territory	No. of introduced species	No. of species established in wild		Reasons for introduction
Afghanistan	3	2		aq
Amer Samoa	4	4		mc, bait, f
Australia	30	25	(1)	o, a/s, mc, ac, f, aq
Bangladesh	8	4	(1)	aq
Bhutan	10	2	(1)	aq
Brunei Darus	2	-		
Cambodia	7	-		
China	26	8	(2)	aq, mc, ac, o
Cook Islands	4	3		aq, mc, u
Cyprus	20	9	(4)	a/s, aq, fen
Fiji	27	13	(4)	aq, wec, o, mc, res, a/s
Guam	23	14	(1)	aq, o, u, a/s, mc, wec
Hawaii	59	46	(9)	o, f, ac, a/s, aq, mc, u, a/s, wec, bait
Hongkong	14	8		mc, a/s, aq, o
India	28	17	(6)	wec, o, aq, mc, a/s, pc
Indonesia	34	14	(3)	o, aq, u, res, mc
Iran I R	3	-		
Iraq	8	6		aq, mc
Japan	49	27	(3)	aq, a/s, u, f, mc, o, ac
Kiribati	3	2		mc, ac
Korea (Rep of)	12	8	(4)	aq, fen, o
Laos	8	3		aq
Malaysia	24	15	(3)	mc, aq, o, a/s
Maldives	2	1		f
Marshall Island	1	1		mc
Mauritius	1			aq
Micronesia	2	2		mc, aq
Myanmar	5	-		
N. Marianas	3	4		mc, f, aq
Nauru	1	1		mc
Nepal	10		(1)	aq
New Caledonia	10	10	(1)	u, aq, mc, f
New Zealand	24	20	(1)	a/s, o, wec, mc, pc, f
Niue	1	1		aq
Pacific Island Trust Territory	2			
Pakistan	13	10		aq, a/s, f
Palau	4	4	(1)	u
Papua New Guinea	25	15		diffusion from neighbor, aq, u, mc,
Philippines	39	30	(7)	aq, res, o, mc
Samoa (Western)	5	5		u, mc, aq
Saudi Arabia	2	1		u
Singapore	24	7		o, aq
Solomon Island	2	2		mc, aq
Sri Lanka	24	15	(4)	u, mc, aq, a/s, o, ac
Tahiti (French Polynesia)	9	6	(1)	mc, u, aq
Taiwan	31	11	(4)	aq, mc, fen
Thailand	26	12	(4)	aq, o, mc
Tonga	1	1		mc
Turkey	7	3	(2)	u, f,
Tuvalu	1	1		aq
United Arab Emirates	2	-		
US Minor Island	1	-		
Vanuatu	1	1	(probably)	u
Vietnam	14	11	(1)	aq
Wallis Fut. Island	3	3	(1)	aq, u

[a]Numbers in parentheses indicate the numbers of 'probably yes'. Abbreviations: ac - accidental (ship ballast, imported, alone or with other species); aq - aquaculture; a/s - angling/sport; f – fisheries; fen- fill ecological niche; mc - mosquito control; o – ornamental; pc - phytoplankton control; res – research; u – unknown; wec – weed control.

Source: FishBase (1997).

germplasm available is bound by the same provision;

(e) that the responsibility to comply with the country's biosafety and import regulations and any of the recipient country's rules governing the release of genetic material is entirely theirs;

(f) follow with the quarantine protocols suggested by INGA/ICLARM; and

(g) abide by the International Codes of Transfer of Germplasm in case the germplasm is transfered beyond the boundaries of their country."

Transfers of or trade in aquatic animals without risk of transfer of diseases are not possible. Hence there is a need for strict quarantine and health certification protocols and policies and their implementation, if the spread of diseases is to be avoided. The observance of strict quarantine programs could be the first defense against possible adverse effects from introduction of alien species. Therefore, protocols should be developed, within the context of larger national and international plans, for addressing this problem. These efforts should be accompanied by the development of regionally agreed upon lists of notifiable pathogens, standardization of diagnostic techniques and health certification (Bartley et al. 1996).

A workshop, organized in 1996 by the Food and Agriculture Organization (FAO), Network of Aquaculture Centers in Asia-Pacific (NACA), the Aquatic Animal Health Research Institute (AAHRI), and Australian Center for International Agricultural Research (ACIAR), came up with a strategy for development and implementation of quarantine guidelines for the responsible movement of aquatic animals in the Asia-Pacific region (FAO 1997c). Presently FAO, NACA and the Office of International Epizootics (OIE), are organizing a regional program for development of technical guidelines on quarantine and health certification and the establishment of information systems for the responsible movement of live aquatic animals, in which 20 countries from the Asia-Pacific region are participating.

One of the few documented examples of the application of strict quarantine protocols for a fish introduction in Asia was the importation of tilapia germplasm from Africa for genetic improvement research by ICLARM and its partners (Eknath et al. 1992; Danting and Somga 1999). Based on these protocols, the INGA member-countries developed quarantine protocols to be followed by the exporting and importing countries (Gupta and Acosta, unpubl.). ICLARM and/INGA insist on strict adherence to quarantine protocols by importing and exporting countries, when involved in the transfer of germplasm for research.

Genetically Modified Organisms

The development of transgenic fishes involves ecological and ethical considerations that could constrain its progress. Knowledge useful for quantifying the benefits and risks posed by aquatic genetically modified organisms (GMOs) (e.g., those produced by gene transfer or chromosome set manipulation) is currently limited (Hallerman and Kapuscinski 1992; Hallerman and Kapuscinski 1995; Kapuscinski et al., this vol.). The perception that GMOs with altered phenotypes might pose risks to human health and/or to the environment is leading some governments and international organizations to promote guidelines regulating research and development of GMOs. However, unlike in the case of terrestrial plants, research for genetic manipulation of aquatic organisms and the use of GMOs is still in its infancy in the Asia-Pacific region and is not yet looked upon as a problem by the governments. Chapter 16 of Agenda 21 (UNCED 1992a) states specifically that governments and NGOs should evaluate the use of various biotechnology techniques to improve the yields of fish, algal and aquatic species. Responsibility for regulating laboratory production of GMOs in Japan is divided among several public agencies depending on where it is carried out (McCormick 1987). Research that address the genetic modification of aquatic organisms is being carried out in a number of Asian countries (Table 4) where there are no public policies mandating safe laboratory practices or restricting environmental release of GMOs. Outdoor release of transgenic fish has taken place at least in one Asian country, China (Hallerman 1993).

A number of issues complicate the development of public policies regulating development of GMOs in developing countries. One is the lack of relevant technical expertise and management expertise. The FAO Expert Consultation on Utilization and Conservation of Aquatic Genetic Resources (FAO 1993) recommended that quantitative risk assessment and risk management be conducted when evaluating GMOS, and that the burden of proof for safety of application of GMOs be placed on the party requiring the use permit. Despite this, there are no binding international agreements addressing situations where GMOs cross national boundaries. The legally binding biosafety protocols being developed by CBD cover only GMOs produced by genetic manipulation, overlooking the fact that wild exotic species and breeds developed by conventional breeding methods can also be biohazards.

The National Biosafety Committee of the Philippines has drafted detailed guidelines for release of GMOS and potentially harmful exotic species (Anon. 1997). These guidelines envisage that the organisms proposed for release must have been tested previously in laboratories or other contained facilities and risk to human health and the environment resulting from such planned releases must be deemed acceptable on rational risk-benefit analysis. The guidelines further state that the proponent of the release should submit a detailed report within 90 days of the release specifying, among other things, the nature and consequences of any adverse effects. Policies developed/adopted by individual countries and international institutions do not adequately apply to aquatic GMOs, as evident from the Philippine case. Impact of release of aquatic organisms cannot, of course, be fully assessed within 90 days of their release. These guidelines have been basically developed for terrestrial plants and animals. It is much more difficult to contain and to control aquatic organisms once they are released into natural waters.

Regional Cooperation

Regional cooperation in conserving and regulating access to living aquatic resources is critical, as neighboring countries may share a considerable part of these resources. Parties should share information and conduct joint research on transboundary impacts, shared ecosystems, migratory species, etc. The Code of Conduct for Responsible Fisheries (FAO 1995a) requires that States with neighboring coastal areas cooperate with each other in facilitating sustainable use of coastal resources and conservation of the same. The National Action Plan for Biodiversity of India clearly states the need for strengthening cooperation with neighboring countries, through regional bodies such as the South Asian Association for Regional Cooperation, Association of the South-east Asian Nations and the Economic and Social Commission for Asia and Pacific.

Table 4. Countries in Asia where research on genetically modified organisms is conducted and presence or absence of regulations (modified from Hallerman and Kapuscinski 1992).

Country	National regulation
India	yes
Indonesia	no
Japan	yes
Malaysia	no
People's Republic of China	no
Thailand	no

Biodiversity prospecting is underway in a number of ASEAN and neighboring countries. Such bioprospecting includes the collection and screening of aquatic organisms. Given biological similarities of countries in this subregion, there are good reasons for ASEAN countries to consider the possibility of establishing common or at least harmonized policies on biodiversity prospecting (RAFI 1994).

The 13 member-countries of INGA, including nine from Asia and the Pacific, reviewed the declining fish catches from natural resources and came up with the "Manila Resolution" which stresses the need for concerted regional and international efforts for advancing the science of fish breeding and genetics through cooperation and networking (Anon. 1997a). ICLARM has, moreover, initiated a number of regional projects in Asia for the management of coastal resources, the genetic improvement of cultured species, etc., which would be useful in developing management measures for shared resources and exchange of information/methodologies for conservation of resources and improving productivity.

Concerning information, to date there is no complete documentation of aquatic genetic resources and their potential for aquaculture. FishBase, which contains information on 20 000 species of finfish, is, however, a useful tool for understanding and managing fishery resources in terms of conserving biodiversity and its sustainable use (Froese and Pauly 1998). Many countries in the region, have in recent years, embarked on characterization of and documentation of aquaculture species (e.g., see Gupta and Acosta 1999; Gupta et al. 1998 and the development of the Clearinghouse Mechanism of the CBD).

Conclusion

There is great potential for living aquatic resources to continue to contribute to the food security of countries in the Asia-Pacific region. However, despite being signatories to the CBD and having endorsed the FAO Code of Conduct for Responsible Fisheries (FAO 1995), very few countries in this region have effective policies or regulations for the conservation and sustainable exploitation of aquatic genetic resources. Similarly, issues of property rights, transfer, quarantine and health, and the equitable sharing of benefits from the exploitation of living aquatic resources are yet to be widely tackled. The lack of policies is resulting in countries undertaking programs/projects that undermine the importance of aquatic biodiversity and this is resulting in many aquatic organisms either becoming extinct or endangered. In the absence of policies on introduction of alien species and genotypes, public and private sector agencies are importing these without making any risk assessment. These shortsighted acts, for short-term benefits, will lead to irrevocable damage to aquatic ecosystems in the long term.

If the potential of aquatic genetic resources is to be realized and sustained, it is high time that the nations take note of the issues that need to be addressed and the necessary laws/regulations/acts made for sustainable conservation and responsible management and use of genetic resources. Enactment of laws/regulations by itself will not serve the purpose unless equal importance is given for their implementation. Often times, there is willingness on the part of the agencies involved in the implementation of the regulations, but they are ineffective due to lack of human and financial resources. Hence, it is necessary that along with enactment of regulations, care is taken for allocation of needed resources for the implementation of regulations.

In addition to the enactment of national laws, there is a need for regional collaboration in the implementation of the regulations, since many of the countries in the region have common watersheds and common borders, making it difficult to control overexploitation of resources and movement of aquatic organisms across borders.

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Discussion

Kapuscinski: It is possible that China now has a policy on biosafety that has a section dealing with aquatic organisms. This has been under discussion in recent years. With respect to the INGA Material Transfer Agreement (MTA), does that still apply if one of the countries is not a member of INGA?

M. Gupta: Yes.

Kapuscinski: Regardless of whether the donor country is a member of INGA?

M. Gupta: Yes, and any country that wants germplasm from an INGA member country has to sign this agreement. For example, we received a request from a private company in Jordan for GIFT tilapia. We sent an MTA to be signed by the appropriate government minister. We are waiting for the response. We will not send the material without that agreement.

Kapuscinski: So if a company in the USA wanted material from an INGA member country, it would have to sign an agreement not to claim ownership over that material?

M. Gupta: Yes.

Kapuscinski: Would that apply to material after they had done some genetic modification?

M. Gupta: Probably not.

M. Gupta: The MTAs of INGA are mutually agreed upon by the 13 member countries of the network. These agreements are applied whenever germplasm is transferred from one country to another. If a country in the network is approached by a non-member country, we still follow the same procedures.

Pullin: These INGA protocols and MTAs were mutually agreed upon by the INGA members (who are actually states) and by ICLARM, as Member Coordinator, in an attempt to conduct germplasm transfers responsibly, safely and for mutual benefit. Of course, it is still a matter for each sovereign state to handle arrangements for what happens to such germplasm within its own borders; for example, to which watersheds it is moved.

M. Gupta: But there are problems across borders; for example, species can move between Bangladesh, India and Nepal through common watersheds. Also, people can easily take a bag containing exotic fishes from one country to another. Guidelines are there, but they are not being implemented.

Penman: With respect to transgenics, you would need to know what to look for. Transgenics can be developed with DNA from the same species, so even a test for foreign DNA would not necessarily identify them. So it would be very difficult to control movement of these.

Wang: I have a question about monitoring the movements of germplasm. Are you concerned only with movements across borders or also within borders; for example, from the east to the west coast of India. How would this be monitored?

M. Gupta: The criterion is movement of organisms beyond their national boundaries.

Wang: But how is this actually implemented?

M. Gupta: Well, even where the policies exist, implementation guidelines may be lacking.

Wang: For example, in a country like Indonesia that spans thousands of kilometers, a box of postlarvae could simply be put onto a plane, with no controls.

M. Gupta: As you say, implementation is not there even though legislation may exist.

Wang: At least across borders you have to go through customs and quarantine. There are check points.

Correa: The MTAs that you describe take essentially a bilateral approach. As you know, a multilateral system is under negotiation for plant germplasm, with free exchange for participating countries, under the auspices of FAO. This reflects the great interdependence of countries with respect to genetic resources for agriculture. To what extent does a similar interdepedence exist for aquaculture? If this does not exist, then a bilateral process is probably the best, provided there are good prospects for this process to be controlled.

Bartley: At FAO, Rohana Subasinghe is developing health and quarantine guidelines for aquatic organisms in the Asian region (Subasinghe and Arthur 1997). These are based largely on a European model in which zones are delineated as free of specific pathogens. The guidelines consider watersheds and the potentials for the spread of diseases.

A. Gupta: I was struck by the comments regarding the high proportions of hatchery-reared fish in some rivers. I know of no other area of biodiversity where such erosion has occurred. Could ICLARM make a brochure reviewing this situation around the world, rather like Tom Hargrove did years ago for rice, showing how much of cultivated rice comes from limited numbers of parental strains? This would raise public awareness. On biosafety, India has a National Committee on Biosafety which is responsible for sanctioning any experiments in the country on transgenic organisms.

Pullin: ICLARM is always interested in compiling information such as you suggest and in making that available to the rest of the world, usually through FishBase. The prerequisite for this is that the information used must be published and therefore able to be checked.

With respect to the high percentages of hatchery fish in rivers, for silver barb (*Barbodes gonionotus*) in Thailand, the main example used, there is some question as to whether this species is native to Thailand. The populations there might derive largely from old introductions and, most recently, from hatcheries. ICLARM and the University of Wales, Swansea, are presently being supported by the Department for International Development, UK, to determine the natural centers of genetic diversity of this species, principally in Indonesia. We hope to determine whether it is indigenous to the Mekong basin or not.

M. Gupta: Nearly 75% of the seed of this species produced in government hatcheries is released to rivers and lakes.

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National and Regional Perspectives on Aquatic Genetic Resources in Latin America

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ABSTRACT

Latin American countries in general do not have laws, regulations or protocols focused on the conservation of aquatic genetic resources. The situation regarding the roles of the different institutions, relative to the conservation and use of natural resources, varies considerably. Overlapping of institutional roles is common. The issues of conservation and management of genetic variability of aquatic resources are new in this continent. Strategies of resource conservation have been developed only in severe cases of overexploitation that have endangered the resource, and these consider conservation only at the species level, not genetic variability. The Chilean case is discussed in some detail, as a case where aquaculture is growing fast. The issue of conservation of aquatic genetic resources is analyzed within the context of the important effects of the recent development of aquaculture, at the national and regional levels. Aquaculture is regarded as an animal production activity in which it is recognized that it is essential to elaborate the concept of sustainable use of aquatic genetic resources, along with the notion of sustainable aquaculture, such that the latter can contribute directly to the conservation of these resources. Intensive aquaculture should be carried out away from natural populations. This will require artificial control of the complete life cycle of the farmed organisms.

Introduction

In general, the conservation of natural resources has been focused mainly on terrestrial environments and tropical forests, where the deterioration of ecosystems has become more evident and intense (Ryman 1991). This indicates the tendency of humans to be concerned about the conservation of species, as well as their genetic conservation, only when deterioration is great or irreversible. In this sense, the conservation of living aquatic resources has been particularly directed towards freshwater and anadromous populations, where the problems of habitat modification, species introduction and overfishing are more critical and urgent (Smith 1996).

Progress made in the conservation, preservation and management of natural resources has generally been aimed at avoiding the deterioration of natural ecosystems and preserving areas regarded as highly valuable for their wealth in biological diversity, their unique character, or their importance as representative of specific ecosystems. Such efforts, particularly those devoted to living aquatic resources, have mostly considered biodiversity at macro (landscape and ecosystem) levels, including species but usually disregarding consideration of genetic diversity.

The factors limiting the conservation and management of aquatic genetic resources correspond mainly to gaps in scientific and technological information, absence of appropriate programs and institutions involved in the subject, and lack of national and international policies (Thorpe et al. 1995). This is particularly true in Latin America, where research in these issues has followed economic criteria, by which particular aquatic species that are considered economically important have been studied. The elaboration of an inventory of aquatic species and of their genetic diversity becomes necessary to tackle these problems adequately. Only by starting from such information will it be possible to know what natural systems comprise and how to adopt criteria for the objectives of conservation.

The development of adequate management strategies and programs is further complicated by the great diversity of aquatic species of tropical systems. It is estimated that, in Venezuela, there are about 790 species of marine fishes (Cervigón and Rodríguez 1997) and 1 065 species of freshwater fishes (Taphorn et al. 1997) as well as numerous invertebrate species in these environments. Biodiversity in the Amazonian system is even greater. This contrasts with the situation in temperate countries where the diversity of the aquatic fauna is much smaller.

Both the responsibility for and jurisdiction of the supervision of aquatic genetic resources have been poorly defined, at global, regional and national levels. In many countries, the management and conservation of living aquatic resources and the regulation of the human activities affecting them are not within the domains of any institution or sector (Thorpe et al. 1995). In general, genetic considerations have not been a priority in the management of living aquatic resources, and few programs aim at conserving aquatic genetic resources. Several programs have been designed to manage the environment of protected species, but rarely with genetic conservation criteria.

Factors Affecting Aquatic Genetic Diversity

The establishment of policies for the conservation and use of genetic aquatic resources requires an adequate knowledge of what needs to be conserved, its genetic diversity and the factors that affect it. There is much literature on this matter; some of its results are summarized below for a better understanding of some of the propositions presented.

Studies conducted so far have demonstrated that the populations of marine species are less differentiated than freshwater species (Avise et al. 1987), probably due to their greater ability to move and hence their exposure to a greater gene flow (Waples 1987).

Seawater species are hardly affected by genetic drift because natural populations, in spite of having been severely affected by human interventions, have maintained effective population sizes large enough to conserve their variability (Stephenson and Kornfield 1990; Smith et al. 1991). However, low levels of heterozygosity found in some species could be attributed to bottleneck effects (Bartley et al. 1992).

Genetic variation changes over time in marine populations have often been reported (Smith 1979; Lacson and Morizot 1991), and attributed sometimes to gene flow effects (Lacson and Morizot 1991) or to releases or escapes (Bartley et al. 1992). However, cases of great genetic stability over time have also been reported (Gjøsaeter et al. 1992; Gold et al. 1993).

Genetic conservation problems are more severe in freshwater and anadromous species than in marine species and originate from environmental changes, introductions and overfishing (Nyman 1991; Ryman 1991; Moyle and Leidy 1992).

A fishery activity, which is essentially extractive, and (apart from the effect of "fishery renewal") described by Baranov (1918) produces changes in natural populations. These changes include:

- depletion of species due to overfishing (Garrod 1973; Loftus 1976; Beverton 1990), a situation which usually recovers when fishing decreases or finishes (Beverton 1990);
- changes in the biomass and composition of species (Fogarty 1992; Sissenwine and Cohen 1993); and
- changes in gene frequencies resulting from selective fishing (Borisov 1979; Smith et al. 1991).

Environmental and, in particular, climatic changes bring about the following important alterations in the populations of marine species:

- substitution of one species for another (Ahlstrom and Radovich 1970; Cushing 1975, 1982); and
- variations in the capture biomass (Maan 1993).

Pollution can also have the following important effects in coastal populations:

- massive mortalities;
- changes in species composition (Bonilla and López Rojas 1997); and
- changes in the genetic frequencies (Battaglia et al. 1980; Lavie and Nevo 1986).

Genetic improvement programs for farmed aquatic species have produced important genetic changes through selection of quantitative traits of economic interest for aquaculture (Gjedrem 1997).

In farmed populations, loss of genetic variability has been commonly recorded (e.g., Cross and King 1983; Verspoor 1988; Koljonen 1989; Gaffney et al. 1992; Smith and Conroy 1992).

Laws and Protocols

In general, Latin American countries do not have laws, regulations or protocols focused on the conservation of aquatic genetic resources. At present, international treaties are in force which, after ratification, have become national laws. Examples are the Convention on Biological Diversity (CBD), and the Andean Pact. In the CBD, Article 15 clearly addresses access to genetic resources in general and their subsequent utilization. These agreements do not cover aquatic genetic resources specifically, but rather apply to living resources in general.

In some cases, specific initiatives have been taken to assure conservation measures. For example, in Mexico, the Fishery and Aquaculture Program for 1995-2000 includes a subprogram of Protection Conservation and Rehabilitation of Habitat and Species, aimed at identifying and evaluating the most important aquatic ecosystems that are in danger of severe deterioration or whose fragility is considered as critical. Likewise, this subprogram will strengthen ongoing programs of protection of marine species through research and development of new conservation alternatives. This action is a responsibility of the National Fisheries Institute through its Programa de Pesca y Acuicultura, 1996.

Chile as an Example

Chile is a good example of aquatic genetic resources issues in Latin America because of its large influence, its model of economic growth (oriented towards the world market and competitiveness, and initiated since the mid-1970s), its inland aquatic resources and its protected coast, which have allowed the rapid development of aquaculture, regulated by relatively recent legislation. The Chilean institutions that have participated in this process are cooperating with countries like Argentina, Canada, Ecuador, Mexico, Peru, Venezuela and others on issues related to aquaculture.

Castilla (1996) has reviewed the concepts of conservation, preservation, and management in Chilean legislation and this paper draws upon his work. His main subject is the conservation and protection of marine areas, proposing a Chilean Network of Parks and Coastal Marine Reserves and a work plan to achieve this.

In Chile, there are three main laws involving the management of aquatic resources: LEY 18,362 (1984) "On the Establishment of the National System of State-Protected Wild Areas", LEY 18,892 (1991) "On Fishery and Aquaculture" and LEY 19,300 (1994) "On Bases of the Environment".

State-protected wild areas

Law 18,362, promulgated in December 1984, is one of the tools upon which the country relies for the protection of terrestrial or aquatic wild areas. It defines the different systems of wild areas that are identified and protected by the State of Chile and includes conservation definitions and measures which are accepted by international institutions such as the World Conservation Union (IUCN), but which are applied only to populations contained in wild areas. This law defines wild areas as the natural, terrestrial or aquatic areas that are owned by the state and which the state protects and manages in order to attain the objectives indicated for each of the management categories therein contained. These are classified as: (1) Virgin Reserves, where all commercial exploitation is prohibited; (2) National Parks and National Monuments, for which there is educational, scientific or recreational interest; and (3) National Reserves, that require conservation and utilization with special care. Under this terminology, no land or water defined as wild areas can be privately owned.

The conservation objectives established in this Law are as follows:

"1. To maintain areas of unique character or representative of the ecological diversity of the country or places with animal or plant communities, landscapes or natural geological features so as to ensure the continuity of evolution processes, animal migrations, patterns of gene flow, and regulation of the environment.
2. To maintain and to improve wild floral and faunal resources and to rationalize their utilization.
3. To maintain the productive capacity of soils and to restore eroded soils or those in danger of erosion.
4. To maintain and to improve natural hydrological systems.
5. To preserve and to improve natural landscape resources and the cultural elements that are linked to a natural environment."

It should be noted that this law makes a clear distinction between conservation and preservation. For its conservation definition, it utilizes the concept of "management of biosphere utilization by man" which "involves actions aimed at the preservation, maintenance, sustained utilization, restoration, and improvement of the environment". Thus, humans are considered as part of the natural system. Clear concepts of sustainable development and environmental impact are also incorporated. Regarding wild areas as management categories aims in the same direction, considering educational, scientific and recreational activities as important (except when preservation measures are explicitly defined).

These elements make this Law consider the presence of humans as not necessarily undesirable, and education to be an objective of primary importance within the management categories. The conservation challenge consists of maintaining or preserving ecological units or natural systems in harmony with humans (Castilla 1996). It further contains the elements necessary for good conformity with laws and rules regulating agricultural activities, including aquaculture.

The Fishery and Aquaculture Law

The Fishery and Aquaculture Law was promulgated in September 1991 and regulates aquatic species in particular. It defines the conservation concept as "the present and future, rational, effective, and efficient utilization of natural resources and their environment". For the conservation of hydrobiological resources, it defines two categories. Marine parks are defined as "specific and delimited areas devoted to the preservation of ecological units of scientific interest and to safe guarding areas which assure the maintenance and diversity of aquatic species, and where no activities can be conducted, except those authorized for observation, research, or study purposes". Marine reserves are areas protected as breeding zones, fishing grounds and locations for restocking through management. Transitory fishing activities are allowed under special resolution of the Subsecretary of Fisheries and supervised by the National Fisheries Service.

In addition, under the Title of Artisanal Fishing of the Fishery and Aquaculture Law, a novel concept is defined: Areas of Management and Exploitation of Benthic Resources, to which artisanal fishers' organizations can gain access, based on an exploitation plan, by means of an operational agreement for a two-year period. For this management category, which transforms free-access zones into restricted-access areas, exclusively for a community of fishers and designed to restore and to regulate populations of benthic resources under exploitation, there is an official regulation: published in the "Diario Oficial – Chile" (DECRETO N°. 355, 1995). This Law further considers the possibility of transforming these areas into Aquaculture Concessions over time.

Of much importance for fishery and aquaculture activities is the Regulation of Maritime Concessions of June 1988 (DECRETO SUPREMO N° 660, 1988), which grants to the Ministry of National Defense the control, inspection and surveillance of the entire coast and territorial sea of the Republic. This regulation authorizes the State to negotiate private concessions for all or any utilization of beaches, beach areas, seabeds, waterbodies and rocks inside and outside bays. This regulation has been used by most aquaculture enterprises, requesting maritime concessions for their development, by numerous artisanal fishers' organizations for their exploitation of the benthos and

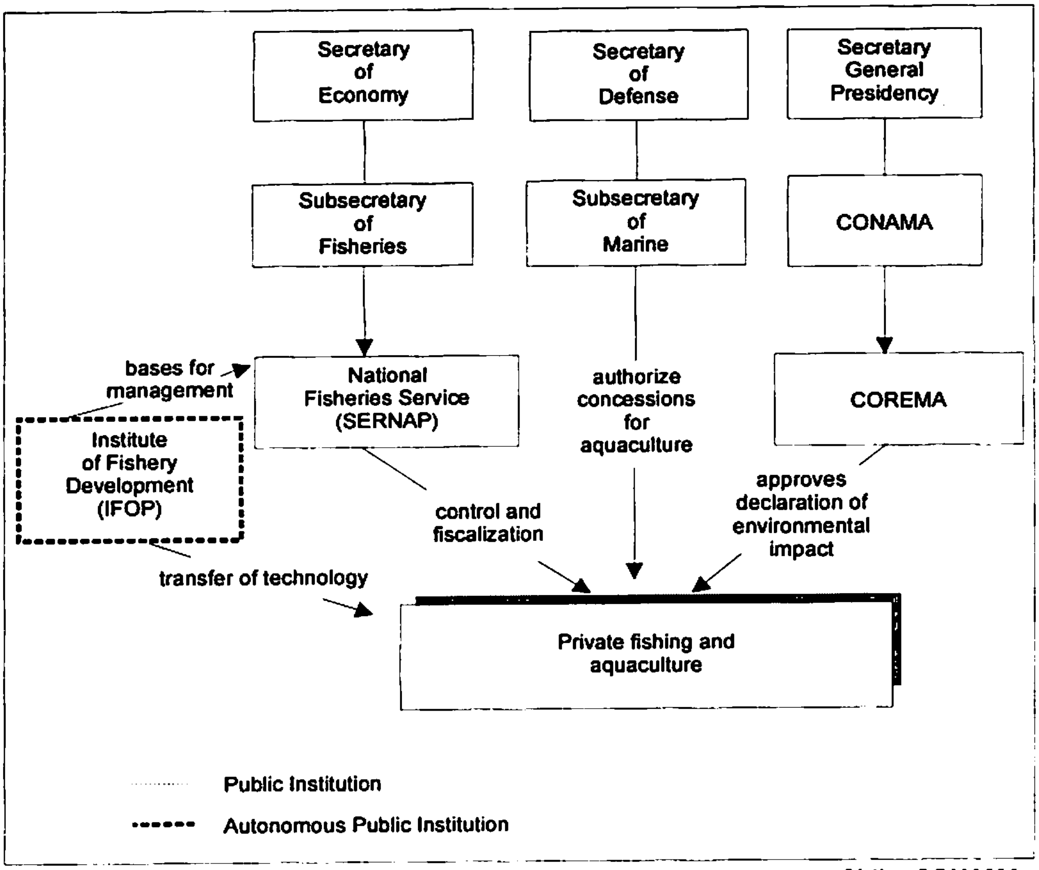

Fig. 1. Institutions concerned with conservation of aquatic resources in Chile. CONAMA-National Commission of the Environment; COREMA-Punta Arenas Regional Environmental Commission.

by at least six universities, for research and conservation of coastal resources (Castilla 1996).

The only specific reference to genetic management under the Fishery and Aquaculture Law concerns the introduction of alien species, but the criteria utilized to authorize importation are mostly based on health and disease prevention. These provisions are enforced. Studies of environmental impact and management plans are required under various other laws, but these are assigned responsibilities to the interested parties.

The entity in charge of regulating and managing the Chilean fishery sector, based on technical criteria, is the Subsecretariat of Fisheries. This arrangement, created in 1978, falls under the Ministry of Economics (Fig. 1). It implements one or more of the following measures concerning living aquatic resources.

1. Biological bans that prohibit harvesting a given species from a particular area during a given period.
2. Prohibition of temporary or permanent capture of protected species, according to international agreements of which Chile is a signatory.
3. Determination of annual quotas for capture of a given species in a given area.
4. Destination of specific areas as marine parks.
5. Determination of the percentage of bycatch, by species.

Moreover, this Subsecretariat is empowered to authorize the introduction of alien aquatic species and to develop aquaculture activities.

The National Fisheries Service (Sernapesca) (SERNAP) is in charge of implementing fishery policy. It controls and inspects ongoing fishery activities and collects and publishes fishery statistics. The law also grants this institution responsibility for the protection of marine parks and reserves. However, because of its multiple functions and low budget, it has not yet established marine parks or the marine reserves. Indeed, the Fisheries and Aquaculture Law is at present non-operational in this respect.

The Institute of Fishery Development (IFOP) is an autonomous public institution which is devoted to research in the areas of fisheries and aquaculture. Among the IFOP's tasks are advising and supporting public and government research as well as generating scientific and technical bases for fisheries management. In aquaculture, IFOP is devoted to technological innovations and their transfer to the private sector. Among its priorities is the genetic improvement of species used in aquaculture.

Environmental Law

The Law on Bases of the Environment was promulgated in March 1994. The arrangements for its routine functions are still evolving. Its direct aspects, concerning genetic conservation are indicated in Articles 37 and 38, where the need for classification of natural species on a scientific-technological basis, assessment of their conservation status and an inventory of species are established to set the norms for the management of each species. The document also incorporates the concept of conservation, which includes the rational utilization of resources and environment by humans. After the promulgation of the Law on Bases of the Environment, a Ministry of the Environment was created and its National Commission of the Environment (CONAMA) remains in charge of coordinating and planning environmental policy.

The Law on Bases of the Environment outlines the bases of other laws and decrees for protecting air, water and soil, and regulates related environmental damage, taxes, contributions and permits. Both the law and its cited instruments are based upon the principle of "the polluter pays" and the precautionary principle. The law enables a territory to be classified as "saturated" or "latent", according to its pollution level, and to assign recovery and prevention measures to the pertinent responsible party.

Situation in Latin America

In other Latin American countries, the situation regarding the roles of the different institutions relative to the conservation and use of natural resources varies considerably. Overlapping of institutional roles is common. For example, in Venezuela, the only national institution with a mandate for the protection of wild fauna and flora (Wild Fauna Protection Law 1970) is the Ministry of the Environment and Renewable Natural Resources (MRNR) through the National Parks Institution (INPARQUES), Forestry Service, Wild Fauna Service, etc. However, the mandate for aquatic genetic resources is held by the Ministry of Agriculture and Breeding, through the Autonomous Service of Fishery and Aquaculture Resources (SARPA). This role of the national executive is shared by the Ministry of the Environment and Natural Renewable Resources under the 1992 Penal Law of the Environment and by the Ministry of Agriculture and Breeding under the 1944 Fishery Law. These two public entities, according to the Central Administration Law, are in charge of planning, managing and conserving continental and marine waters, as well as the biological species that live in them. The result of the functions assigned to them by the legislature is, in some cases, a clear overlapping of activities. It should be noted that no law or regulation has yet been promulgated that directly governs living aquatic resource management; however, the Congress of the Republic is at present dealing with the Biodiversity Law and the Wild Fauna Law, through which aquatic genetic resources will supposedly be regulated. The activities of management and use of aquatic organisms are currently governed by general laws and by laws which have been regulated by Ministerial Resolutions, which make the legal basis of these activities rather complex.

Education

In Latin American countries, the issues of conservation and management of the genetic variability of aquatic resources are new and are addressed only by biological scientists. At the administrative level, there is no clarity even in the concept of genetic diversity. This is clearly reflected in laws dealing with natural resource conservation, where the management of genetic variability is not a concern as yet, nor is it defined, and consequently specific references to it and measures for this management do not exist. Moreover, strategies for natural resource conservation have been developed only in the most severe cases of overexploitation and these strategies consider conservation only at the species level and not intraspecific genetic variability.

In Chile, for instance, the issue of conservation of genetic resources proper is not dealt with specifically. Several universities consult agencies such as CONAMA and, therefore, opportunities exist for national and international experts in various fields to participate in different consultancies: opportunities which could be utilized for introducing the concept of conservation and genetic management of living aquatic resources more accurately. Biodiversity has been addressed in discussion groups organized by government institutions, but genetic variability and its management were not considered. Seemingly, there is not much clarity about the factors which regulate biodiversity and which should be addressed more deeply so that more concrete measures can be taken in the governmental sector.

Programs designed to inform and to educate, in relation to the conservation and sustainable use of aquatic genetic resources do not yet exist in Latin America, but are urgently needed. Without question, the universities in Latin America should play a lead role, at least during this stage, in the debates, definitions and, partly, in promoting awareness of this subject at the national level. First, consciousness should be raised of the importance of the issue and subsequently the concepts of biological and genetic diversity should be clearly defined so that the State can adequately regulate and inspect the conservation of living aquatic resources and natural resources in general.

Rational Exploitation of Natural Populations; Bans and Regulations

The issue of conservation of aquatic genetic resources cannot be discussed out of the context of the important effects of the recent development of aquaculture, at the national and regional levels. In several countries where aquaculture has shown important growth, it should be regarded as an activity of animal production having great similarity to agriculture, or even as a part of it. Aquaculture is in a transitional stage, evolving from a basically extractive to a renewable culture activity. The artificial management of the reproduction

The concept of "rational exploitation or management of natural populations" (RMNP) has been defined. For example, it appears in some definitions relating to conservation, as in the case of the Chilean definition (Law on Bases of the Environment). This concept is not yet applied to aquaculture-related activities because, once important investments are made requiring appropriate high returns (a legitimate matter of course), all rationality in the management of natural populations is lost and "the tragedy of the commons" (Hardin 1968) inevitably takes place.

The Chilean abalone fishery

Temporary bans have not been a definitive solution to avoid the pernicious effects of overexploitation. The Chilean abalone (*Concholepas concholepas*), locally known as "loco", is an example. This mollusc from the family Muricidae, is distributed from Lobos de Afuera island, Peru (16°57'S), all along the continental coast to Cabo de Hornos (55°40'S), including the Juan Fernandez island (33°40'S; 74°40'W) and is found in waters up to 40 m deep. The official statistics of the exploitation of this resource, which date from 1938, indicate that landings had already doubled by 1955, reaching 5 000 t. From 1972, there was an accelerated increase in harvests, which reached 25 000 t in 1980, the year in which *Concholepas* exports started (Fig. 2). The nearly 30% increase in the 1981 landings necessitated a succession of bans, which did not cover the entire country but were restricted to certain regions in each case, and a minimum commercial size was fixed at 12 cm. In 1982, landing quotas were imposed, reducing the minimum commercial size to 10 cm. Besides the fact that many of the landing quotas were not observed during the interban periods, continuous strong harvesting pressures continued along almost the entire national littoral zone, from Region II to the southern zone. Exploitation focused on animals around the minimum size as these occur in large numbers. This resulted in a generalized decrease in the size of individuals and in the numbers of individuals captured in exploited areas since 1986. A complete stock evaluation using stock reduction analysis (Rivas 1989, based upon Kimura and Tagart 1982; Kimura et al. 1984) showed an alarming reduction of broodstocks in the exploited areas, with a high risk of depletion, which ended with a moratorium on fishing for loco, starting in 1989. This measure brought about severe economic problems for the artisanal fishers as well as for the industry, resulting in increasing illegal landings and marketing of this mollusc. Expecting an end of the ban in 1992, both artisanal and the industrial fishers experienced a tense climate and many began collecting large numbers of the molluscs and storing them underwater for future selling. The end result was the implementation of individual nontransferable landing quotas, assigned to each properly registered diver, starting in 1993.

Castilla (1988, 1994) tackled the recovery of this re-

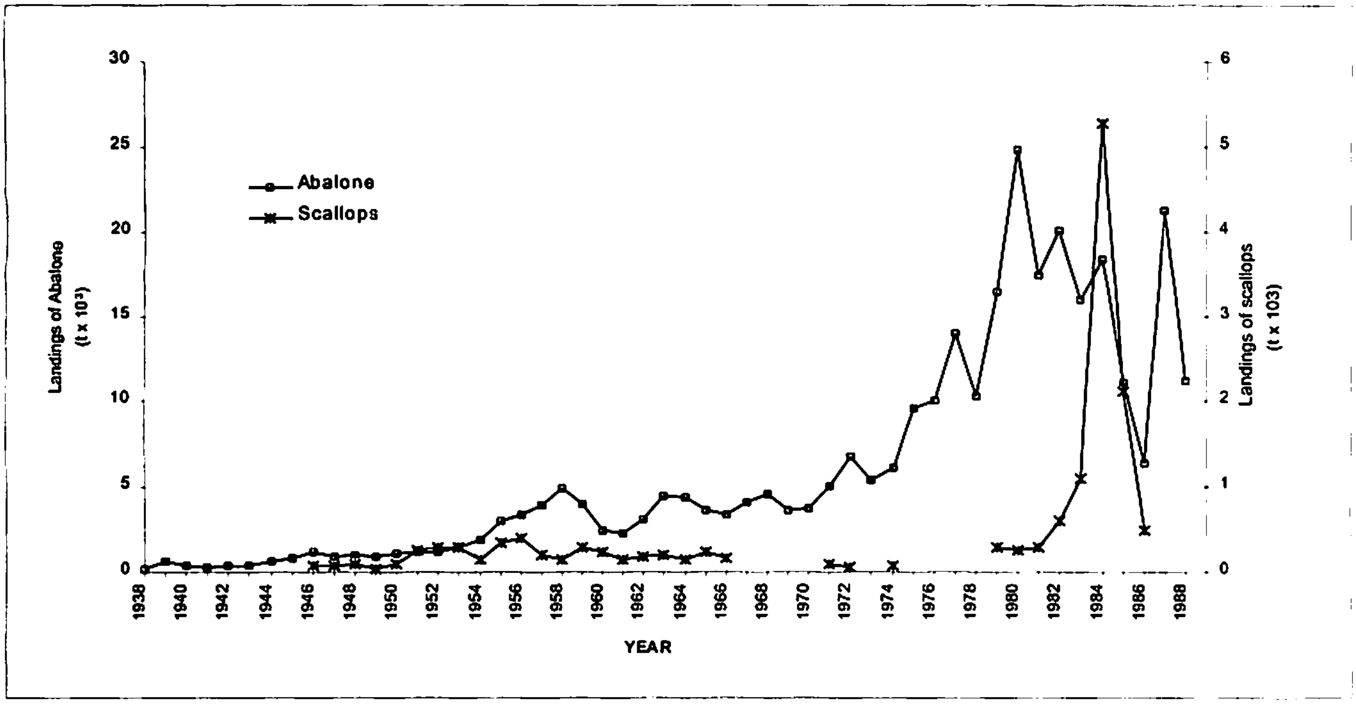

Fig. 2. Historical landings of Chilean scallop *(Argopecten purpuratus)* and abalone *(Concholepas concholepas)*, until a total ban and landing quotas were established for scallops and abalone, in 1986 and 1994, respectively (data from IFOP 1979, 1994).

source in an interesting way. He proposed the category of Management Areas of Benthic Resources, as a model for management, which was included as such in the Fishery and Aquaculture Law. After a few years of protection with no fishing activities, some locations and coastal reserves, such as Las Cruces and Quintay, became densely populated with *Concholepas*. In these studies, however, possible changes in genetic variability were not monitored. Different efforts were carried out by IFOP in Putemún, Chiloé Island. These were designed to give a definitive solution to the conservation of this resource, through research projects focused to manage captive populations for farming.

The Chilean scallop fishery

Another example of the inapplicability of RMNP to aquaculture is shown by the history of exploitation of the Chilean scallop (*Argopecten purpuratus*). Its high commercial value was the cause of reckless exploitation that made its stocks collapse in the northern zone of the country during the 1950s. The main scallop beds in Chile were located at Tongoy, Guanaqueros and Mejillones bays in the northern zone of the country. From these areas, 100 to 400 t were landed per year from 1945 to 1954 (Fig. 2). Because of the heavy damage from overexploitation, a series of bans, of varying degrees of severity, was initiated in 1958. This culminated with the imposition of a total ban in 1986, after alarmingly high landings (5 000 t) in 1984.

Faced with this problem, the Subsecretariat of Fisheries, the Catholic University of the North and the Japan International Cooperation Agency (JICA) started a project to develop techniques to farm this mollusc in its natural environment, based on capture of wild seed (spat). The National Fisheries Service (SERNAP) with the Japanese Overseas Fisheries Cooperation Foundation (OFCF) started another program in 1982, centered on cultivation and restocking. Commercial farming of this species started in 1984 with 57 t produced. Farmed production reached 10 740 t in 1994, but declined to around 8 000 t in 1997. The industry reported that this decline was due to a reduction in the caliber of the harvested scallops: from about 71 individuals·kg^{-1} in 1992-1995, to 83 and 106 individuals·kg^{-1} in 1996 and 1997, respectively (I. Etchepare, pers. comm.).

It should be noted that Chilean scallop culture is not a completely integrated activity, because seed supply is yet not managed. The seed are normally obtained from spat collectors in the natural environment and, in spite of the ban, from some direct harvesting from the natural beds. In both cases, if those of greater size are taken or those of smaller size discarded, the result is a negative selection based on size. A solution to this problem might be achieved by separating scallop farming from its dependence on natural populations, by making the entire production cycle including seed production completely artificial. Setting up the scallop farms at sites remote from those where natural stocks of scallops are found (and especially away from where these resources are very localized) could also help. This is a case where the belief that it seems impossible to build a sustainable production system without controlling the whole reproduction cycle (Gjedrem 1997) is shown to be sound.

Seaweed harvesting in Chile

The failure of regulatory measures for a resource of great export value can be illustrated with the case of the agar-producing, red alga *Gracilaria chilensis* (Bird et al. 1987). The commercial exploitation of this resource, commonly known as "pelillo", was initiated in the 1960s on natural beds at Playa Changa (29°56'S Lat; 71°21'W) and Santa María Island (36°59'S; 73°32'W). In 1967, landings were close to 7 000 t wet weight, from Regions IV and VIII. Starting from 1961, standard practices for *Gracilaria* conservation and extraction were established nationwide, regulating the effort through the duration of the fishing season and regulating harvesting and farming as well. In the 1970s, the exploitation was mostly from the natural beds mentioned above, increasing the extracted volumes. During the 1980s, exploitation efforts were shifted to the southern zone, to natural beds near Puerto Montt (Maullín 41°37'S; 73°76'W and Piedra Azul 41°29'S Lat.; 72°58'W) and the Island of Chiloé. This was due to the abundance and quality of the alga in this area and to the overexploitation of natural beds in the northern zone (Santelices 1989). The landings reached maximum extraction values of 113 000 t wet weight in 1985. A marked increase occurred in 1982-1985, due mainly to increased demand and high export prices (Avila and Seguel 1993). For the southern zone, a regulation on extraction was initiated in 1971 with a decree (Decree 63) which established the extraction period as well as the system and method of harvesting. A year later, the extraction and industrialization of this resource were prohibited for a three-year period. In 1983, new regulatory measures (Decree 136), were taken for the extraction of algae in the southern zone. These specified extraction period, boat size and the number of harvesting tools per boat and included penalties for noncompliance. The result of this measure was very negative. It produced an increase in harvesting effort, without decreasing the landings. This caused the collapse of the natural beds and subsequent closing of the harvesting areas. Landings then decreased from

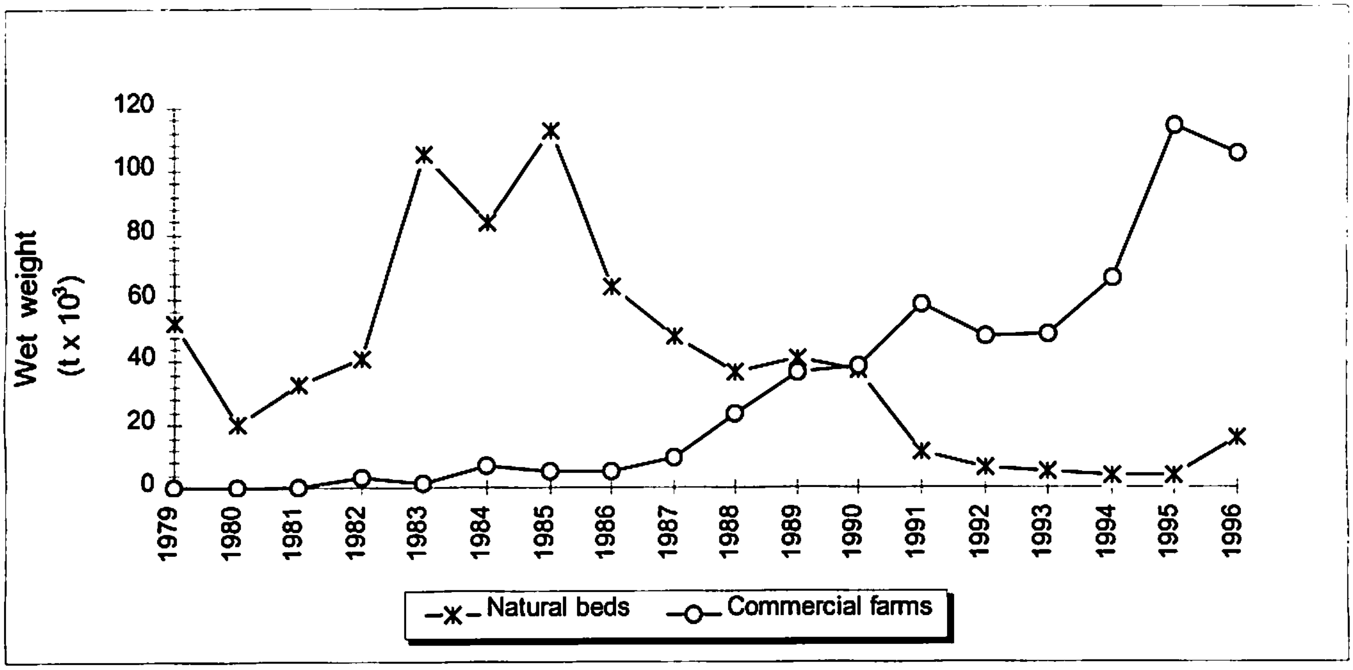

Fig. 3. Production of *Gracilaria chilensis* in Chile (1979-1996). Harvests from natural beds and from commercial farms (Avila and Seguel 1993; IFOP 1998).

117 525 to 61 862 t (Fig. 3). This situation encouraged the private sector to develop farms and, from 1987, these acquired great importance, providing over 80% of production in the 1990s.

The numerous studies carried out during the last 20 years (Santelices and Fonck 1979; Westermeier 1986; Santelices and Ugarte 1987; Santelices and Doty 1989) and the management measures established have been insufficient to avoid the collapse of *Gracilaria* stocks in Chile. Unlike other living aquatic resources of economic importance, there were no marine reserves to protect the reproductive phases or to preserve the stocks, because the natural beds were opened for commercial farming.

Introduction of Alien Species

Another subject of great concern in Latin America is the introduction of alien species. Introduction of alien species or hybrids to natural areas may become a severe problem. For example, the freshwater prawn *Macrobrachium rosenbergii* was introduced for aquaculture to natural areas of Venezuela in 1980 (Pereira et al. 1996). It is not known what will be its impact on local shrimp populations, but there is no doubt that its rapid and successful establishment and settlement might cause the displacement of native species, with the subsequent loss of biodiversity. This is a recent concern. Last century and early in the present century, large introductions of salmonid species, especially rainbow trout (*Oncorhynchus mykiss*), took place in all continents, except the Antarctic (Hershberger 1992), with few conservationist considerations. In Latin America, there are naturalized populations of rainbow trout from the Venezuelan Andes up to the austral zones of Argentina and Chile and is widely farmed in 50% of its countries (FAO 1994). Very little is known about the damage caused to the diversity of the local systems or the number of displaced species. Massive introductions of this type are not at present authorized, but introductions of alien species are continuously taking place for the development of aquaculture in the region, including the use of salmonids (*Oncorhynchus mykiss*, *O. kisutch*, *Salmo salar*, etc.), common carp (*Cyprinus carpio*), red tilapia (*Oreochromis* spp. and hybrids), marine shrimp (*Penaeus vannamei*), sturgeon (*Acipenser* sp.), abalone (*Haliotis* sp.), Pacific oyster (*Crassostrea gigas*), turbot (*Scophthalmus maximus*), and others (FAO 1994).

Even though there are strict regulations aimed at the protection of local species, these have not prevented accidental escapes of individuals from farms, as has happened more than once with salmonids in Chile and with tilapia hybrids in Venezuela, for example. The consequence of such events may be very different depending on the amount released, the behavior of the alien species and the local populations present. It is important to consider that this development model for aquaculture, dependent upon the introduction of alien species, is the one used by Chile, the world's largest producer of farmed salmon, as of 1994.

Another species, the marine shrimp (*Penaeus vannamei*) must also be mentioned for its outstanding development in the region. It is farmed in 17 countries that account for around 15% of world production; about 80% of this contribution is from Ecuador. The substantial growth of tilapia culture in the region has followed the same model. At present, tilapia has been introduced in 19 countries in Latin America and the Caribbean, among which Cuba, Mexico, Jamaica and Colombia rank as the main producers (FAO 1994).

Sustainable Aquaculture and Aquatic Genetic Resources

It seems essential then to elaborate the concept of sustainable use of aquatic genetic resources along with the notion of sustainable aquaculture. This may be more difficult than was experienced for agriculture, as aquaculture is still in a very early stage. Most of the species used in aquaculture today resemble wild individuals. Eggs or juveniles are usually collected from wild populations, and less than 1% of aquaculture production is based upon genetically improved animals (Gjedrem 1997). It is not difficult to foresee that aquaculture will follow the same pattern of growth and development as that of animal production, which means that it will be necessary to be prepared, among other things, for:

1. massive introductions of alien species, whether national, regional or continental, into places where aquaculture activities are developed;
2. utilization of hybrids and species that have been genetically modified by any available means, from traditional selection systems to the production of transgenic sterile individuals;
3. utilization of domesticated animals, with characteristics that make them more profitable in spe-

cific production systems, often with loss of characteristics required for the normal development of their natural life cycle in the wild;
4. progressive differentiation of wild-caught from farmed products in their marketing and appraisal by the consumer; and
5. growing utilization of closed production systems, isolated from natural systems.

Breeding programs will play a significant role in the development of sustainable aquaculture. As pointed out by Gjedrem (1997), the genetic improvements obtained from selection programs in aquatic species have been far less than those achieved with traditional livestock, where production has increased manifold. However, genetic gains per generation in growth rate have been 10.6-14.2% in Atlantic salmon and 13% in rainbow trout (Gjerde 1986), 12-20% in channel catfish (Dunham 1987), 10.1% (Hershberger et al. 1990) and 8.2% (Neira et al. 1997) in coho salmon, 17% in Nile tilapia (Eknath et al. 1997) and 4.4% in marine shrimp (Fjalestad et al. 1997). These high responses are due to the high genetic variability and high fecundity of these aquatic species, which allow for high selection intensities.

Aquaculture can meet the world's future needs and demands and contribute directly to the conservation of natural resources, but only if conservation of genetic variability is achieved in the management of species and if technologies are developed for avoiding pollution and impacts on natural populations by escapes from farms.

Conclusions

1. In coastal states that base their model of economic growth upon exports of natural aquatic products to world markets, it is fundamental to generate and to implement programs of conservation and preservation of aquatic genetic resources. These programs should include marine parks, marine reserves, and management areas, so as to avoid the deterioration and depletion of natural marine ecosystems and to preserve areas considered as valuable for their diversity, or for being repre-sentative of ecosystems of particular characteristics.
2. For aquaculture, the application of genetics and biotechnology will increase production considerably and decrease costs, and will change farmed aquatic species genetically. Therefore, necessary precautions will need to be taken to conserve such genetic materials through the creation of germplasm banks, with a policy similar to that existing for agricultural species.
3. It is necessary to generate research programs aimed at the elaboration of a regional inventory of natural living aquatic resources and their genetic status so as to allow the incorporation of genetic considerations in the management of living aquatic resources.
4. International cooperation and interaction programs should be created so that the experiences and knowledge gained can be shared among participating countries.
5. In Latin America, areas of great biodiversity, such as the Amazonian forest, should be set apart and protected as world patrimony.
6. Intensive aquaculture should be carried out away from natural populations, for complete control of the life cycle of the farmed organisms.
7. The harvesting of natural populations of aquatic organisms that have high economic value should be limited (for example, to artisanal fishers, under supervised management plans).
8. Natural populations under conservation or exploitation should be periodically monitored for genetic variability, to assess their genetic status and any changes.
9. Genetic modification of natural populations or severe modification of their environmental conditions, in an attempt to make them more productive for humans, should be avoided because, in the long term, these will benefit neither the natural population nor humans. Such modifications should be reserved for populations that are farmed under conditions of complete confinement.

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Discussion

Pullin: You already have an alien species well established in the waters of Chile – the salmon. Have there been any known effects?

Neira: Salmonids have been introduced around the world. The first introduction of trout to Chile was in 1905. At that time, there were no conservation efforts. The damage by salmon species around the world has mostly been done long ago. There must have been a lot of damage, but it is very poorly documented in Chile, if at all.

Entis: What about Atlantic salmon – a more recent introduction?

Neira: Well, some runs have been established, but there have also been many attempts at introducing salmon which have not worked. Known coho salmon runs established in Chile originated from more recent escapes.

Pullin: Doesn't the history of domestication of plants and livestock show that the separation of domesticated organisms and their breeding and husbandry from wild populations and ecosystems are not as easy as you seem to hope for. The wild relatives of domestic livestock are now virtually nonexistent and the wild relatives of most crop plants only exist in very limited quantities. So how do you expect to maintain a supply of wild aquatic organisms, separate from their domesticated relatives? In water, these organisms cannot even be seen. Moreover, wild relatives will be needed from time to time to contribute genetic material to breeding programs. I think that the 'decoupling' that you are suggesting will be very difficult to achieve.

Neira: I tend to agree with you. But, in agriculture, who remembers where the chicken or the pig came from? In aquaculture, it is going to more difficult, but the concern that we now have for conservation will help. Aquaculture cannot be stopped and it can, in certain cases, assist conservation. I believe that, for example, the abalone situation in Chile will be solved only when we have the complete cycle controlled and can take it to culture. After a few generations of selection, we will go back to the natural population only if we need to. Natural populations will be a safer, different product, inefficient to the industry. At present, Chile is not importing coho salmon eggs from the Northern Hemisphere, as it was three years ago, because they are producing eggs locally from genetic improvement programs under cultured conditions.

Smith: Your description of your scallop fishery is similar to that in New Zealand. When problems arose, the management of that fishery was transferred from the government to the fishers. They adopted a Japanese low technology method, collecting spat and reseeding the sea floor. The areas were subdivided, and each area is only fished every third year. This is more like a sea ranching situation than an aquaculture situation.

Fishes Under Threat: An Analysis of the Fishes in the 1996 IUCN Red List[1]

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ABSTRACT

Biological characteristics of threatened fishes contained in the 1996 IUCN Red List were analyzed using data in FishBase 98, a large database on finfish. The following trends or relationships were determined: (1) fishes that depend on freshwater at any stage of their life cycle are 10 times more likely to be threatened than marine and brackishwater fishes; (2) fishes that have a restricted latitudinal range such as occurring in only one country face a higher threat; (3) fishes that depend on wide feeding or spawning migrations are more likely to be threatened; (4) freshwater fishes that entrust the development of their eggs and larvae to the environment (nonguarders) are more threatened than bearers and guarders; (5) large, slow-growing and late-maturing fish are more threatened; (6) herbivorous freshwater fishes, and probably feeding specialists in general, are more at risk than opportunistic feeders; (7) there is a relationship between human population density and percentage of threatened fishes; (8) there is a relationship between number of threatened freshwater fishes and number of introduced fishes; (9) threatened fishes are often rare and poorly studied or discovered only recently. No relationship was found between the likelihood of threat and phylogenetic rank, climate zone, or human use.

Introduction

Fishes are the most specious group of vertebrates exploited by humans. They provide food and employment through commercial and traditional fisheries as well as recreation and enjoyment in sport fisheries and as ornamental species in aquaria and ponds. They are subjects of cultural importance in the arts, in religion and symbolism, and in science. Despite the economic value of these activities, fishes and especially freshwater fishes are probably the most threatened of all vertebrate groups (Bruton 1995). This serious situation is likely to worsen, as demand for protein and conflicts over the use of freshwater fishes continue to increase. These issues have been widely reviewed (see Andrews 1990; Nyman 1991; Beverton 1992; Kaufman 1992; Maitland 1994; Bruton 1995; Maclean and Jones 1995; Kottelat and Whitten 1997; McAllister et al. 1997). This paper attempts to quantify these mostly qualitative assessments of risk by analyzing the information on threatened fishes that is available in FishBase 98 (Froese and Pauly 1998), a large database containing biological information on more than 20 000 species of finfish (see also http://www.fishbase.org). The 1996 Red List (IUCN 1996) is a first attempt to apply objective and transparent criteria to the redlisting process (IUCN 1994). The list contains very few marine fishes and still has some inconsistencies, e.g., when threatened populations of nonthreatened species are listed. We therefore restricted our analysis to the exploration of major trends which were likely to be confirmed by future, more coherent Red Lists. We did not try to fit regression lines or to explore multiple regressions, leaving this approach to future analyses.

[1]ICLARM Contribution No. 1496.

Material and Methods

This study is based on information contained in the 1996 IUCN Red List of Threatened Animals (IUCN 1996), subsequently referred to as 'Red List'. The term 'redlisted' is used to refer to all fishes in that publication, independent of their status of threat. The term 'threatened' is used to refer only to the 637 fishes in the categories vulnerable (VU), endangered (EN), and critically endangered (CR) (see Table 1 and IUCN 1994). Biological information was taken from FishBase 98 and subsequently referred to as 'FishBase.' Some information was taken from FishBase 99 prior to its release. Hence, anyone wishing to repeat this analysis should use FishBase 99.

Table 1 shows the categories of threat assigned to the 1 128 fishes contained in the Red List. The Red List categories and the classification process are fully explained in IUCN (1996). Note that these assessments have been applied to less than 10% of the estimated 24 618 fish species (Nelson 1994).

One species (*Eurypegasus draconis*) has been listed twice in the Red List as data deficient (p. 205) and as vulnerable (p. 236), both for Madagascar. Because of its wide range (South Africa to southern Japan), we classified it here as data deficient (DD).

Results and Discussion

Nomenclature

Of the 1 128 scientific names of fishes listed in the Red List, 168 names (15%) were found to be invalid when compared with names in FishBase: four percent were considered misspellings and 11 percent were synonyms. Some of these discrepancies were due to unresolved taxonomic issues. For example, many of the cichlids of the African lakes are placed in the genus *Haplochromis* by some taxonomists (and in FishBase) whereas other taxonomists (and the Red List) have assigned them to the genera *Allochromis, Astatotilapia, Chetia, Enterochromis, Gaurochromis, Harpagochromis, Labrochromis, Lipochromis, Paralabidochromis, Prognathochromis, Psammochromis, Ptyochromis, Pyxichromis, Xystichromis* and *Yssichromis*. This case alone accounts for 71 of the discrepancies. Similarly, there are often conflicting views among taxonomists whether some of the populations of a species constitute subspecies or even different species. For example, Kottelat (1997) has discussed many cases of this for European freshwater fishes. Such cases accounted for 16 of the discrepancies. The remaining 28 synonyms were mainly cases where the Red List compilers had not followed recent revisions. Most of the 43 misspellings were of the 'slip of the pen' type. Others were common misspellings, such as *A. schrencki* instead of *A. schrenckii*.

Determining the correct spelling of a scientific name is not a trivial task and requires the consultation of the original description and a good understanding of the respective rules in the International Code of Zoological Nomenclature (ITZN 1985). This task is now greatly facilitated by Eschmeyer's (1998) authoritative *Catalog of Fishes*, which contains over 53 000 scientific names of fishes as originally published, with indication of the current status of their nomenclature.

Table 1. Number of finfish by category of threat, as contained in the 1996 IUCN Red List.

Category	Abbreviation	No. of species
Extinct	EX	75
Extinct in the wild	EW	10
Critically endangered	CR	130
Endangered	EN	125
Vulnerable	VU	382
Lower risk (conservation dependent)	LR (cd)	11
Lower risk (near threatened)	LR (nt)	93
Lower risk (least concern)	LR (lc)	92
Data deficient	DD	210
Total		1 128

Note: The term 'redlisted' is used in this study to refer to all 1 128 species in this table, whereas the term 'threatened' is used only for the 637 species in the categories VU, EN and CR.

Threats at higher taxonomic levels

Higher taxonomic levels, such as Family, Order and Class, group species that are thought to have evolved from one common ancestor. The higher the category, the more ancient is the common ancestor and the more distinct are its descendants from those in other groups at the same level. In the following, we explore the magnitude of genetic diversity at risk at the various taxonomic levels.

Threats at the Class level

The threatened fishes in the Red List belong to 93 Families, 30 Orders and 4 Classes (Eschmeyer 1998). The only Class that has not been listed is the hagfishes (Myxini) with 43 species in 6 genera (Nelson 1994). They are marine scavengers of the temperate zones of the world and are probably protected by their wide distribution. They may even benefit from high fishing pressure as they often feed on fishes entangled in gillnets or hooked on longlines. In contrast, 2 of the 41 extant species in the related Class of lampreys (Cephalaspidomorphi) are threatened, probably due to their dependence on freshwater. They are anadromous or landlocked.

Of the seven recent species within the Class of lobe-finned fishes (Sarcopterygii) the coelacanth *Latimeria chalumnae* is listed as endangered, making the monotypic Order Coelacanthiformes the highest ranking taxon among fishes that is "facing a very high risk of extinction in the near future" (IUCN 1996). The Australian lungfish *Neoceratodus forsteri* is not contained in the Red List, but is trade-restricted and listed in Appendix II of the CITES (1975) treaty. The southern African lungfish *Protopterus annectens bieni* is also considered vulnerable in South Africa (Skelton 1993).

Within the Class of sharks and rays (Elasmobranchii), 14 of about 800 species are threatened. However, this number might increase substantially in the near future due to the dramatic and unregulated increase in the fishery for shark fins, as evidenced in contributions presented at the International Seminar and Workshop on Shark and Ray Biodiversity, Conservation and Management, held on 7-10 July 1997 in Sabah, Malaysia. The remaining species belonged to the large Class of ray-finned fishes, the Actinopterygii.

Threats at the Order level

McDowall (1969) referring to New Zealand birds, noted "... much more extinction amongst the old endemics than amongst most recent species", implying that–at least in the case of an island–ancient species were at higher risk of extinction than more recent species. When the 58 Orders of fishes are sorted into phylogenetic sequence, following Nelson (1994), only 3.6% of the species belonging to the more ancient half of Orders are seen as redlisted, compared to 5.0% of the species in the more modern half. This does not support an assumption that ancient fish are generally more threatened than modern fish. However, these numbers might change considerably as more species, especially sharks and rays, are assessed.

Table 2 shows Orders of fishes with numbers of threatened species, in phylogenetic sequence after Nelson (1994). The Orders with highest percentage of threatened species are sturgeons and paddlefishes (100%), coelacanths (100%), sawfishes (75%) and trout-perches, pirate perches and cavefishes (44%). The remaining Orders in Table 2 have less than 25% threatened species and 28 Orders do not yet contain any threatened fishes. Five of six Orders with more than 10% threatened species are ancient ones with relatively few extant species, possibly indicating that natural extinction processes are exaberated by anthropogenic threats.

Threats at the Family level

Of the 502 Families recognized in FishBase, 20% have members in the Red List. Among these are 10 Families in which 50% or more of their species are threatened. All of these Families have relatively few species (minimum = 1, maximum = 23, median = 2), stressing the danger of losing the genetic diversity of entire Families of vertebrates in the near future.

Most fish Families have 10 or less species (minimum = 1, maximum = 2 070, median = 10). If Families are sorted by species number and split into equal halves, only 22 Families in the half with fewer species have threatened member species, as opposed to 71 Families in the half with more species. Of the species belonging to the less species-rich Families, 3.3% are threatened, as compared with 2.6% of the

Table 2. Total number of species (after Nelson 1994) and threatened species and subspecies (IUCN 1996) by Order. Orders without threatened species are not included.

Order	Total no. of species	Threatened	
		No.	%
Petromyzontiformes (lampreys)	41	2	4.9
Carchariniformes (ground sharks)	197	4	2.0
Lamniformes (mackerel sharks)	17	4	23.5
Hexanchiformes (frill and cow sharks)	5	1	20.0
Squaliformes (bramble, sleeper and dogfish sharks)	74	1	1.4
Pristiformes (sawfishes)	4	3	75.0
Rajiformes (skates and rays)	255	1	0.4
Myliobatiformes (eagle rays, stingrays and mantas)	143	1	0.6
Coelacanthiformes (coelacanths)	1	1	100.0
Acipenseriformes (sturgeons and paddlefishes)	25	26	100.0
Osteoglossiformes (bony tongues)	213	1	0.5
Clupeiformes (herrings)	358	5	1.4
Cypriniformes (carps)	2 423	179	7.4
Characiformes (characins)	1 273	1	0.01
Siluriformes (catfish)	2 268	32	1.4
Salmoniformes (salmons, pikes and smelts)	321	32	9.97
Percopsiformes (trout-perches, pirate perches and cavefishes)	9	4	44.4
Ophidiiformes (cusk eels)	298	2	0.7
Gadiformes (cods)	436	2	0.5
Batrachoidiformes (toadfishes)	64	4	6.2
Lophiiformes (anglerfishes)	253	1	0.4
Atheriniformes (silversides)	239	40	16.7
Beloniformes (needle fishes)	177	12	6.8
Cyprinodontiformes (rivulines, killifishes and live bearers)	671	57	8.5
Gasterosteiformes (sticklebacks and seamoths)	16	2	12.5
Syngnathiformes (pipefishes and seahorses)	257	28	10.9
Synbranchiformes (spiny eels)	78	1	1.3
Scorpaeniformes (scorpionfishes and flatheads)	1 156	8	0.7
Perciformes (perch-likes)	8 960	179	2.0
Pleuronectiformes (flatfishes)	552	2	3.6
Tetraodontiformes (puffers and filefishes)	329	2	0.6

more species-rich families. Considering that less than 10% of fish species have been assessed so far, we consider this difference as insignificant and conclude that species-richness of a Family does not seem to be a strong indicator of its likeliness to contain threatened species.

Recently discovered vs. long-known species

It has been said that the Earth is losing species before they have been discovered (e.g., Kottelat and Whitten 1997). To explore this suggestion, we looked at the percentage of threatened fishes in relation to their year of first description. As can be seen in Fig. 1, there is a steady increase in absolute numbers of threatened species, with 31 described before 1 800 and 246 described after 1950. In terms of percentage of threatened species, a similar trend is visible from 1800 onwards, with about 5% of newly described species being threatened. Thus it seems probable that some species will become extinct before scientists have a chance to describe them formally.

Knowledge about redlisted fishes

Conservation measures need to be based on sound knowledge of the species in question. FishBase records all references from which relevant information was extracted. The median number of references used per redlisted species is four (minimum = 1, maximum = 267, for *Gadus morhua*, listed as vulnerable for the Northwest Atlantic). More enlightening is an analysis of the type of information that is available for redlisted fishes. FishBase contains large, fairly exhaustive compilations of key information on various aspects of fish biology. As shown in Table 4, crucial information on food items, diet composition, predators, growth, maturity and spawning is missing for 85-95% of the redlisted fishes, indicating an urgent need to focus research on the life histories of this group.

Table 3. Total number of species (after Nelson 1994) and numbers of threatened species and subspecies (IUCN 1996) for Families with 50% or more threatened members; m = marine, a = anadromous, f = freshwater.

Family	Habitat	Total no. of species	Threatened No.	Threatened %
Cetorhinidae (basking sharks)	m	2	1	50.0
Pristidae (sawfishes)	m	4	3	75.0
Latimeriidae (coelacanths)	m	1	1	100.0
Acipenseridae (sturgeons)	a	23	23	100.0
Polyodontidae (paddlefishes)	f	2	2	100.0
Diplomystidae (diplomystid catfishes)	f	2	1	50.0
Heteropneustidae (airsac catfishes)	f	2	1	50.0
Plecoglossidae (Ayu fish)	f	1	1	100.0
Amblyopsidae (cavefishes)	f	6	4	66.7
Adrianichthyidae (ricefishes)	f	11	10	90.9

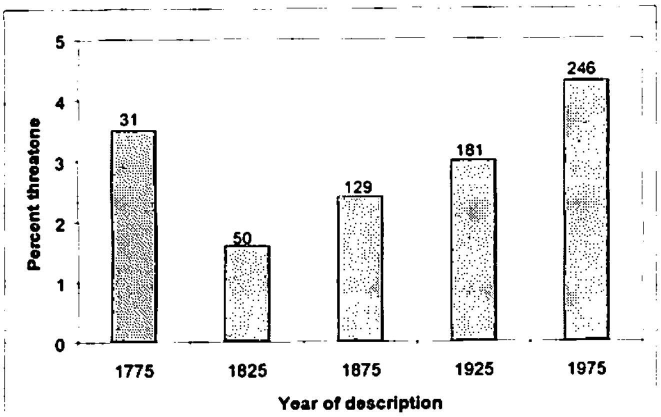

Fig. 1. Percentage of threatened species (IUCN 1996) by year of first description. Numbers above columns indicate number of threatened species described in the respective 50-year periods. See text for details.

Environment/salinity

Nelson (1994) estimated the total number of finfish species at 24 618. Of these, he classified 10 465 as 'species using freshwater' which 'would either not exist or whose range would be significantly reduced if freshwater habitats were denied to them.' This definition correlates with the 9 884 FishBase species in the categories 'primary freshwater', 'secondary freshwater', and 'diadromous species' (Table 5). Within these categories, 547 (5.5%) are threatened, compared with 90 (0.8%) of the remaining species that do not depend on freshwater. This comparison confirms the trends in Table 5, showing that fishes that depend on freshwater at any time of their lifecycle are about 10 times more likely to be threatened than marine species. This trend was confirmed by McDowall (1997) who found that it was mainly the freshwater phase that deter-

Table 4. Number and percentage of redlisted fish species for which key information is available in FishBase (Froese and Pauly 1998).

Type of information	Redlisted species No.	Redlisted species %
Food items	137	12
Diet composition	52	5
Predators	66	6
Growth	95	9
Maturity	111	10
Spawning	167	15

Table 5. Numbers of total and threatened (IUCN 1996) species by salinity of habitat. The upper three categories include freshwater-dependent fishes exhibiting a higher level of threat.

Salinity	Species in FishBase	Threatened Species	Threatened %
Primary freshwater	8 788	494	5.6
Secondary freshwater	465	24	5.2
Diadromous	631	29	4.6
Brackishwater/Marine	1 074	15	1.4
Marine	10 199	75	0.73
All species in FB 98	21 157	637	3.0

Note: FishBase (FB) (Froese and Pauly 1998) does not yet contain all of the estimated 25 000 species of finfish. See text for more information.

mined the status of threat for diadromous fishes. Lower extinction risk for marine species is also suggested by the fossil record, where the average duration of marine species is 3-8 times longer than that of freshwater fishes (McKinney 1998). The above assessment may, however, be biased by the fact that only 121 marine or brackishwater species have been assessed so far. Because of this low level of assessment (less than 1%), no attempt was made to analyze any correlation between biological traits and status of threat for marine/ brackishwater species. See Roberts et al. (1998) for proposed future listings of marine species.

Climate

Table 6 shows the numbers of freshwater-dependent fishes by climatic zones as entered in FishBase. Temperate and subtropical freshwater-dependent fish seem to be about four times more threatened than tropical species. These climatic zones are typically more developed by humans, with few freshwater habitats remaining undisturbed. However, this result is probably strongly biased by the fact that tropical species are less well assessed. In Mexico, which is one of the few well-assessed countries having substantial numbers of tropical species, the percentage of threatened tropical species was higher than the percentage of threatened subtropical species. Overall, it seems that climatic zone, i.e., a preferred range of temperature and habitat types, is in itself not a factor that strongly influences the status of threat.

Migratory behavior

McDowall (1992, 1997) stressed that migratory species are threatened by changes in any of their 'passage habitats', especially densely populated river mouths, which might become bottlenecks where threats are higher. Table 7 shows the statistics of migratory freshwater-dependent fishes, as contained in FishBase. Overall, 5.5% of these species are threatened. Limnodromous (15%), oceanodromous (13%) and anadromous (13%) species clearly face a higher than average threat. Catadromous fishes (1.5%; mostly eels) appear less threatened than others, possibly due to their hardiness and their relatively undisturbed and remote spawning grounds. Many species of the 'unknown' category are probably nonmigratory, which would bring that percentage closer to the average. With the exception of catadromous fishes, it seems that species that depend on wide migrations are more threatened than others.

Table 6. Numbers and percentages of threatened freshwater-dependent fishes by climatic zone.

Climatic zone	Total	Threatened	
		No.	%
Temperate	1 386	187	13.5
Subtropical	826	108	13.1
Tropical	7 643	252	3.3
Total examined	9 855	547	5.6

Source: FishBase (Froese and Pauly 1998).

Note: The numbers are biased by the better assessment of temperate and subtropical fishes.

Trophic level

FishBase contains estimates of trophic levels, i.e., the rank of a species in the foodweb for 1 197 better known and commercial species (Pauly et al. 1998), but for only 57 threatened fishes. To evaluate the trophic levels of threatened fishes, we estimated the trophic level for additional 16 000 species using the average trophic level of the genus or the family (Table 8). When the frequency of plant feeders (trophic levels 2.0-2.9), omnivores and carnivores (trophic levels 3.0-3.9), and top predators (trophic levels 4.0-5.0) is compared between all fishes and threatened fishes, there are considerably more (45%) herbivorous threatened species than suggested by their contribution (30%) to all fishes. This surprising result appears to be solid because (1) using trophic level averages of genera or families to replace missing specific values tends to mask differences; (2) with 69% of the estimated 25 000 recent fishes covered, the pattern for all fishes is not likely to change significantly; and (3) with 85% of the threatened fishes covered, that pattern is also not likely to change significantly.

Assuming that environmental degradation such as habitat loss, eutrophication and turbidity, as well as introductions, are the most prominent causes of threat

Table 7. Numbers and percentages of threatened freshwater-dependent fishes by type of migratory behavior. Oceanodromous species, such as some sharks, migrate in the oceans and regularly enter freshwater for feeding. Amphidromous species, such as some sticklebacks and flounders, regularly migrate between freshwater and the sea (in both directions), but not for the purpose of breeding.

Migration type	Total	Threated species	
		No.	%
Unknown	8 651	435	5
Nonmigratory	847	73	9
Oceanodromous	16	2	13
Catadromous	65	1	2
Anadromous	136	18	13
Amphidromous	62	3	5
Limnodromous	102	15	15
Total examined	9 879	547	6

Source: FishBase (Froese and Pauly 1998).

to freshwater fishes, these seem to have a stronger impact on plant feeders, possibly by changing or reducing aquatic vegetation and by introducing predators and competitors. This new relationship and its implications need more work beyond the scope of the present study.

Human use of threatened fishes

Fishes are used for a variety of human purposes, several of which support large industries. Table 9 gives an overview of these uses and the percentage of threatened fishes in each category. With the exception of game fishes, the pattern of use of threatened fishes is very similar to that for all fishes. The classification used in FishBase for game fishes is based on angling records (e.g., IGFA 1994), which list the largest specimens ever caught by anglers but do not necessarily indicate that the species is widely targeted as a game fish. We do not believe that sport fishing poses a direct threat of extinction to fishes. Rather we think that game fishes are better known and assessed than others because of higher public awareness.

The 'Fisheries' category includes stocks of nine highly commercial species, such as the Atlantic cod (*Gadus morhua*) and the Nassau grouper (*Epinephelus striatus*). Most of these species are considered under threat because of a recent drastic reduction in some of their stocks. However, whether this constitutes a threat of extinction at the species level is a matter of debate (see e.g., Beverton 1992). No marine fish species is yet known to have been driven to biological extinction by fishing (Musick 1998). However, this may change soon. Roberts et al. (1998) list four marine fish species that are on the edge of extinction due to fishing and collection for the aquarium trade.

Table 8. Numbers and percentages of all and of threatened fishes (IUCN 1996) by trophic level.

Trophic level	All fishes		Threatened	
	No.	%	No.	%
2.0-2.9	5 166	30	243	45
3.0-3.9	11 004	64	274	50
4.0-5.0	1 044	6	26	5
Total	17 214	100	543	100

Source: FishBase (Froese and Pauly 1998).

Note: The high percentage of herbivores (trophic level 2-2.9) among threatened fishes.

Of the threatened freshwater-dependent fishes, 45 species (7%) are used as food, i.e., they are captured in at least one country of their range. They are threatened by habitat loss, dams, pollution, and by subsistence or commercial fisheries. Most of these species are sturgeons, also threatened by the high price of and demand for their eggs as caviar (Birstein 1993).

The use of fishes in fisheries, aquaculture, as bait, game or aquarium fish is usually not considered as contributing to the threat of extinction (e.g., Beverton 1992; Kottelat and Whitten 1997). However, the high demand and price for species such as the humphead wrasse (*Cheilinus undulatus*) in the live foodfish trade or the use of seahorses (Syngnathidae) in the Chinese traditional medicine are posing a very serious threat.

Only 70 (11%) of the threatened freshwater-dependent fishes are reported as protected or restricted in at least one country, indicating a lack of recognition of the problem by national governments and fishery managers.

Fishes as alien species

Fishes introduced as alien species have been mentioned as a major threat to native fishes (e.g., Kottelat and Whitten 1997). Fig. 2 shows the correlation between international introductions of fishes and the number of threatened fishes for countries with at least 10 native freshwater fishes and with at least one introduced or threatened species recorded in FishBase. The United States, Mexico, and Indonesia are not true outliers but are countries with high numbers of freshwater fish, which have been more thoroughly assessed than those of other countries. Australian freshwater fishes are also

Table 9. Numbers and percentages of all and of threatened fishes (IUCN 1996) by category of human use. Columns do not add up to totals because species can be used in more than one category.

Human use	All fishes		Threatened	
	No.	%	No.	%
Fisheries	4 213	20	119	19
Aquaculture	302	1.4	17	3
Game	1 077	5	62	10
Bait	191	1	1	0.2
Aquarium	3 009	14	97	15
Traditional medicine	60	0.3	5	0.8
Total used	6 944	33	219	34
Not used	14 213	67	418	66
Total	21 157	100	637	100

Source: FishBase (Froese and Pauly 1998).

well assessed. These countries demonstrate a trend of increased numbers of threatened species with increased numbers of introductions. In most other countries, such as the Philippines, a thorough assessment of the freshwater fish fauna can be expected to significantly increase the number of threatened fishes. In Uganda, Kenya and Tanzania, the high number of threatened species is caused by a single introduction, that of the predatory Nile perch (*Lates niloticus*) into Lake Victoria. In many remote island countries, such as Hawaii, the number of introduced fishes is higher then the number of native freshwater fishes. However, these islands normally do not have primary freshwater fishes and introductions are often restricted to artificial waterbodies, whereas the secondary freshwater fishes (mainly gobies) spawn in the sea and migrate upwards in small creeks for feeding.

Abundance

In FishBase, 5 788 species are assigned a level of abundance for the countries in which they occur. Fishes that are threatened with extinction should, by definition, be occasional (usually not seen) or scarce (very unlikely to be seen). As shown in Table 10, 225 (80%) of the threatened fishes for which abundance data are available do fall into these categories. Also, there is a clear increase in the percentages of threatened fishes towards the 'occasional' and 'scarce' categories. The finding that 20% of the threatened freshwater fishes are listed as 'abundant' or 'common' in FishBase results from the fact that the RedList contains species of which only populations or stocks but not the species in general are under threat.

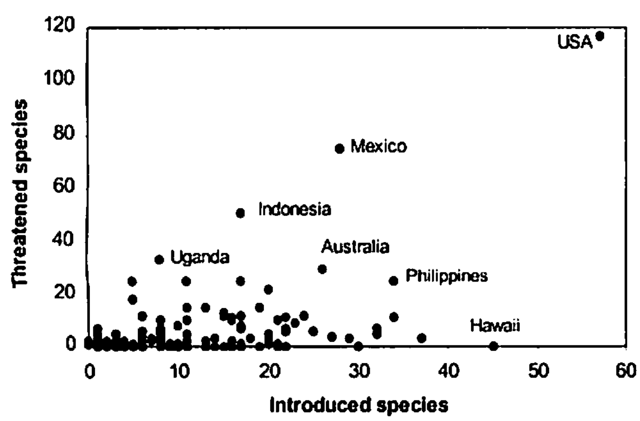

Fig. 2. Numbers of threatened (IUCN 1996) vs. introduced fish species per country. Source: FishBase (Froese and Pauly 1998).

Table 10. Abundance of threatened (IUCN 1996) freshwater-dependent fishes.

Abundance	Total no.	Threatened	
		No.	%
Abundant	550	7	1.3
Common	1 995	37	1.9
Fairly common	419	11	2.6
Occasional	876	44	5.0
Scarce	1 948	181	9.3
Total	5 788	280	4.8

Source: FishBase (Froese and Pauly 1998).

Distribution

FishBase assigns species to the countries from which they have been reported. This information is used to see whether species that are reported from only one country face a higher risk of threat than species that occur in many countries. Of the threatened freshwater-dependent fishes, 82% occur in only one country, compared to 59% for all freshwater fishes in FishBase. Similarly, 91% of threatened plants occur in only one country (IUCN 1997).

FishBase also assigns a latitudinal range to species. This range can be understood as a measure of environmental adaptability of a species. Table 11 shows the median latitudinal range for freshwater-dependent fishes, by category of threat. Note that threatened species have narrower ranges (2-3°) than all examined species (median=6°) or species of least concern (median=9°). Maximum latitudinal ranges of threatened fishes often belong to diadromous fishes such as sturgeons.

Size distribution of threatened fishes

It has been suggested that large fishes, because of their attractiveness to fishers and because of life history characters that correlate with size (e.g., slow growth, late maturity) will be more vulnerable than small- and medium-sized fishes (e.g., Roberts et al. 1998). Fig. 3 shows the numbers of threatened freshwater fishes by logarithmic length class, as compared with non-threatened freshwater fishes. There is a clear increase in the relative number of threatened fishes above 100 cm (log 2) maximum length, to a point where most very large freshwater fishes are threatened.

Table 11. Latitudinal range of redlisted (IUCN 1996) freshwater-dependent fishes.

Category	n	Latitudinal range (median)	Range Minimum	Range Maximum
Extinct	50	4	1	20
Extinct in the wild	8	2.5	1	4
Critically endangered	67	2	1	41
Endangered	81	3	1	81
Vulnerable	186	2	1	70
Lower risk (conservation dependent)	11	2	1	4
Lower risk (near threatened)	56	4	1	67
Data deficient	99	2	1	43
Lower risk (least concern)	45	9	1	71
Total	2 658	6	1	94

Source: FishBase (Froese and Pauly 1998).

Note: The narrower median ranges of threatened fishes (2-3°) compared with 'least concern' and 'not evaluated' fishes (6-8°).

Mode of reproduction

All reviews on threats to species agree that habitat loss is the most critical one (e.g., Heywood and Watson 1995). It can be hypothesized that freshwater-dependent fishes that bear or guard their eggs or larvae are less affected by environmental disruption than fishes that depend on specific habitats and environmental conditions for successful reproduction. FishBase contains 2 376 records with a classification of parental care into bearers, guarders and nonguarders, following the classification of Balon (1990) (see Table 12). The percentage of threatened fishes is clearly higher among nonguarders than among bearers and guarders. Nonguarders typically have high fecundities to make up for high mortality rates, and to quickly replenish and expand the population under favorable environmental conditions (r-strategists). This strategy seems to fail when degrading environmental conditions cause repetitive recruitment failures. On the other hand, the strategy of having few offspring with considerable parental care fails when an introduced predator preys directly on the spawning population and thus quickly reduces the ability of the species to recover, as was apparently the case with many mouthbrooding haplochromines of Lake Victoria after the introduction of the piscivorous Nile perch.

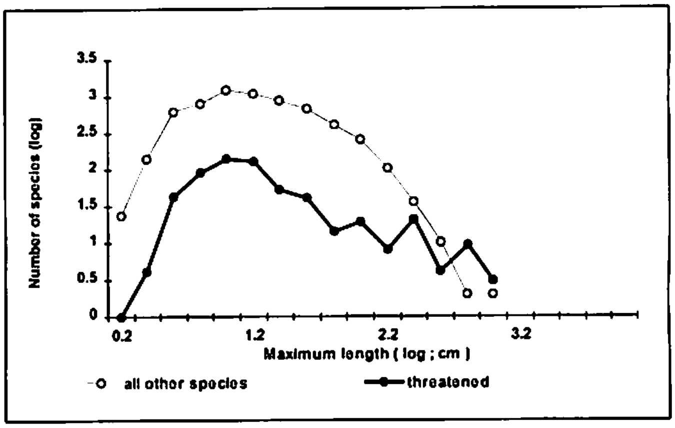

Fig. 3. Size distribution of threatened (IUCN 1996) freshwater-dependent fishes as compared with the size of other freshwater fishes. Source: FishBase (Froese and Pauly 1998).

Human population density

Conflicts over freshwater resources constitute the largest threat to freshwater fishes (e.g., Kottelat and Whitten 1997; McAllister et al. 1997), and coastal habitat is lost in direct proportion to human population density (Camhi et al. 1998). Fig. 4 shows the relationship between human population density and the percentage of threatened freshwater-dependent fishes for countries with more than 10 freshwater fishes in FishBase. City states such as Hong Kong and Singapore with more than 1 000 people per square kilometer were excluded.

Several factors contribute to the variance in this relationship:

- In many countries, the conservation status of freshwater fishes has not been assessed, hence there are many zero values for threatened fishes;

Table 12. Status of threat (IUCN 1996) of freshwater-dependent fishes vs. reproductive guild.

Reproductive guild	Total no.	Threatened No.	Threatened %
Bearers	590	89	15
Guarders	561	85	15
Nonguarders	1 225	373	30
Total	2 376	547	23

Source: FishBase (Froese and Pauly 1998).

- The population density was derived by dividing the total population number by the total area of the country, and thus does not reflect well the population density in the river basins, where more people tend to live;
- Densely populated countries with more than 100 people per square kilometer are often islands or small countries where freshwater fishes that are sensitive to human pressures have probably disappeared long before baseline checklists of freshwater fishes were assembled, resulting in a low percentage of threatened fishes.

Considering only the data below a threshold of 100 people per square km, a clear trend of increasing numbers of threatened fishes with increasing population density is visible, despite the confounding factors discussed above. The decrease in percentage of threatened fishes above 100 people per square kilometer probably results from the disappearance of aquatic habitats altogether.

What to conserve?

Zeide (1998) argued that the claim to conserve "every scrap of biological diversity" is fashionable but not honest, given that there is widespread consensus on the need to eradicate disease vectors and a number of human parasites and competitors, such as pests of important crops. There is indeed consensus on the eradication of several introduced fishes, such as the lampreys in the Great Lakes of North America, which considerably damage important commercial species.

There are threatened species that are reported to feed on juveniles or adults of commercial or highly commercial fishes (Table 13). Most of these threatened predators are themselves of high commercial value, thus far outweighing any theoretical gain from their extinction and reduced predation on their commercial prey. Some threatened fishes pose danger to humans and thus their extinction would theoretically reduce human risks of being wounded or poisoned (Table 14). Notably, the incidence of shark attacks on humans reached an average of 30 a year for the period 1940-1970 (Last and Stevens 1994). However, this is considerably less as compared to hazards caused by other animals and we are not aware of any conscious attempt to eradicate a native fish species. Rather, income from

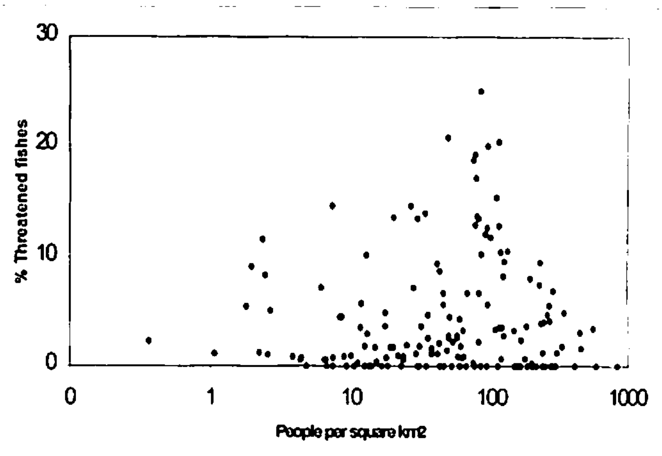

Fig. 4. Relationship between percent threatened freshwater fishes (IUCN 1996) and population density. Source: FishBase (Froese and Pauly 1998).

'shark watching' enterprises is increasingly providing incentives to protect sharks in developing countries such as the Maldives (Andrews 1990).

Summary and Policy Implications

We looked at a wide range of biological characters of fishes to see whether there are any traits that make a species especially vulnerable. The following factors seem to contribute to threats and the likelihood of extinction of fishes:

(1) Dependence on freshwater at any stage of the life cycle;
(2) Restricted latitudinal range or occurrence in only one country;
(3) Occurrence in countries with high population density;
(4) Dependence on spawning or feeding migrations;
(5) Feeding at lower trophic leads (2.0-2.9), for example, herbivorous fishes;
(6) Being large and thus slow-growing, late-maturing, and attractive to fishers;
(7) In freshwater fishes, dependence on the external environment for development of eggs and larvae (nonguarder, r-strategist);
(8) Occurrence in countries with high numbers or aggressive nature of introduced fishes;
(9) Being rare, such as many recently discovered fishes.

Table 13. Threatened fishes (IUCN 1996) that compete with fishers by feeding on juveniles or adults of commercial or highly commercial fishes.

Predator		Prey	
Green sturgeon	*Acipenser medirostris*	Pacific sand lance	*Ammodytes hexapterus*
White sturgeon	*Acipenser transmontanus*	Eulachon	*Thaleichthys pacificus*
Macedonia shad	*Alosa macedonica*	Roach	*Rutilus rutilus*
Duckbill sleeper	*Butis butis*	Milkfish	*Chanos chanos*
Dusky shark	*Carcharhinus obscurus*	Bluefish	*Pomatomus saltator*
Sandbar shark	*Carcharhinus plumbeus*	Bluefish	*Pomatomus saltator*
Atlantic menhaden	*Brevoortia tyrannus*		
Spot croaker	*Leiostomus xanthurus*		
American eel	*Anguilla rostrata*		
Esonue grouper	*Epinephelus itajara*	Southern stingray	*Dasyatis americana*
Nassau grouper	*Epinephelus striatus*	Bar jack	*Caranx ruber*
French grunt	*Haemulon flavolineatum*		
Yellowtail snapper	*Ocyurus chrysurus*		
Spotted goatfish	*Pseudupeneus maculatus*		
Coney	*Cephalopholis fulva*		
Atlantic cod	*Gadus morhua*	Norway pout	*Trisopterus esmarkii*
Atlantic herring	*Clupea harengus*		
Huchen	*Hucho hucho*	Grayling	*Thymallus thymallus*
Gudgeon	*Gobio gobio gobio*		
Beluga	*Huso huso*	European anchovy	*Engraulis encrasicolus*
European river lamprey	*Lampetra fluviatilis*	Common whitefish	*Coregonus lavaretus lavaretus*
Sea trout	*Salmo trutta trutta*		
Roach	*Rutilus rutilus*		
Bigeye tuna	*Thunnus obesus*	Chub mackerel	*Scomber japonicus*

Source: FishBase (Froese and Pauly 1998).

Table 14. Threatened fishes (IUCN 1996) that are dangerous to humans and whose extinction might therefore be considered as desirable.

Type of danger	Fish	Species
Poisonous to eat	Bluntnose sixgill shark	*Hexanchus griseus*
	European river lamprey	*Lampetra fluviatilis*
	Queen triggerfish	*Balistes vetula*
Reports of ciguatera poisoning	Common seabream	*Pagrus pagrus*
	Cubera snapper	*Lutjanus cyanopterus*
	Hogfish	*Lachnolaimus maximus*
	Humphead wrasse	*Cheilinus undulatus*
Traumatogenic	Blacktip shark	*Carcharhinus limbatus*
	Dusky shark	*Carcharhinus obscurus*
	Sandbar shark	*Carcharhinus plumbeus*
	Sandtiger shark	*Carcharias taurus*
	Great white shark	*Carcharodon carcharias*
	Esonue grouper	*Epinephelus itajara*
	Ganges shark	*Glyphis gangeticus*
	Porbeagle	*Lamna nasus*
	Largetooth sawfish	*Pristis microdon*
	Smalltooth sawfish	*Pristis pectinata*
	Giant grouper	*Epinephelus lanceolatus*
Venomous	Bocaccio	*Sebastes paucispinis*
	Freshwater whipray	*Himantura chaophraya*

Source: Fishbase (Froese and Pauly 1998).

Phylogenetic rank, size of taxon, human use, or climate zone did not seem to contribute to the risk of extinction.

Most of the identified factors such as range, abundance, exposure to introduced species and exposure to human development have been suggested before as factors contributing to the threat of extinction, and are thus confirmed by our data. Similarly, most policy implications resulting from these threats are well known and a review of strategies and existing instruments is beyond the scope of this study (see citations in Introduction). That herbivory and nonguarding reproductive mode add to the vulnerability of freshwater fish species has, to our knowledge, not been suggested before, and we are looking forward to more detailed studies of these aspects of conservation biology. If confirmed, these threats would call for even more effective measures to preserve wetlands and aquatic ecosystems as important parts of the terrestrial ecosystems that support humans.

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Discussion

Pullin: The World Conservation Union might soon have to think within the species level for a red list of fish. For example, if some of the populations of *Oreochromis niloticus* in Africa were to disappear, the world would lose genetic resources of great importance for aquaculture. The species though would not be in danger. The same can be said for *Sarotherodon melanotheron* in West Africa. A red list that only operates at the species level will not capture threats to important intraspecific taxa and populations.

Froese: I agree. The Red List does include subspecies, but not populations, and it is not targetted at the national level.

Kapuscinski: The same point applies to a number of anadromous species, such as salmon. They follow the dendritic patterns of rivers in their spawning migrations and there is great genetic variation among the different populations.

A. Gupta: In this presentation, you seem to find no role for people in conserving, say, spawning sites or sacred waters, estuaries, etc. Is this just by chance?

Froese: Well, that was not really my topic. I was considering indicators of threats. It is difficult to protect resources, especially in freshwaters because they are under such pressure. The main thing is to limit their disturbance.

A. Gupta: Do you know of any examples of conservation of such resources by community action and institutions – conservation that would not otherwise have been possible?

Froese: In the USA, I know of some species that occur in only one lake and they are conserved because of restricted access.

Kapuscinski: I am only just beginning to get into the literature on this topic. There is a book called *Folk Management in the World's Fisheries* (Dyer and McGoodwin 1994) that has a number of interesting examples. For example, an island population in the Dominican Republic that had settled there only about 200 years ago, were managing a coral reef fishery very successfully until outsiders came in. The fishers were then able to convince the government of the need to continue their form of management and to prevent access by outsiders, including those involved in spearfishing and sport diving. I'm sure there are many other examples.

A. Gupta: The literature on this is very rich. I was just interested as to whether scientists are acknowledging these contributions.

Kapuscinski: In general, biologists (like myself) are not trained to appreciate this literature and are not aware of it. This needs to be put right.

Welcomme: I think that biologists in the tropics are more aware of these contributions and take note of them more than biologists in the temperate zones.

Pullin: Anil Gupta is right. There is a very rich literature on traditional management systems.

Schei: I was a bit surprised that this presentation ranked introduced species so low in the categories of threats.

Froese: Yes – it might seem surprising, though there were no comments from Brian Groombridge on this. The point is that, although there have been a few spectacular examples of species being wiped out by introductions, the number of extinctions due to introduced species is very few, statistically speaking. The number one threat is habitat destruction.

Welcomme: Introductions are often perceived as a far greater problem than they really are. In freshwaters, it is difficult to unravel the impacts of introductions from those of environmental degradation. Many introductions have become problematic only after environmental change in the area. There is no doubt that some introductions, like those of rainbow trout and brown trout, have eliminated some catfish and other stream-living species but, on the whole, most introductions are inocuous. So I agree with Rainer Froese. What did surprise me in this analysis is that migratory species did not appear under greater threat.

Schei: Well, I disagree very much with this point of view because you are mixing up the amount of introductions leading to something wrong with the damage done by a few. I agree that most introductions cause little damage, but in general they are the second most important threat.

Welcomme: This is a question of perception and it is a deeply emotive issue but, when you actually examine the data, the problem is not as severe as it is thought to be. This might send the wrong message, but that's the position.

Schei: I agree that most introductions are not a problem, but most people are 'nice' people and some can do a lot of harm!

Harvey: The people who report the status of stocks have, I think, a duty, especially where there are deficient data or unknowns, to make the public aware of these situations in language that the public can appreciate. A 'twenty per cent of stocks at risk' statement does not seem particularly worrisome to the general public, but in fact the risks might be much higher – the data being deficient.

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Fishing in the 'Troubled Waters': Recognizing, Respecting and Rewarding Local Ecological Knowledge, Innovations and Practices Concerning Aquatic Biological Diversity

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ABSTRACT

Local, indigenous knowledge is an important resource for the conservation and sustainable use of aquatic biodiversity. However, it is an endangered resource because of the lack of recognition, rewards and incentives given to its originators, holders and practitioners. This paper reviews the issues affecting local knowledge about aquatic biodiversity and gives examples of its status and importance, drawing upon published and unpublished examples and referring to the work of the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) and the Honey Bee Network and database.

Introduction

Studies of indigenous ecological knowledge are getting attention not only among resource managers, policy planners and parties to the Convention on Biological Diversity (CBD) but also within and among local and indigenous communities themselves. During modernization, many of these communities have realized the threat of knowledge erosion and are attempting to take control of such knowledge, which outsiders have often documented and appropriated without sharing benefits with the providers. External researchers rarely share the gains made through publication, value addition to or commercialization of this knowledge. Their relationships with the knowledge providers are extractive and utilitarian, with no accountability, hence this paper's title 'troubled waters'. Fishing for knowledge in such waters is fraught with risks and threats.

This paper deals first with the empirical context of local knowledge about aquatic biological resources. 'Local' and 'indigenous' are here considered as synonymous terms. Such resources are considered by some users as existing in a wider socio-ecological context than simply to be exploited by humans. Some local communities have elaborate rituals which they perform before hunting or fishing, so as to seek the permission of the spirits that guide their own lives, those of aquatic and other living systems and the connections between these. Examples are given from the Honey Bee Network and the activities of the Society For Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), a developmental voluntary organization hosting textual, electronic and multimedia databases on indigenous technological, educational and institutional innovations that help overcome the barriers of localism, literacy and language.

Local communities and innovators can learn about new ideas, innovations and institutions from different areas through a combination of local language textual facilities, sound, pictures and films. Thus even an illiterate person can learn from ideas not just from the same village and through sound and films.

The paper then discusses the relationship between biodiversity and poverty and suggests appropriate incentives for different kinds of local knowledge and related contextual settings, proposing certain directions for policy and research towards a better understanding of aquatic biodiversity through local ecological, technological and sociocultural knowledge systems. The development of the database of SRISTI is given as an example of a tool that could be used for this kind of lateral learning. SRISTI has several kinds of databases, for instance: (1) common property resource institutions, having examples of self-designed collective solutions of resource management problems dealing with grazing, fisheries, water, forests, etc., from 23 countries; (2) more than 8 000 technological innovations and outstanding examples of traditional knowledge for sustainable natural resource management; (3) medicinal plants; and (4) natural products, patents on herbal products, educational innovations in primary education, literature on sustainable natural resource management (more than 23 000 reprints and documents), rural development, etc.

Making Connections: Understanding the *Context*, in order to Appreciate the *Content* of the Local Knowledge

How context changes content

The following story illustrates the relationship between context and content. Akbar was a Moghul King during the fifteenth century and was very popular among his subjects due to his secular orientation. He had a quick witted minister called Birbal. Akbar and Birbal used to play games of one upmanship. Each one would try to prove that the other was not very intelligent. Once Birbal asked whether the king believed in the dictum 'as is the king, so are his subjects.' Akbar replied of course, that it was true. Since he was a wise king, so should be his subjects. Birbal suggested that they should test this assumption. He wanted to prove that Akbar was not a very wise king, though of course in the lighter vein. Birbal drew a line on a paper. He asked the king to challenge everybody to shorten the line without erasing it. After several weeks, a child came forward. He drew a longer line adjacent to the original, which then appeared shorter. The context changed the content. Similarly, once the context of a knowledge system is changed, as is seen next, its content and the scope of its applicability changes enormously.

Three indigenous communities in Alaska and four in Chukotka, Russia (an autonomous *okrug* (national area) in Siberia; north of the okrug of Koryakia and bordered by the Bering Sea, the Chukchi Sea, and the East Siberian Sea; total area 737 700 km^2). were studied by Huntington and Mymrin (1995) to analyze knowledge about beluga whales in each community. How the status of ice, fish and wind, and the presence of killer whales affected the belugas was described in detail. The researchers realized, during relaxed but intensive discussions with local community members, that these discussions would veer towards some other subjects seemingly unconnected. The researchers tried to bring the discussion back to the topic but before they succeeded in doing that, they discovered a new connection. A structured inquiry would have made accessing such data impossible. For example, one digression was about beavers. Beavers, a local respondent informed, build dams in the streams where salmon and other fish spawn. When the beaver population expands, the spawning habitat of salmon may be reduced. In turn, this affects the belugas, which feed on salmon. Hence, as these authors pointed out, traditional ecological knowledge cannot be preserved merely by documentation. This requires combining knowledge with experience, which in turn means conserving the way of life which produced the knowledge. The same authors discovered similar observations by communities that live very far apart. For example, a community in Alaska and another in Russia both described how belugas assist a female in their group while giving birth: one beluga swims on either side of the female, helping to squeeze out the calf.

Aquatic biodiversity in a local community context

Chambers (1999) has reviewed the cultural conflicts that can occur over natural resources, and includes an aquatic example – Japanese indignation at worldwide protests on their killing of whales. The Japanese counter with a question of their own, about the ethics of killing domesticated animals. Chambers thus asks: who is biodiversity conservation for? He found that conflicts are bound to arise whenever local knowledge, (cultural) and environmental values are at variance with the values of a wider public, be it a multinational corporation, the international community, or a state.

The Commissioner of the Sea Otter Commission, Alaska, raised in 1990 a fundamental issue about the politics of defining resource boundaries and the legitimacy of the particular ways of local people in dealing with these. Distressed at the poverty of many of the First Nation peoples of Alaska, he decried the tendency of 'Animal First' activists to deny such peoples their autonomy in pursuing a sustainable coexistence in their ecological context and stated:

> "They do not understand that in their desire to protect animals, they are destroying culture, economic and spiritual systems which have allowed humans and wild life to be sustained over thousand of years... Their's (Animal First activists' concept) is based upon a belief that animals and humans are separate and they project human values into animals. Ours is based on the knowledge from hundred of generations which allows us to understand that humans are part of all living things– and all living things are part of us. As such it is spiritually possible to touch the animal spirit. In order to understand them, our relationship with animals is incorporated into our cultural systems, language and daily lifestyles. Theirs is based upon laws and human compapas-sion...Because we are intricately tied to all living things, when our relationship with any part of such life is severed by force, our spiritual, economic, and cultural systems are destroyed, deep knowledge about wild life is destroyed, knowledge which western science will never replace...I leave you with this last thought – we have an obligation to teach the world what we know about proper relationship between humans and other living things" (Merculieff, cited in Gupta 1991a).

Sacred Waters

Biegert (in Chambers 1999) recalled striking narratives which contrast the perspectives of First Nation North Americans about waters with those of white settlers. He gave the example of the late Philip Deere of Oklahoma, medicine man of the Muskogee Nation, who termed rivers and streams as the veins of the world. Clogging them, one could say without doubt, would clog not just the in life in them but the life of humans as well. The sacredness of water in all such cultures indicates that by polluting waters we are also polluting the spirits that sustain these waters. Ecological indicators of aquatic life may be observed from terrestrial plants, showing the artificiality of separating the world into aquatic *vs.* terrestrial or floral *vs.* faunal. An example from Cree culture highlights a striking case of how a fish migration is forecast. Nakashima and Roue (1995; unpublished field notes) described a very productive fishery at Fort George Cree, on the first rapids of the La Grande River, for two species of white fish, cisco *(Coregonus artedii)* and white fish *(C. clupeaformis)*. The Cree people forecast the return of these fish from sea to the La Rapids by looking at the flowering of fireweed, *(Epilobium angustifolium)* growing along the banks of the river close to the fishing sites. The Cree prepare their nets when these weeds flower. The same authors described a very rich knowledge system which has grown around the capture, processing, storage and disposal of these resources and their byproducts. For example, fish scales are fed to dogs used for traction work. Regrettably, while locating hydropower dams, authorities did not heed local concerns about conserving sites of economic, spiritual and sociocultural importance (Nakashima and Roue 1995). The fishing sites were sites not just for capturing fish but also for social exchange and the generation and sharing of knowledge. Similarly, Raygorodetsky (1997) details how the Gwichin Nation of North Western Canada select the best sites and times for fishing and use ingenious ways to utilize every part of the fish they collect. The communities have also evolved institutional arrangements to share nets and to share catches of fish, like charr *(Salvelinus* spp.*)* with those who do not have access to these resources. For whitefish, elaborate arrangements existed for locating eddies at river bends (where flow is slower and where fish congregate), for repairing nets, and for setting these under the ice for fishing in winter, after making holes in the ice.

Osseweijer (1997) illustrates some local knowledge and rituals associated with fishing in Aru archipelago, Indonesia. Tobacco offerings are made to the ancestral keepers of pearl oysters and sea cucumbers before embarking upon diving. The Beltabur community leaders hold that the sanctity of the sea has to be maintained by correct behavior, just as in our own backyard in the village. People are not supposed to make any noise, shout or engage in rowdy behavior while at sea. The ancestors of the sea might otherwise get angry and send big waves or strong winds as indicators of their displeasure. People have their own beliefs about the way retribution is provided for not following the rules of good behavior at sea. Osseweijer (1997) recalled a local belief that when two local communities were fighting about the rights over certain territories, the sea cucumbers became rare during that period, as if the elders in the community did not like the conflict.

Wallace and Steiner cited by Chambers (1999) showed how local communities in Hawaii relate marine and terrestrial biodiversity. For some marine species, they recognize a counterpart terrestrial species. Dudley (1990) described how this sometimes happened. In Hawaiian medicine, whenever one took a land-based medicinal herb, the first food to be taken next had to be a marine species paired with this land-based herb. Polynesian culture, it seems, has also established such relationships between the use of aquatic and terrestrial species. This deserves the attention of policymakers, not just for its ethical, spiritual and cultural dimensions, but also for its scientific aspects.

The Honey Bee Database

The Honey Bee Database (see Honey Bee Newsletters 1990-1999) was established 10 years ago to scout, spawn, sustain, disseminate and reward grassroots innovators and experts in traditional, ecological, technological, educational and institutional knowledge developed by local communities and individuals without any outside help. This database can be accessed by innovators and others who aim to empower them by adding value to their innovations and by sharing benefits with the knowledge providers and innovators in a fair and equitable manner.

SRISTI members and the Honey Bee Network have been involved in the documentation, experimentation and dissemination of indigenous knowledge, innovations and practices in the agricultural and animal husbandry sectors for 16 years, working closely with farmers, and using a variety of methods to document about 7 500 innovations and practices from 3 200 villages in Gujarat (SRISTI 1996) and in other parts of India. In addition, innovations have been documented from local communities in many countries in Africa, Asia and Latin America. Through the Honey Bee Newsletter, grassroots innovations have been disseminated to more than 75 countries. This has produced *probably* the world's largest database on grassroots innovations, with name and address of the innovators (individuals or communities) and communicators in most cases.

This database has 71 entries on the traditional use of fish and fish products, wastewater, etc., for curing animal diseases, improving crop productivity (e.g., grape vines are supposed to particularly benefit from fish compost), etc. Such local knowledge about aquatic diversity and its uses has not been adequately appreciated and there is a strong case for launching a global drive to strengthen efforts in this direction.

Biodiversity, Poverty and Knowledge Erosion

Biodiversity cannot be conserved by keeping people poor even if, historically, biodiversity survived largely under such conditions. Our studies (e.g., Gupta 1989a, 1989b,1991a,1991b,1997a,1997b) have shown that many of the communities which conserve diversity have remained poor because of their superior ethical values. This happens when healers refuse to accept compensation for their services provided to individuals within and outside their community. Further, when they decide not to pluck more plants than is necessary for immediate use, they forego the opportunity of accumulating wealth by processing the herbal diversity in larger quantities and selling or dispensing it to others. At the same time, there are others, local people as well as large corporations (national as well as international), who have no hesitation in extracting biodiversity without taking care of regenerating the same. The challenge is to modify ethical positions that threaten biodiversity and, at the same time, to ensure improvements in livelihood prospects for indigenous peoples, through the implementation of the CBD. These communities will then continue to conserve biodiversity along with their associated ethical and cultural values.

The rate of erosion of local knowledge about biodiversity has never been so high as it is in the current generation in areas which did not go through large-scale annihilation of local tribal communities, as happened in many Latin American and African countries through the influx of missionaries. The factors which explain this include: the changing structure of families from joint to nuclear, consequently weakening links between the grandparents' generation (who have much of this knowledge) and the grandchildrens' generation (the parents' generation is alienated from this knowledge system already, due to the heavy influence of modernity); less esteem for this knowledge in primary school curricula; transition from oral to written culture; inability or unwillingness of many older healers and herbalists to share this knowledge or to agree to its transcription (or to do this themselves). Such unwillingness arises, in many cases, because outsiders, like ethnobiologists, have extracted the local knowledge, commercialized or published it without any attribution and reciprocity or benefit sharing, and have thus offended local communities.

Knowledge erosion is a threat as serious as resource erosion itself. Not only does it become difficult to locate what is useful or known, but incentives for conserving what is not known also go down. In ecological economic terms, the option values decline if the probability of finding something useful in the current generation is lower because of loss of knowledge about resources. Conserving biodiversity without conserving associated knowledge systems is thus like building and maintaining a library without a catalog. It is true that users of such a library might in fact develop a catalog over a long period of time, but meanwhile the users would suffer. By analogy, biodiversity users, without a knowledge base, will not benefit from centuries of experimentation and knowledge accumulation by local communities and indigenous people. It is true that formal scientific knowledge of plants and animals is diverse and rich. However, the bases upon which different communities have classified and organized their knowledge as well as practices, are similarly complex and dynamic.

There are three crucial assumptions underlying this perspective. First, not all knowledge, innovations and practices prevalent in a community are communal in nature. There are individuals who have great expertise in various aspects of local knowledge that are not known at all or known only partly to the local community. Second, not all the knowledge in use by a community is traditional in nature. There are many examples of contemporary innovations by local communities, developed collectively or individually. Third, local knowledge can be conserved perhaps in a more sustainable and dynamic manner (that is in a manner that it grows through constant experimentation and innovation rather than just maintained as a 'fossilized form' of historical knowledge, produced at one point of time and carried forward by succeeding generations) if the associated cultural values and ethical institutions contributing to conservation of biodiversity are also conserved and/or strengthened. The implications are obvious. Incentives for the conservation and sustainable use of biodiversity will have to be sufficiently flexible and diverse so as to provide for the growth and development of the traditional as well as the contemporary knowledge held by individuals and groups. The same or similar incentive structures or philosophical assumptions cannot provide adequate motivation to conserve what exists and to restore what is lacking. Devising appropriate incentives is challenging because many local communities lack access to some basic needs and are impoverished. Factors that have contributed to this linkage between high biodiversity and poverty are discussed by Gupta (1989a, 1991a, 1998b). SRISTI has noted the following factors:

- Biodiversity is high in the rainforests, mountains, some of the arid and semi-arid areas, and humid areas, primarily due to diversity in soil, climate and other physical and social structures.
- Poverty is high because markets are often unable to generate demand for diverse colors, tastes, shapes and qualities of natural products. Products of mass consumption, particularly when processed by machines, have low variability because throughput by machines has to be of uniform quality and maturity level (for instance, for processing tomatoes to make ketchup, local varieties are not suitable because these ripen unevenly and thus taste, color and flavor cannot be standardized). The cost of inventorying, transportation, display in shelves, etc., of a large number of varieties of, say, tomato is obviously quite high compared to that for one or a few varieties. Consumers who do not demand larger variety, either because they have not been exposed to it or are

unwilling to pay the extra costs, also contribute to lower demand of biodiverse products.

- The regions of high diversity also have very poor public infrastructure (in tandem with weak private market forces) because the people have limited surplus to attract public servants, and they are less articulate and organized to create political pressure (except through insurgent movements as is becoming evident from different parts of the world).
- The low demand for ecological and technological skills of these communities characterizes them as 'unskilled' labor fit for being a part of the urban slums or squatters. Once the knowledge system is devalued, cultural and social decline follow. The tenuous relationship with nature is ruptured. The ecological degradation spurred by various external resource extractors is aided and abetted by many poor as well as not so poor people for whom survival in the short-term seems possible only through ecodegrading strategies.

Thus, when demand for local biodiverse products (major items for the communities to dispose of) is low, exchange value is also low. Consequently, purchasing power is less and poverty is bound to follow. Supply of basic needs also gets constrained due to administrative and political apathy towards people in these regions, where population density is low and thus number of votes and other kinds of political pressures are less.

Incentives

To overcome many of the above constraints, four kinds of incentives have been proposed: individual-material; individual-nonmaterial; community-material; and community-nonmaterial (e.g., see Gupta 1991a, 1991b, 1995, 1997b). These can be conceived as a 2 x 2 matrix: individual/community *vs.* material/nonmaterial. Brief descriptions of these incentives follow.

Individual-material

These are rewards in material form, such as patents, copyrights or trademarks, user fees, royalty, monetary rewards, fellowships, land assignments or equipment, etc., given to individuals. These could arise from those who license technologies of herbal or animal-based recipes from local individuals or educational or research grants, etc.

Individual-nonmaterial

These rewards include: documentation; coverage in the press, TV and other media; public felicitation; invitations to lecture in schools, centers of learning and research; invitations to conferences and workshops, attaching the name of an innovator to the innovation (an incentive frequently used by local communities themselves, as photographs being placed in village or district councils); access to new skills, etc. SRISTI has been awarding the SRISTI Sanman (honor) for the last five years to outstanding innovators from the grassroots level.

Community-material

These incentives are relatively important. Rewards in material form, to communities or groups of people, help to convey the right signals for mobilizing the collective action that is so important for conservation. The instruments of such rewards could include: risk funds; trust funds; priority in the development of infrastructure such as schools, health care facilities, roads, etc.; free or easy access to databanks; access to external expertise; community awards; community grants; external aid in developing common property assets; marketing intervention for organic produce etc.

Community-nonmaterial

These incentives are rather difficult to implement but may have a durable impact, particularly when they change the values of the communities in a positive direction. Rewards include: policy changes to ensure greater control over local natural resources; removal o. perverse incentives to conservation (i.e., those that encourage nonsustainable use of resources); favorable policy environment for ecofriendly products; conservation practices; media attention; community awards; capacity building through transfer of technology; building up of negotiation skills; changes in pedagogy; and inclusion in curricula of lessons which raise social esteem for local ecofriendly practices and innovations etc.

The magnitude, manner and form of incentives or benefits may influence the degree of involvement of the local communities or individual innovators in future projects of biodiversity conservation. The following considerations apply:

- incentives can be in cash or kind, conditional (linked to research) or unconditional;
- community incentives can be direct or indirect in nature, and provided at one point in time or over an extended period;
- incentives can be provided by external agencies or by the local communities themselves (improved status of innovators, on account of social recognition, may or may not be associated with a greater say in decisionmaking at the societal level);
- incentives may focus on empowerment of local communities so that they may have better negotiating skills and knowledge for conservation of local resources. Alternatively, incentives may be targetted directly at conservation;
- incentives targetted at the community may lead to action at the community or individual levels.

The Relevance and Importance of Local Knowledge

Concern for local knowledge has been there for a long time. Verma and Singh (1969) asked a question about the continued relevance of indigenous knowledge, in the context of animal husbandry. The modern health system for human beings was quite weak. For animals it was even weaker. Local communities in many parts of the tropical developing world rely, even today, on local knowledge of animal husbandry. This is indicative that mainstream education and public policy still do not give due attention to the peoples' knowledge system. One implication of this is the downgrading of that knowledge system in the eyes of young people of the same community. Once esteem for local knowledge goes down, there are less incentives for young people to acquire that knowledge and to experiment and rejuvenate it. This leads to serious discontinuities in the intergenerational flow of knowledge. Once the "local experts", the older generation, are gone and there are no successors, the knowledge held in trust by those individuals for future generations is lost forever. Young people are not acquiring the skills of local experts because of a lack of incentives. However, some of these skills might lead to new career options; for instance, the skills of restoring the health of the degraded lands, waterbodies or forests as international conventions and their implementation gain momentum.

The failure of the state delivery system to consult local communities, including local experts, before implementing large-scale projects intended to benefit the rural poor, have often led to adverse impacts on livelihood and survival strategies of local communities. The existence of perverse incentives such as subsidies for non-sustainable technologies (e.g., free electric power in many Indian states leads to excessive withdrawal of groundwater and its inefficient use) has also blocked the efforts of local innovators and conservers who are interested in developing and promoting sustainable natural resource practices. The near absence of a legal and institutional framework to implement incentives for biodiversity conservation has led to overexploitation of diverse biological resources by the corporate sector, as well as by other users, without compensating indigenous peoples.

Knowledge systems for survival and sustainable biodiversity management

It has been generally believed that the knowledge systems of local communities and indigenous peoples are holistic in nature. Centuries of association with an environment have produced a deep understanding of the interrelationships among the different elements of a landscape or a habitat. Because fluctuations in the environment require adaptive responses, communities have developed a wide range of diversified survival strategies at intra and interhousehold levels and at community level. However, local and indigenous knowledge systems, while generally holistic, have some reductionist elements. In order to cope with the complexity of ecological change, some people in the community specialize by knowing more and more about less and less. Such specialized expertise requires focusing, targeting and steering strategies on specific themes or aspects of nature.

So-called western science is biased in favor of reductionist relationships, whereas local knowledge systems are biased in favor of systemic linkages and an holistic perspective on nature. Where efficiency of resource use has to increase, for coping with increasing population pressures (where applicable), scarcity, fluctuations in the environment, or other contingencies, a blending of formal and informal science may be necessary. Achieving sustainability in resource use requires the fusion of sacred with secular, formal with informal, and reductionist and holistic views.

The production of knowledge and its application takes place in a given socioecological context, through innovations over a long period of time. It has been suggested that this context influences and, to some extent, shapes the world views of people, which in turn influence the heuristics used for generating new solutions and knowledge (Pastakia 1995). The heuristics are like decision rules which also are accompanied by criteria of choice. Local and indigenous knowledge systems are not static. They evolve, adapt and transform dynamically with time. New materials are incorporated, new processes are developed and sometimes new uses or purposes are evolved for existing knowledge as well as the acquisition of knowledge. Hence, there is a need for rewarding not only traditional knowledge but also contemporary innovations. The concept of Traditional Resource Rights (Posey et al. 1995; Posey, this vol.), implying recognition of primarily customary rights, does not do full justice to the individuals who are responsible for contemporary creativity and innovation. Depersonalizing the process of knowledge production and reproduction, limits the type of incentives considered, and resources end up only in the hands of governments or, in rare cases, of local community leaders. Moreover, communities that have kept local experts poor, by not valuing their knowledge systems adequately, are unlikely to pass on to them externally-generated incentives. A homogeneity of local communities and a convergence between the interests of local community leaders and those of local experts are often assumed, but this is difficult to accept. The asymmetry in knowledge systems and related power differentials are apparent in discourses on incentives and consultations. These have been dominated by so-called representatives of indigenous communities, though of western origin, both in terms of numbers and ideas. For instance, in various consultations held by United Nations Environment Programme (UNEP) and by the CBD, the local communities are largely represented by the more articulate indigenous people from western countries. Many communities have suffered in the past and *they* should be heard. To anyone familiar with the miserable conditions in which most local communities live and strive to conserve biodiversity and associated knowledge systems, it should be obvious that their problems and concerns are very different from those articulated at most international fora. Moreover, the concerns of local experts and innovators within impoverished communities may be very different from those of the rest of the people. How can their concerns be heard and addressed?

Many international consultations and studies on knowledge systems have identified a need to distinguish among different types of knowledge and to recognize the need for building bridges between local or indigenous knowledge vis-à-vis formal scientific knowledge (e.g., Atte 1989; Berkes 1988; Gupta 1989a, 1991a, 1991b, 1995; Honey Bee Newsletters 1990-99; Warren and McKiernan 1995). Both formal and informal science are capable of producing abstract as well as practical knowledge, although the latter tends to produce more of the practical kind. Different incentives might nurture different types of knowledge. However, the same knowledge systems can pursue different functions simultaneously, in various combinations. For instance, a fishing community might use classificatory skills to deal with variations in the movements of fish and locations of spawning sites. It might use indicators for spotting sites where fish would be found in abundance at different times of the year. It might have to use systemic linkages to relate temperature, wind velocity, water turbidity and behavior of the fish, to decide how far to go in the ocean without courting too much risk or uncertainty. One way to understand the complexity of knowledge systems is to link the functions of nature with processes of sense making; i.e., drawing meaning from empirical observations. Berkes (1988) provided a strong argument for sensitivity in 'sense' making. He observed:

> "The traditional ecological knowledge of the Cree is empirical knowledge, as in the observations of the disappearance of animals in extremely cold weather, the way black bears try to cover their tracks before denning, the sensing and the avoidance of (predatory) otters by the fish. However, the 'sense' the Cree make of empirical knowledge is not scientific, mechanistic, or analytic... That is not to say that the Cree approach is either superior or inferior to the Western scientific one, but it is different...the Cree model of caribou cycles shows a better fit with the actual caribou population dy-

namic in Quebec–Ungava Peninsula than does the current scientific model."

Diversity, complexity, simultaneity and change in ecological systems are codified in knowledge and practices through language and culture. Just as Inuits are recognized as having the highest number of words for classifying snow, fishing communities have many words for distinguishing and discriminating different kinds of sea conditions, fish spawning sites, etc. (Johannes 1981). Conceptually, any community which is dependent upon a resource for its survival, has to develop a pattern or a set of categories to deal with variations in the availability of that resource. For example, farmers have a rich taxonomy for clouds and soils and, in some cases, for insects and other animals. Leather workers have taxonomy for leather, carpenters for wood and, likewise, fishing communities for water and aquatic life.

In the context of the CBD, its very important to understand and to appreciate that different indigenous and local communities develop knowledge systems through a tradition of invention and also develop languages through which to articulate their knowledge systems. If a language dies, a knowledge system partly or completely dies with it. Hence, conservation of language becomes a crucial factor for conserving taxonomies because each word, conceptually speaking in the context of a natural resource, is a category. Modern science will benefit a great deal and so will the ability of humans to understand their environment and cope with it, if the scientific basis for these categories is better understood. The etymological roots of different words might elucidate the process of codification of knowledge over time in languages, as influenced by exogenous knowledge systems migration, and wars and other social interactions. Palomares et al. (in press) provide an interesting study of local names of fishes in the Philippines, drawing upon FishBase (a database maintained at ICLARM). They present a rather counter intuitive insight that, in subsistence fisheries, 50% of species did not have Philippine names, whereas in the commercial category, almost 90% had such names. Since the number of species in the subsistence category was only 34, as against 455 in the commercial category, the difference may be explained by the possibility that subsistence category fish were not so crucial to survival of a community. But the commercial category fish were apparently very crucial; hence the variety of names.

Formal science, in its effort to generalize over large time and space boundaries, often masks finer categories. Indigenous or local knowledge systems (LKS) often do the opposite. LKS help to distinguish small variations in phenomena, and do so within relatively small habitats. The higher the extent of local fit of a resource management strategy in LKS with local environmental conditions, the less may be the negative externalities on the environment. But this also means an inability or limited ability of the local community to deal with wider connections. For the sustainable development of this planet, both telescopic and microscopic visions are needed: ability to see connections among larger systems and also to appreciate interconnections at microlevels; in other words, we need both reductionist science and an holistic vision. Functional and causal knowledge systems are different. Farmers have been known to do right things for wrong reasons. Their practices do not become invalid merely because a supposed causal connection has no known factual basis. Even in modern science, there are effective medicines for which the causal mechanisms came to be known only after a long history of use; e.g., aspirin. A knowledge system should not therefore be downgraded merely because of such limitations. Rituals and some symbolic totems may be ways of constraining particular healing strategies lest they be used in inappropriate cases, doses or situations. A marriage between local and exogenous knowledge, and between formal and informal science, will succeed only on the basis of reciprocal respect and a well-deserved restraint in exploring their logical bases. Hence, many local knowledge systems emphasize the questions that should not be asked rather than those that should be. Modern minds reject such boundaries to inquisitiveness, but the sacredness of certain kinds of knowledge rests on faith and its power. It is true that superstitions, particularly those that cause definite harm to local communities as well as those that generate other kinds of social or ecological biases, have to be tempered with a scientific attitude. It is not easy to determine when faith becomes a source of superstition. Thus, there is a great need to exercise care in understanding and especially in attempting to influence local conservation practices. In their attempts to unravel the mysteries underlying local faiths, outsiders can erode the power of local experts and institutions without putting anything better in their place. Reductionist knowledge by itself has rarely generated the social responsibility required to guide collective behavior towards conservation. The sacredness of certain sites, species and symbols must be respected even if modern minds find this incomprehensible or even irrational.

Production and reproduction of knowledge

The process of local knowledge production and reproduction may differ. Production of local knowledge can be through (1) discovery of problem-solving on a small scale or in an episodic manner, and (2) through interaction with wider knowledge systems, ranging from networking with kith and kin, to networking with external partners, etc.

In a dynamic knowledge system, some knowledge is lost when it becomes redundant on account of changing perceptions of needs, changes in access to resources, and changes in socio-ecological conditions. In a vibrant culture, much of the knowledge that is passed down from one generation to another depends upon social structures and the needs of changing times. Knowledge related to livelihood strategies is embodied in practice. Once the livelihood strategies themselves undergo change due to reduced or modified access to the underlying natural resources, as has happened in most developing countries, the LKS get fragmented and become inadequate to take care of a given resource in a sustainable manner. Cultural knowledge is embedded in rituals, folklore, art and other cultural and social artifacts and processes. Some other specialized forms of knowledge such as making nets or fish traps may be reproduced by local experts individually rather than at community level in a given community.

Knowledge that is embodied in practices usually takes the form of skills which are learned. Skills can be repetitive or non-repetitive. Judgmental skills are often scarce and individuals who possess such skills may become recognized as local experts. Examples of such judgmental skills are weather forecasting, judging the quality of diamonds (diamond polishing using labor intensive methods has grown into an important off-farm employment in many villages of Gujarat, India) cattle judging, and diagnosing human and animal ailments and problems of soils and lakes, finding potential sites with rich fish populations, etc.

Performance of indigenous knowledge

The performance of indigenous knowledge has been reviewed by Richards (1987). Performance from an indigenous perspective might include a number of criteria considered by formal science as less relevant: e.g., risk management, contributions to system maintenance, soil health, etc. The same practice could have different impacts on the natural resource base depending upon the criteria emphasized by a community while deciding the appropriateness of a practice in a given cultural and spiritual context. The values underlying the choice of criteria serve as a guide for dealing with each other (social equity) with nonhuman sentient beings, with nature (ecological responsibility) and with supernature (ethereal or spiritual beliefs). For instance, the bowhead whale, which was a protected species for 65 years, was allowed by the Canadian government in July 1998 to be killed for consumption as well as for ceremonial purposs by an Inuit community. The Bowhead Traditional Knowledge Study, coordinated by Keith Hay of the Nunavut Wildlife Management Board, revealed the existence of 350 bowheads rather than "few tens" believed by scientists. This number made permission to kill for ceremonial purposes one whale a year, quite sustainable. Such an approach has been gaining ground in Canada's public policy, observed Daniel Buckles of the International Development Research Centre (see New Scientist, 17 October 1998). Traditional knowledge embedded in culture and embodied in practice, serves as the mechanism to preserve and to pass on sustainable livelihood strategies to future generations.

Communities give expression to their belief systems, norms, values and ideologies through folk art, crafts and rituals, taboos, myths, symbols, etc. These values are also reflected in their livelihood strategies which are also closely woven with local institutions, social networks, kinship networks and knowledge systems.

The ecological context in a given region or for a given community defines the nature of environmental risks or threats. A drought, a flood, erosion of biodiversity or an increase in salinity levels are examples of threats. Regions that have low exposure to such threats are preferred by markets and are therefore at an advantage in land-based community strategies. Given the low trans-action costs of exchanging resources in these regions, the adaptive responses of their households are fast. Their social structures are also different from those of disadvantaged regions that have higher perceived or real exposure to risks or threats. In Table 1, the key contrasts that characterize the advantaged (market-dependent) and disadvantaged (nature-dependent regions) regions are summarized.

In market-dependent communities, most exchanges are mediated through markets. Commoditization of labor, products and skills is high. In contrast, nature-dependent communities draw their major sustenance through use of natural resources, often without much value addition. The regions where each type of community predominates are also contrasting. Market-dependent regions are the high growth, green revolution regions and commercial fisheries, while nature-dependent regions are rainfed drylands, hill areas or forest fringe areas and small-scale fisheries.

This contrast between nature-dependent and market-dependent communities is like comparing analogue and digital systems. Many local experts have a symbolic language through which they communicate their understanding of a problem. Many scientists and policymakers do not appreciate this basis of communication and jump to the conclusion that such expertise involves more 'mumbo jumbo' than actual skills. In some cases, this might be so, but to generalize this over entire packages of traditional knowledge in contemporary institutional contexts is quite unfair. The persistent neglect of traditional ecological and technological knowledge as well as the contemporary creativity of local communities and individuals should be avoided. Building bridges between knowledge evolved through several generations of interaction between humans and nature and the western scientific scholarship evolved over a few centuries will only enrich both. The fair trial of contemporary creativity by formal scientists will enlarge the repertoire of those institution builders who want farmers and fisherfolk to have low cost, nature friendly technologies coupled with institutional structures, restraining greed and unleashing respect for the rights of the unknown and unknowable, e.g., perfect strangers, like future generations.

Table 1. Comparison between market-dominated and nature-dominated regions.

	Market-dominated	Nature-dominated
Communication system	Digital	Analogue
Pooling of resources	Very low	Very high
Reliance on common property	Low	Very high
Settling of books of account	Very short-term	Long-term
Proportion of households headed or managed by women	Very low	Very high
Participation by women	Very low	Very high
Reciprocity	Specific	Generalized

Conclusions

Communities and individuals who have long conserved biodiversity have done so not entirely on the basis of an utilitarian logic. The efficiency of ethics may sometimes be tempered by the inefficiency of technology which local communities use. That is, while the local communities may not like natural resources to be exploited beyond their sustainable limits, they may use non-sustainable and inefficient technologies. Use of such technologies, in the wake of unfair competition with well equipped market forces, may lead them to use destructive technologies to catch fish, e.g., dynamite. Extractive uses of biodiversity can sometimes be less conducive to the long-term conservation of a species, even though the norms and values guiding the extraction may be very noble. This happens when poachers, combined with impoverished local communities, may bring a species to near extinction even though such local extraction may be much less than that done by outsiders. Once ethical values, cultural norms and belief systems become weak, the inefficiencies of extraction methods may start generating negative feedback effects. That is, the restraint for extracting diverse resources within their sustainable limits becomes weaker. The important point is that improvement in technical methods may not necessarily lead to evolution or restoration of ethical norms.

The challenge, thus, is to devise incentives that fulfill four conditions of sustainability: (1) access to biodiversity for local communities, to ensure their sustainable livelihood systems, should take priority over access for outside institutions or individuals; (2) assurance to individual healers, local experts, communities and other stakeholders of sustained access to the resources and viable collective responsibility for using biodiversity; (3) blending traditional skills/abilities to convert biodiversity resources into investments with or without value addition; and (4) conservation of cultural lifestyles and value systems in such a manner that basic needs are met without impairing the life support systems of local communities.

Unless arrangements are made for sharing value-added knowledge and benefits from value-added gains made possible by converting local knowledge into economically profitable investments or enterprises) and other learning made in the process, in local languages and in an easily understandable manner, the collectors have no ethical right to collect more of such knowledge. Codes of conduct for gene bank managers, researchers, funding agencies, and other development managers should provide for such sharing in an unequivocal manner. Local communities have already paid a heavy price because the designers of dams, hydropower projects, waterways, commercial prospectors of biological resources and landfill programs that have damaged wetlands, have ignored their knowledge and institutions. These communities must not be robbed of the only resource left with them, i.e., their knowledge.

Some concrete actions that can invigorate ongoing efforts to build upon local knowledge about aquatic resources are:

- Changes in methods and curricula at different levels, so as to incorporate insights from local innovations, ecological knowledge and institutions in education for conservation and sustainable use of biodiversity;
- development of a bold global program to document, disseminate (in local languages), experiment with and to add value to local knowledge, as, for example, in the Honey Bee Network;
- multimedia and multi-language databases on local knowledge, creativity and innovations to encourage people-to-people learning and also as an incentive to encourage local communities to share their knowledge;
- development of knowledge networks to link local creative communities, using various media, so as to help lateral consultations among the people, experts and policymakers;
- documentation of ecological indicators to monitor the health of aquatic ecosystems sharing this information among stakeholders and validating it through participatory research;
- prioritization of benefit-sharing mechanisms that build bridges between formal and informal knowledge systems, with non-monetary incentives given as much importance as monetary incentives, both for individuals and communities;
- incorporation of local knowledge in developing descriptors of aquatic germplasm.

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Discussion

Schei: I congratulate you on this presentation. Could you outline the sociocultural preconditions for a 'local system' to have control mechanisms that work– and when do these systems break down? Is it, for example, when Western cultures come in with money?

A. Gupta: I will answer with reference to forest and agrobiodiversity. When we were visiting herbalists in villages, we never met any young herbalists. So we asked, why are the young people not learning this? Why are they not interested whereas some other people know practically every plant in the forest? Second, we observed that most herbalists are extremely poor. We concluded that they don't charge for their services. Should this knowledge be conserved by keeping such people poor? And what incentives could be given to preserve this knowledge and to attract young people to acquire this knowledge? We have been thinking about having a kind of apprenticeship program. Fisherfolk know a lot about navigation, to return home everyday. This knowledge is also eroding and there must be incentives for young people to learn it: a system of rewards for individuals, not just communities. There should be an entrepreneurial approach here, to traditional knowledge and innovations. While a lot of people in a community may know some things, there are usually just a few who specialize in that knowledge. Without this specialization, the knowledge will be lost. It is essential to provide incentives to local experts.

Fowler: You have raised a number of questions about common and private property and about monetary and nonmonetary reward systems. At the international level, there is a range of agreements from binding to nonbinding (such as codes of conduct). Codes of conduct sometimes specify a relationship between a party (say, a researcher) and the state. Very often, such codes of conduct cover relationships with local people, including the 'etiquette' to be followed in dealing with them. This etiquette has to deal, very often, with systems of reward, recognition, respect, etc. By comparison, legally binding agreements, such as Conventions do not deal with relations at the local level. They do not incorporate codes of conduct. Moreover, they do not deal very much with nonmonetary benefits, despite all the talk about 'transfer of technology', etc. The rewards that they deal with are usually monetary. I wonder if you have reflected at all on the discrepancy and the conflict between codes of conduct (which are agreed by states and often refer to rewards that are nonmonetary) and Conventions (which are also agreed to by States, but which sometimes have provisions that are antithetical to those in codes of conduct).

A. Gupta: Most developing countries are facing this problem while drafting their biodiversity laws. Last week, we saw a draft law that dealt only with international access to biodiversity and did not deal with domestic access. We questioned this because a tribal person who is being exploited with respect to biodiversity can be exploited by international or national companies. There is, however, tremendous pressure from domestic companies on the government to exclude them from such provisions and responsibilities. The position became one of a 'codes of conduct' approach for domestic companies and 'regulations' for international companies. The argument was that domestic companies and researchers should be given time to adapt, because they have never had to face these issues before, whereas international companies and researchers have experience and must be subject to regulations right away. My own opinion is that there is some truth in this. Some domestic researchers have not even had any code of conduct. Further information on codes of conduct and ethical guidelines is available on our website. The American Society of Economic Botany has the best code of conduct that I could find. It has a provision that every researcher shall do all in his or her power to ensure that if the employers gain anything from the research, they must share part of the benefits with the communities from which the knowledge was taken. This is the strongest statement that I have come across in any such code of conduct or ethical guidelines. In India, we do not have such guidelines yet. At the meeting last week to which I referred, the Minister for Scientific Research undertook to bring the need for such codes of conduct to the next Indian Science Congress.

Mires: What are your views about intellectual property rights on aquatic genetic resources?

A. Gupta: My views on this are very unequivocal and I've argued this since 1988. I believe that a good intellectual property rights regime provides incentives for people to disclose what they know. Without IPR, 'trade secrets' become the order of the day–and trade secrets do not encourage research or value addition. I cannot build upon your research if you keep it secret. Intellectual property rights are not instruments of secrecy, they are instruments of disclosure. In my paper, I refer to INSTAR–the International Network for Sustainable Technology Application and Registration. A similar system has been mentioned in Brazilian law–a kind of reference file. Australia has developed a system in which eight-year protection is given, with five claims. Creative IPR systems provide incentives for people to disclose their knowledge and yet offer protection for a limited period.

Correa: This would be OK for knowledge that meets the requirements for patentability–but very little of the knowledge, generated by communities in developing countries can actually meet these requirements. If you look at the statistics, not more than 2% of the patents in the world originated in developing countries. There is a dramatic asymmetry here. The patenting system is not adequate to protect knowledge from different economics and societies. Your paper also refers to 'local ecological knowledge'. A driving concern in India and other countries seems to be the so-called 'biopiracy': the use of IPR, etc., not to promote local innovations, but rather to expropriate these. How, do you think, could IPR systems be changed, in international and national legislation, to accommodate these needs and to avoid negative effects?

A. Gupta: I did a review in December 1997 for the Pharmaceutical Congress. The Indian drug industry is a great opponent of a strong IPR regime. My role is to help them to see the opportunities. Last year, I analyzed, from the government's pharmaceutical database, about 4 000 patents on herbal drugs: 45% are owned by Chinese; 38% by Japanese; 16.8% by Russians and the remainder by the EU, USA and other countries. So, as far as local herbal knowledge is concerned, these patents have built upon that knowledge, not patenting the local knowledge itself (because it can be easily improved) but characterizing that knowledge and adding value to it. Biopiracy will continue as long as this knowledge is public domain. We accept private ownership of land, copyright in music and books. We respect rights of ownership throughout society– so why must the knowledge of local communities be public domain?–so that they can never bargain or negotiate contracts for return on this knowledge? Without IPR, there can be no value addition. For value addition, there must be some form of property rights. IPR is only one step in this direction. I would advocate that every country should have a national register for local knowledge. This would facilitate its wider use. Without this, the 'golden triangle' of innovator, investor and entrepreneur will never meet. This 'golden triangle' is where the benefits will actually come from.

Developments in the Legal Regimes Governing Aquatic Genetic Resources

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ABSTRACT

Aquatic biodiversity, as such, has lacked comprehensive treatment by lawmakers. The many types of threats to, and potential uses of, aquatic resources have tended to trigger their own legal responses. This paper analyzes a number of legal instruments that, directly or indirectly, influence the aquatic environment, using the Convention on Biological Diversity (CBD) as a framework for examining recent legal trends. Three of the five thematic areas of the Jakarta Mandate are reviewed–integrated marine and coastal area management; marine and coastal protected areas; and sustainable use of marine and coastal area living resources. In addition, the paper analyzes three recent international fisheries instruments–the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (the Compliance Agreement); the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (the Fish Stocks Agreement); and the Code of Conduct for Responsible Fisheries (the Code of Conduct). Together, these instruments reflect a new environmental orientation of legal instruments formulated within the overall framework of the 1982 Law of the Sea Convention (UNCLOS).

Introduction

The conservation, management and utilization of aquatic genetic resources is an immense subject, with a correspondingly diverse array of international and national laws that make up its legal environment. Aquatic biodiversity, as such, has lacked comprehensive treatment by lawmakers. Instead, the many types of threats to, and potential uses of, aquatic resources have tended to trigger their own legal response–sometimes complementary, sometimes overlapping. Thus, a full account of the legal aspects of aquatic biodiversity would include many legal instruments which individually are fairly narrow in scope; others that may have relevance for aquatic resources, while covering a far wider subject matter; and still others that may make no explicit reference to the subject at all, but may have importance for the role that they may play in controlling activities that directly or indirectly influence the aquatic environment (see also M.V. Gupta this vol.).

Categories of legal instruments of relevance to aquatic genetic resources therefore include a wide range of instruments dealing with a wide range of topics, for example:

- Conservation and exploitation of the sea;
- Fisheries and aquaculture;
- Identification and conservation of endangered species;
- Introduction and control of alien species;

- Creation and management of protected areas;
- Water pollution, whether from marine-or land-based sources;
- Navigation;
- Mineral extraction;
- Wetlands;
- Environmental management and land use within coastal areas;
- Climate change;
- Technology transfer and intellectual property rights;
- International trade.

It is beyond the scope of this paper to discuss all of these areas, as important as each may be in understanding the complexity of the legal framework that governs aquatic resources. Some of the specific issues–such as intellectual property rights are dealt with elsewhere (see Correa this vol.).

The purpose of this paper is rather to examine relatively recent trends in the design of broad legal approaches in this area. The Convention on Biological Diversity (CBD) provides a suitable framework with which to evaluate these trends. While dating back to 1992, the CBD's implications for aquatic biodiversity have become the subject of more elaborate attention only in the past few years when meetings of the CBD's Subsidiary Body for Scientific, Technical and Technological Advice (SBSTTA) have developed for the CBD's Conference of the Parties, a work program called the Jakarta Mandate on Conservation and Sustainable Use of the Marine and Coastal Biological Diversity. This was adopted at the Second Conference of the Parties of the CBD in Jakarta, Indonesia, 6-17 November 1995 (UNEP/CBD/SBSTTA/3/4 1997).

The Jakarta Mandate provides a useful tool with which to examine many of the legal considerations affecting the conservation and utilization of aquatic genetic resources within the marine and coastal areas. Three of the Jakarta Mandate's five thematic areas will be addressed, specifically, those concerning integrated marine and coastal area management; marine and coastal protected areas; and the sustainable use of marine and coastal living resources. Special attention will be paid to recent international fisheries instruments, such as the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 and the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks of 1995, also called the "Fish Stocks Agreement", that represent a new environmental orientation of legal instruments formulated within the overall framework of the 1982 Law of the Sea Convention (UNCLOS).

It should be noted that the emphasis in this paper is on marine and coastal biodiversity. The paper does not, therefore, address the complex of critical issues associated with the biological diversity of inland waters, many of which have distinct legal ramifications. Biological diversity of inland waters has been the focus of parallel processes under the umbrella of the SBSTTA, and was specifically considered by its Third Meeting in Montreal from 1 to 5 September 1997. The Executive Secretary's report discusses aspects such as identification and monitoring of the status of inland water biological diversity, impact assessment, access to and transfer of technology, institutional arrangements, capacity-building, financial resources and mechanisms which are important to analyze the situation of the biological diversity of inland waters with reference to the relevant articles of the CBD.

The Convention on Biological Diversity and Its Jakarta Mandate

The Convention on Biological Diversity (CBD) has three principle objectives, set forth in its first article. These are: (i) the conservation of biological diversity; (ii) the sustainable use of its components; and (iii) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources (Art. 1).

The CBD elaborates various obligations towards achieving these objectives. For example, Contracting Parties are required to develop national biodiversity strategies (Art. 6.a); to integrate biodiversity conservation and sustainable use of its components into sectoral and cross-sectoral plans, etc. (Art. 6.b); and to take steps to identify and monitor biodiversity (Art. 7). Under Article 8, countries are obligated to establish *in situ* conservation strategies. This includes the development of protected area systems (Art. 8.a); however, the obligation to regulate and manage "biological resources important or the conservation of biological diversity" applies both within and without protected areas (Art. 8.c), including such requirements as the maintenance of viable populations of species in natural surroundings (Art. 8.d).

The CBD is intended to deal comprehensively with the subject of biodiversity; as such, it does not tend to deal specifically with different types of resources. Thus, living aquatic resources are not singled out for special treatment in the text of the CBD but become the subjects of specific programs: the Jakarta Mandate for marine and coastal biota and another program that is under development for inland aquatic biodiversity. The CBD's obligations with respect to biodiversity apply generally whether or not the resource in question is marine, terrestrial or otherwise. Moreover, the CBD's Article 8 prescribes an ecosystem approach and this has been adopted for the Jakarta Mandate and other programs.

Nevertheless, there are several aspects of the CBD that should be highlighted within a discussion of its application to aquatic genetic resources. The first of these concerns the scope and jurisdiction of the CBD. Article 4 stipulates that the provisions of the CBD apply "(a) In the case of components of biological diversity, in areas within the limits of its national jurisdiction; and (b) In case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control, within the area of its national jurisdiction or beyond the limits of national jurisdiction." As it concerns the conservation of marine resources, therefore, the powers of Contracting Parties to make comprehensive rules are limited to the marine areas falling within national jurisdictions. On the high seas, however, Contracting Parties do have the power and responsibility to control the "activities and processes" of their nationals. With respect to such areas beyond national jurisdictions, Article 5 requires Contracting Parties to cooperate "directly or, where appropriate, through competent international organizations... for the conservation and sustainable use of biodiversity."

An important related provision is found in Article 22. Paragraph 2 of that Article states that "Contracting Parties shall implement this Convention with respect to the marine environment consistently with the rights and obligations of States under the law of the sea." This paragraph is interesting, in part because it constitutes an exception to the general rule set forth in the preceding paragraph, namely that rights and obligations under existing international agreements could be overridden to the extent that they would "cause serious damage or threat to biological diversity" (Art. 22.1). By contrast, the "law of the sea" (which is understood to mean both customary international law concerning the sea and UNCLOS) takes precedence, (Glowka et al. 1994). This is important because UNCLOS and related agreements are highly significant with respect to the sustainable use of marine biodiversity.

It is important to recognize that the CBD is a framework agreement. The details of its implementation are, for the most part, left to Contracting Parties to handle through domestic legislation or in further regional and international agreements. Indeed, from a lawyer's point of view, the CBD is impressive both for its comprehensive scope and, on the other hand, for the extensive amount of legal work that it leaves to be done elsewhere. It may be, as the CBD Secretariat states, that the CBD "is unique in the sense that it is the only multilateral, legally binding instrument that covers all the world's ecosystems, thereby taking a comprehensive rather than sectoral approach" (UNEP/CBD/SSSTTA/3/4 1997). The job of giving detailed, substantive legal content to this multisectoral vision, however, will be the task of laws and agreements drafted on specific subjects, often shaped by the perspectives of particular sectors.

In order to implement the Jakarta Mandate, there have been further meetings of the SBSTTA, and a Meeting of Experts on Marine and Coastal Biological Diversity took place in Indonesia in March 1997 (UNEP/CBD/JM/Expert/1/5. 1997).

This paper will not discuss the Jakarta Mandate activities in depth, but its five themes, set forth in SBSTTA recommendations, provide a useful organizational device for reviewing the current state of law with respect to aquatic genetic resources. These five thematic areas are: (1) integrated marine and coastal area management; (2) marine and coastal protected areas; (3) sustainable use of marine and coastal living resources; (4) mariculture; and (5) alien species.

This paper examines the legal frameworks and some outstanding legal issues that arise in the first three of these five thematic areas. Due to the prominence given to international fisheries instruments in the following discussion, the thematic areas of the Jakarta Mandate have been reordered so that the issue of sustainable use of marine and coastal living resources (area 3) is addressed first. Thematic areas 4 and 5 are not addressed, though each is of course the subject of an expanding literature in its own right (see, for example, de Fontaubert et al. 1996, and citations therein.)

Sustainable Use of Marine and Coastal Living Resources

Conventions and agreements

This section and the following two sections, of the relevant parts of the Jakarta Mandate are based on the work of de Fontaubert et al. (1996). Under the Jakarta Mandate, the parties to the CBD are urged to take a number of steps in their national plans and programs with respect to marine and coastal living resources. Some of these steps are summarized by de Fontaubert et al. (1996) as:

- Ensuring that management decisions are based on the precautionary approach and best available and sound scientific knowledge, research and information, taking into account ecosystem impacts;
- Ensuring that there is national legislation that is in conformity with UNCLOS, Agenda 21 and the Convention on Biological Diversity;
- Following the provisions of the FAO Code of Conduct for Responsible Fisheries;
- Acceding to and implementing existing international agreements on the overexploitation and conservation of marine and coastal resources, especially the Agreement for the Implementation of the Provisions of United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks;
- Ensuring that monitoring mechanisms are used or established;
- Identifying constraints, including economic, for conservation of fishing gear and phase-out of fishing overcapacity, and considering the possibility of reducing subsidies for fisheries.

The privileged place of "law of the sea" (UNCLOS) under the CBD has been mentioned above. Nevertheless, it is worth emphasizing again that the CBD itself pays no special or detailed attention to aquatic biological resources. As Freestone (1996) has noted, it is

> "paradoxical that, although the particular problems of conservation of many marine creatures, particularly pelagic creatures, make them particularly suitable to regulation at an international level under a treaty on biological diversity, in fact the most important discussions concerning conservation of marine biological diversity are currently taking place in the context of other forums."

Relevant developments in these "other forums," namely the treatment accorded conservation issues in UNCLOS and in several notable instruments negotiated within the framework that it provides, are reviewed briefly here.

UNCLOS

Prior to UNCLOS, the Geneva Convention on Fisheries and Conservation of the Living Resources of the High Seas Geneva Convention (1958) recognized, in its Article 2, the freedom of fishing on the high seas, limited only by "reasonable regard to the interests of other States in their exercise of the freedom of the high seas." The general and limited obligations of this Convention with respect to conservation are framed by a definition of conservation that focuses on obtaining an "optimum sustainable yield... so as to secure a maximum supply of food and other marine products." In other words, conservation is defined primarily in terms of meeting the consumption needs of humankind.

Like this 1958 Geneva Convention, UNCLOS recognizes the right to engage in fishing on the high seas (Art. 116). However, this right is now couched in various environmental obligations that, in the words of Freestone and Makuch (1996), "radically changed the legal regime for marine fisheries conservation, management, and exploitation."

With respect to the high seas, States are now under the duty to take measures for their respective nationals for conservation of living resources (Art. 117). States shall cooperate with each other with respect to such resources, and in particular shall enter into negotiations where their nationals are exploiting "identical living resources, or different living resources in the same are... with a view to taking the measures necessary for the conservation of the living resources concerned" (Art. 118). Article 119 supplants the "optimal sustainable yield" concept of the 1958 Geneva Convention with a more complex formula centered on the calculation of "maximum sustainable yield." For determining allowable catch and taking other conservation measures, States are now obligated to:

"(a) take measures which are designed, on the best scientific evidence available to the States concerned, to maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors, including the special requirements of developing States, and taking into account fishing patterns, the interdependence of stocks and any generally recommended international minimum standards, whether subregional, regional or global;
(b) take into consideration the effects on species associated with or dependent upon harvested species with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened."

Aside from its injection of explicit environmental considerations into the international fisheries framework, UNCLOS addresses marine environmental concerns more generally. Article 192 creates an unambiguous obligation on all states "to protect and preserve the marine environment." States are obligated to take measures for the prevention, reduction and control of pollution of the marine environment from whatever source (Art. 194.1). Pollution is defined widely to include not only the release of toxic, harmful or noxious substances, releases from vessels, etc.; significantly, pollution also includes the "international or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto" (Art. 196). Equally significant from the perspective of biodiversity conservation is the obligation "to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life" (Art. 194.5).

Other relevant fisheries agreements

Two international fisheries agreements, completed within the last five years, deserve special mention as extensions to the overall approach to environmental matters set forth in UNCLOS, although at present neither one has come into force. The first of these is the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, approved at the Twenty-seventh session of the FAO Conference, under Article XIV of the FAO Constitution on 24 November 1993 (the "Compliance Agreement"). The practice of reflagging vessels as a means of avoiding compliance with applicable conservation and management rules for fishing on the high seas was highlighted by Agenda 21 Chapter 17. Under the Compliance Agreement, parties are obliged to take such measures as may be necessary to ensure that vessels flying their flags do not engage in activities that undermine the effectiveness of international conservation and management measures. They may not allow any of their flag vessels to fish on the high seas unless they have been specifically authorized to do so by the competent national authorities. Parties must make it an offense under their national laws to fish without such authorization or in contravention of international conservation and management measures.

The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (the "Fish Stocks Agreement") has been called "the first global fisheries agreement to recognize at a primary level the environmental significance of fishing activities (Freestone and Makuch 1996). The objective of this Agreement is "to ensure the long-term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks through effective implementation of the relevant provisions of (UNCLOS)" (Art. 2). This Agreement, as its title implies, is intended to give practical effect to Articles 63 and 64 of UNCLOS which deal with straddling stocks and highly migratory species. Prominent in this Agreement's Preamble is the recognition of "the need to avoid adverse impacts on the marine environments, preserve biodiversity, maintain the integrity of marine ecosystems and minimize the risk of long-term or irreversible effects of fishing operations."

Because of the important innovations contained in the Fish Stocks Agreement from a biodiversity perspective, its provisions are worth summarizing here in some detail. The Agreement sets out, in its Article 5, general principles on the basis of which conservation and management measures are to be established for straddling fish stocks and highly migratory fish stocks. Many of these are drawn from Article 61 of UNCLOS. These principles are to be applied in the Exclusive Economic Zone (EEZ) as is already required by Article 61 and now, through the Agreement, they are also to be the basis for conservation and management measures in the adjacent high seas areas.

The measures taken must secure long-term sustainability of straddling fish stocks and highly migratory fish stocks. They must be based on the best scientific evidence available and must be designed to maintain and restore stocks at levels capable of producing maximum sustainable yield (Art. 5.a). States are required to collect and share, in a timely manner, complete and accurate data concerning fishing activities, such as vessel position, catch of target and nontarget species and fishing effort, as well as information from national and international research programs (Art. 5.j).

Conservation and management measures for fisheries can only be effective if they are complied with; which implies that there must be effective enforcement. Article 18 sets out the duties of the flag States and essentially repeats the Compliance Agreement except for the restrictions on authorizing reflagged vessels. The Agreement permits a State to authorize the use of a vessel flying its flag for fishing on the high seas only where such State is able to exercise effectively its responsibilities in respect of such vessel. The basic duties of flag States include requirements that vessels are issued with licenses, authorizations or permits, are marked in accordance with FAO Standard Specifications and record and report vessel position and catch of target and non- target species. Flag States are required to implement inspection schemes and observer programs and to regulate transshipment on the high seas to ensure that the effectiveness of conservation and management measures is not undermined.

The enforcement provisions of the Fish Stocks Agreement are contemplated in Part VI and, in many respects, significantly extend the boundaries of existing international law. Under Article 19, flag States are required to ensure compliance and, to this end, to enforce conservation and management measures by investigating alleged violations and, if evidence so warrants, taking appropriate enforcement action. States are required to cooperate to ensure compliance with and enforcement of conservation and management measures for straddling fish stocks and highly migratory fish stocks including taking cooperative action to deter vessels from fishing on the high seas until such time as appropriate enforcement action is taken by the flag State (Art. 20).

Article 22 provides the basic procedures for exercising the powers under Article 21 unless the regional fisheries body agrees on its own procedures. This Article requires flag States to ensure that vessel masters cooperate, and if one refuses to do so, to suspend the vessel's authorization to fish and order the vessel to return to port. Measures taken by a port are dealt with in Article 23. It allows port States to inspect fishing vessels, which are voluntarily in its ports or at offshore terminals as well as to take measures to prohibit landings and transshipment of catches collected in a manner that undermines international conservation and management measures on the high seas.

The FAO Code of Conduct for Responsible Fisheries and related instruments

The FAO Conference, at its Twenty-eighth Session on 31 October 1995, adopted a Code of Conduct for Responsible Fisheries along with Resolutions 4/95 and 5/95 calling on FAO, States and all those involved on fisheries to implement the Code. The Code is a voluntary instrument and a key one in that it deals with *inter alia* fisheries management and development, embracing conservation and environmental issues and taking into account social and economic considerations. The Code also constitutes an important contribution to the implementation of relevant international instruments, because it was formulated to be interpreted and applied in conformity with the relevant rules of international law. It is a comprehensive document that addresses all those involved in fisheries and applies to all types of fisheries, both within the EEZ and on the high seas, in inland waters, as well as aquaculture. In addition to its general principles, six of the Code's articles address substantive technical areas including fisheries management, fishing operations, aquaculture development, integration of fisheries into coastal area management, postharvest practices and trade and fisheries research. Moreover, the Compliance Agreement, approved at the Twenty-seventh session of the FAO Conference, under Article XIV of the FAO Constitution in November 1993, is an integral part of the Code. To assist those concerned with the implementation of the Code's technical principles, and in support of other specific issues that will need to be addressed in the course of implementation, technical guidelines are being developed by FAO as called for by the FAO Conference.

Both the Code of Conduct for Responsible Fisheries and the Fish Stocks Agreement include the concept of the precautionary approach to fisheries management. In the Code there is a specific requirement that:

"States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and not-target species and their environment" (Art. 6.5).

In addition, Article 7.5 of the Code provides more detailed guidance on the application of the precautionary approach in fisheries, while the implementation of the approach in practical terms is addressed in the appropriate guidelines (specifically, the FAO Technical Guidelines for Responsible Fisheries, 1996). The Code envisages that the precautionary approach will be applied in all fisheries, in all aquatic systems, and regardless of their jurisdictional nature, recognizing that many problems affecting the sector result from insufficient application of the precautionary approach faced with high levels of uncertainty. Because uncertainty affects all elements of a fishery in varying degrees, some degree of precaution is required at all levels of the system; in development planning, management research, technology development and transfer, legal and institutional frameworks, fish capture and processing, fisheries enhancement and aquaculture.

The Fish Stocks Agreement includes the precautionary approach in Article 6, to be applied widely to conservation, management and exploitation of straddling fish stocks and highly migratory fish stocks in order to protect the living marine resources and preserve the marine environment. The Agreement's Article 6.3 (b) states:

"In implementing the precautionary approach States shall: apply the guidelines set out in Annex II and determine, on the basis of the best scientific information available, stock-specific information available, stock-specific reference points and the action to be taken if they are exceeded."

The Agreement provides, in Article 3, that the precautionary approach shall be applied also to the conservation and management of straddling fish stocks and highly migratory fish stocks within areas under national jurisdiction as well as on the high seas. This demonstrates the importance attached to the precautionary approach.

The Fish Stocks Agreement, especially when read in conjunction with the Compliance Agreement and the Code of Conduct, has ushered in a new era of environmental emphasis in international fisheries law. In the words of Freestone and Makuch (1996):

"Environmental issues have been present in fisheries agreements before. What is new and innovative is the way in which marine biological diversity and ecosystem protection concerns are introduced as equal factors to food production; sustainability in the Agreement is to be read in ecosystem and biodiversity maintenance terms, rather than, as before, in terms of consistent food supply."

Integrated Marine and Coastal Area Management (ICAM)

International scope

Under this thematic area of the Jakarta Mandate, the following points are made (de Fontaubert et al. 1996):

- Integrated Marine and Coastal Area Management (ICAM) is the most suitable framework for addressing human impacts and impacts of land-based activities on marine and coastal biodiversity.
- Governments need to establish or strengthen institutional, administrative and legislative arrangements for ICAM.
- ICAM should be based on precautionary ecosystem management approaches and best management practices.
- Environmental impact assessment (EIA) should be used to assess all major coastal and marine development activities.
- The impacts of land-based activities on marine and coastal biological diversity should be assessed and addressed in cooperation with the implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities.
- Current sectoral approaches have proven generally

inadequate for the management of marine and coastal resources.
- ICAM should address the socioeconomic needs of coastal communities.

The broad scientific and policy rationales for adopting an ICAM approach are well-known and persuasive. ICAM focuses on the sea-land interface, giving explicit recognition to the influences that work back and forth across this interface and adopting an ecosystem management approach. Agenda 21 gives powerful impetus to the development and adoption of such an approach at national and international levels. Its Article 17.6 urges each coastal state to:

> "... consider establishing, or where necessary strengthening, appropriate coordinating mechanisms (such as a high-level policy planning body) for integrated management and sustainable development of coastal and marine areas and their resources, at both the local and national levels."

ICAM does have international law implications, because many important coastal/marine ecosystems cross national boundaries. In addition to Agenda 21 and the CBD, both UNCLOS and the abovecited Global Programme of Action prepared by the Intergovernmental Conference to Adopt a Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (Washington, 23 October-3 November 1995) (de Fontaubert et al. 1996), provide important international support to the integration of marine and coastal ecological concerns into the planning and implementation of land-based activities, and call for cooperation among countries in this regard.

National and sectoral aspects

From a legal and institutional point of view, the international challenges perhaps pale in comparison to the tremendous jurisdictional constraints to the adoption of ICAM at the national level in most countries. Planning and management expertise and perspectives are traditionally bounded, both conceptually and jurisdictionally, by the coastline. Everything that happens on either side of that line falls within the competence of different agencies with different orientations, professional expertise, policy agendas, etc. Yet, within this broad divide, there are many more divisions that need to be taken into account: well-entrenched, legally reinforced sectoral divisions between fisheries, water management, agriculture, forestry, urban planning, wildlife management, mining, waste management, industries, transportation and many others.

As a recent study by FAO's Legal Office argued, to address these constraints, and to give realworld meaning to sensible but elusive concepts, such as 'integration' and 'cross-sectoralism', will require (among other things) the substantial redesign of the legal framework in which the management of coastal resources currently takes place (Boelaert-Suominen and Cullinan 1994). Although there are many potential legislative designs (and there will be vast differences in the approaches that will work in different countries), Boelaert-Suominen and Cullinan (1994) identified the following broad principles that need to guide the development of a legal framework for ICAM:

- The legislation needs to be comprehensive; that is, it needs to be broad enough in scope to encompass: (1) the geographical area relevant to ICAM (geographical jurisdiction); (2) the institutions with power to control coastal resources (jurisdiction over legal persons); and (3) the subject matter necessary to achieve ICAM (e.g., environmental quality and protection, economic development, living resources, etc., in relation to both the terrestrial and aquatic elements of the coast).
- The legislation needs to adopt an holistic approach, both from a substantive and procedural point of view; that is: (1) the substantive rights and duties created by the law need to be in accordance with overall policy objectives, such as preservation of ecosystems; and (2) the procedural law provisions (e.g., setting out how conflicts between competing resource users will be resolved and who will be involved in planning decisions) need to ensure that all material information will be considered and that holistic as opposed to sectoral criteria will be used in decisionmaking, such as in the granting of development permits.
- The legislation needs to provide for consistency; that is, there need to be mechanisms for ensuring that the legal rules and norms applied by different institutions and at different levels in the governmental hierarchy will be consistent.

Following Agenda 21, more countries are working on addressing coastal areas in a more integrated fashion in their legislation, starting to look beyond the land/sea divide that still characterizes most existing legal frameworks. The FAO Legal Office is in the process of updating its most recent publication on this issue (Boelaert-Suominen and Cullinan 1994). This remains, however, a relatively new area with few existing models actually up and operating and with little evidence yet of how such legislation might work in practice.

Marine and Coastal Protected Areas

Scope and context

Under the Jakarta Mandate, marine and coastal protected areas must be seen within the larger framework of integrated marine and coastal area management; hence, while there are obvious linkages between ICAM and all of the Mandate's thematic areas, the linkages with protected areas may be particularly strong. In stressing the importance of protected areas for conserving and managing marine and coastal biodiversity, the Jakarta Mandate lists a number of considerations, including the following:

- Conservation measures in the context of protected areas should emphasize the protection of ecosystem functioning, in addition to protecting specific stocks.
- Parties should explore means to incorporate marine and protected areas within a broader framework for multiple use planning.
- Local communities and resource users should be encouraged to participate in the planning, management and conservation of coastal and marine protected areas.
- All three levels of biological diversity–ecosystem, species and population, and genetic–should be considered in developing management plans.
- Parties should establish or consolidate representative systems of marine and coastal protected areas and enhance linkages and information exchanges among the sites.

International programs and conventions

Since 1986, IUCN's Commission on National Parks and Protected Areas has been promoting the establishment of a global system of marine protected areas (MPAs). In addition to the references to such areas in the CBD, at least two other international conventions-one dealing with protected areas generally, and one dealing with them in the context of wetlands-deserve mention here.

First, the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage (1972) protects both "cultural heritage" (physical and biological formations and areas) which are of "outstanding universal value." Parties to this Convention commit themselves to do "all (they) can" to accomplish the goals of: identification, protection, conservation, presentation and transmission to future generations of cultural and nature sites (whether listed or not). To this end, a party must act "to the utmost of its own resources and, where appropriate, with...international assistance and cooperation."

Each state, in fulfilling these commitments, shall endeavor:

"(a) to adopt a general policy which aims to give the cultural and natural heritage a function in the life of the community and to integrate the protection of that heritage into comprehensive planning programmes;

(b) to set up within its territories, where such services do not exist, one or more services for the protection, conservation and presentation of the cultural and natural heritage with an appropriate staff and possessing the means to discharge their functions;

(c) to develop scientific and technical studies and research and to work out such operating methods as will make the State capable of counteracting the dangers that threaten its cultural or natural heritage;

(d) to take the appropriate legal, scientific, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage; and

(e) to foster the establishment or development of national or regional centres for training in the protection, conservation and presentation of the cultural and natural heritage and to encourage scientific research in this field."

Second, the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971) is designed to regulate the deterioration of wetlands by human activity (drainage, pollution or saltwater intrusion). For this Convention, the term "wetlands" includes swamps, bogs, salt-water marshes and other wet areas, including marine areas with a depth at low tide of 6 m or less. This Convention requires the member states to:

- designate areas for listing as wetlands of international importance (based primarily on their use by waterfowl). A state is required to list at least one wetland, by submission of a precise decision or map at the time it becomes a party to the Convention;
- promote conservation of listed wetlands;
- promote conservation of unlisted wetlands; and
- promote the conservation of waterfowl.

In addition, the Convention require parties to protect nonlisted wetlands "by establishing nature reserves...and providing adequately for their wardening." Loss of wetlands should be avoided and minimized. Where all or part of listed wetlands is lost, other areas should be listed and protected in its stead (Young 1993). It is also important to note that whereas the Ramsar Convention has historically used criteria for listing sites, based upon their importance to birds, fish are now recognized as a basis for listing new sites (Ramsar Convention 1996).

Moreover, in the international context, mention should be made of the Guidelines for the Designation of Special Areas and Identification of Particularly Sensitive Sea Areas (PSSAs), adopted by the General Assembly of the International Maritime Organization (IMO) in 1991. At the time that these Guidelines were adopted, the Great Barrier Reef was selected as the first PSSA. Since then, no additional PSSAs have been selected (de Fontaubert et al. 1996) although Agenda 21 calls on States "in cooperation with IMO, to take proactive steps to identify rare and fragile marine ecosystems as well as the habitats of vulnerable marine species, and to ensure that measures are taken to minimize, to the fullest extent possible, the threat of pollution from vessels in these areas."

MPAs at national level

As important as the international legal context is, designing the detailed legal framework necessary to support the creation and management of marine protected areas (MPAs) will largely be a matter for national legislation. In approaching this task, countries are typically drawing upon two established bodies of legal doctrine. First, the overall protection of marine resources has typically been the job of fisheries legislation, assisted by general environmental laws. At the same time, the 'park' and 'reserve' aspects draw heavily from well-established legal models for protected areas. These models, however, have evolved mainly in the context of the development of terrestrial protected areas. How appropriate these models are for the aquatic environment remains a matter of debate (Leria 1996). Some observers have concluded that the terrestrial concepts of national parks and protected areas can be transferred quite easily to the marine context. They argue that such issues as buffer zones, participative management planning, involvement of local resource-dependent communities, the recognition (where appropriate) of indigenous rights, and the management of tourism all arise in the context of MPAs, just as they do in terrestrial protected areas. Other observers, however, stress that there are more differences than similarities and caution against transplanting land-based legal models to the marine context. These debates are summarized in Beurier and Le Morvan (1980) and du Saussay (1980).

There does seem to be a trend away from the legislative practice of burying marine protected area legal provisions within a country's general fisheries legislation. This practice has had the effect in the past of creating the impression that marine protected areas were somehow lesser entities than their terrestrial counterparts. It has also tended to mean that the legal framework for MPAs has been thin at best, without the elaboration of procedures, rights and duties that one finds, for example, in modern land-based national parks legislation.

An example from Tanzania

An interesting example from a developing country of legislation dealing specifically with MPAs is the Tanzania Marine Parks and Reserves Act No. 29 of 1994. In many respects, this Act is far more advanced than the antiquated laws that still govern Tanzania's land-based parks, particularly with respect to biodiversity conservation and community management. Among the purposes of this Act are, in its Section 10:

"(a) to protect, conserve and restore the species and genetic diversity of living and non-living marine resources, as well as the ecosystem processes of marine coastal areas;

(b) to ensure that the villages and other local resident users in the vicinity of, or dependent on a marine part or marine reserve are involved in all phases of the planning, development and management of that marine park or marine reserve, share in the benefits of the operation of the protected area, and have priority in the resource use and economic opportunity afforded by the establishment of the marine park or reserve."

This Act goes on to detail the powers, duties and institutional structure of the Marine Parks and Reserves Unit (Sec. 3), and provides for the appointment of the Board of Trustees to provide policy guidance (Sec. 4). Every protected area under the Act requires the adoption of a General Management Plan (GMP) (Sec. 14), and no activities, rights, licenses, etc., may be undertaken or granted unless they are compatible with the GMP (Sec. 13). The GMP may, among other things, designate zones within an MPA subject to different degrees of protection, and within which different activities are prohibited, restricted or controlled (Sec. 17). Finally, substantial provisions deal with the procedures for local community input into planning, participation in management, sustainable utilization of the resources in the MPA, etc. (Secs. 8, 18 and 19): For an excellent account of the background to and rationale for this Act, see Young (1993).

Sectoral aspects

It should be emphasized that where MPAs are intended to encompass both a water and land component–which, in the spirit of ICAM, one might expect frequently to be the case sectoral issues are likely to arise that are similar to those that arise in the ICAM context. Where legislation places the responsibility for MPAs in the fisheries sector, there may be real difficulties in practice in using that legislation to create mixed-resource protected areas, spanning the land-sea divide. Similarly, if the power to create MPAs is placed with the authority that traditionally deals with protected areas–often a forestry department or a national parks authority with a long-standing terrestrial focus–that authority may logically conclude that it does not have the capacity or expertise to deal with offshore matters, and may be reluctant to use the new power vested in it. In short, effective national legislation is likely either to require the establishment of a new entity–free-standing or part of an existing agency–that has competence in these types of protected areas, or a clear framework for intersectoral collaboration between interested agencies.

One interesting issue is the relationship between on the one hand, the establishment of MPAs and the restriction of activities within their boundaries, and on the other freedom of navigation under UNCLOS. Some type of restriction on navigation would, seem in practice to be the most effective way of preventing damage due to dumping, "as the no-dumping rule is extremely difficult to enforce except where the culprits are caught red-handed which is of course infrequent" (de Klemm 1993). The laws of a number of countries-Malaysia and Italy, for example–allow for the imposition of such restrictions in protected areas, and there seems to be no reason why such restrictions could not be seen as compatible with a country's obligation to protect the marine environment under UNCLOS, at least within internal waters and territorial seas. As de Klemm (1993) points out, the situation is different with respect to the EEZ, where no restrictions on navigation as such are allowed. However, countries still have the power within the EEZ to control fishing and activities that affect the sea-bed, as countries have sovereign rights over all living resources and all resources of the continental shelf, living or nonliving (de Klemm 1993).

Conclusion

As even this brief review of selected topics indicates, legal regimes governing or affecting the management, conservation and use of aquatic genetic resources are complex and multidimensional. At the national level, there are seldom comprehensive legislative attempts to deal with the subject. Instead, relevant provisions, having either direct or indirect importance for the aquatic environment, are most often scattered amongst distinct bodies of sectoral legislation. Even within the realm of international law, we have seen how some of the most important legal innovations concerning marine biodiversity have developed within the framework of sectoral instruments such as the Fish Stocks Agreement.

Broad thematic templates, such as that provided by the Jakarta Mandate, help to provide a way of categorizing and understanding the interrelationships of the many strands of law that affect aquatic biological diversity. But this also underlines a rather obvious challenge to the creation of more effective legal frameworks (a challenge that is not, incidentally, unique to this area of law). Different laws are written at different times, guided by different levels of relevant expertise, and often driven by sectoral agendas in which the concerns of aquatic biological diversity may be more or less prominent, indeed sometimes relegated to a secondary role or sometimes missing altogether. The creation of appropriate national and international legal regimes requires a recognition of this frequently ad hoc, mutiple-agenda nature of law making, and the need, therefore, to pursue policy coherence on many scattered fronts at once.

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Discussion

Smith: Thank you for a thorough review of this complex subject. On international agreements, there are still big problems with enforcement; for example, that for the Conservation of Aquatic Living Marine Resources and, in particular, the toothfish stocks. For these, the catches are probably about ten times the recommended quota. We have evidence of signatory countries reflagging vessels and nonsignatory countries also fishing there and defying all attempts to regulate the fishery. I don't know what this group can do to look at other forms of enforcement, to ensure that international conventions can be sustained, before fish stocks completely collapse.

Leria: I agree. Sometimes, international instruments are very good on paper but, even if ratified, they are not always implemented. The solution might be for countries to cooperate more on enforcement. But they are sovereign countries and they do what they like. I don't know what else to suggest. It is difficult enough to go for conservation in EEZs, so what about the high seas?

A. Gupta: Mutual dependence is good for enforcement. Also, if there are public watchdog groups, as for the issues concerning whaling by Norway and Japan, this helps enforcement. Then people have to explain their actions. This is what the Rural Advancement Foundation International (RAFI) did over the plant genetic resources issues.

Correa: The United Nations Conference on the Law of the Sea (UNCLOS) contains some interesting provisions on access and sharing of benefits–for example, the sharing of benefits from the results of scientific research for coastal states. These could be considered as precedents for the provisions on benefit-sharing of the Convention on Biological Diversity . I'm not sure to what extent the negotiators of the CBD were aware of these UNCLOS provisions, some of which are very specific on access and on sharing "one quarter of the benefits". My question is–do you have any information as to how these rules on access and the sharing of benefits of research have been applied? Has any national legislation implemented these provisions? If not, would it be useful to undertake a study on this?

Leria: I do not know of any specific examples of such national legislation, but this should be under development because UNCLOS is regarded as binding by many countries.

Schei: One of the problems is that these issues are still decided by seeking consensus rather than by applying democratic rules for managing the world. Unless liability provisions and enforcement are introduced at the global level, these problems will not be solved. We have global instruments but we have not globalized the institutions. There is also a need for a mechanism for resolving conflicts between legal instruments; for example, the GATT and the CBD. They have conflicting objectives. There is now a fight about under which of these instruments should intellectual property rights be dealt with. A conflict-solving mechanism is much needed.

Leria: Well, a consensus is needed for an international instrument. Then, how to implement it? A good example is the Fish Stocks Agreement, that is implemented through the cooperation of regional bodies. Then countries that are Parties to the agreement, but not members of these regional bodies, are also more likely to feel bound to implement it. There are a lot of regional bodies, some managed by FAO and others, like the Forum Fisheries Agency in the Pacific, not managed by FAO. As you point out, there are a lot of instruments that refer to a given issue. There is no easy way of solving a conflict between two different instruments – other than taking this to the International Court of Justice for a decision.

Pullin: Almost all of the international instruments for natural resources management, including fisheries and forestry, have not considered genetic aspects. This meeting could point this out. Moreover, much as we like the CBD, it doesn't fill this gap. Unless the management of genetic material is included in provisions for the management of fisheries and aquaculture, there will be scope for serious adverse genetic impacts. I don't see this being handled yet by the CBD, but it could be. The genetic aspects of management are missing, explicitly and implicitly from most related legislation.

Governance, and the Conservation and Sustainable Use of Aquatic Genetic Resources

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"In today's shared-power, no-one-in-charge, interdependent world, public problems and issues spill over organizational and institutional boundaries..., but no one person, group or organization has the necessary power or authority to solve these problems. Instead, organizations and institutions must share objectives, resources, activities, power, or some of their authority in order to achieve collective gains or minimize losses". (Bryson and Crosby 1993)

ABSTRACT

Influencing major areas of societal activities has to take seriously the main characteristics–diversity, dynamics and the complexity of those activities and not regard these as avoidable side-effects. Governance is a perspective which takes such traits as starting points. In particular, it stresses that there is a great need for more extensive and intensive interactions between all those involved in major societal issues such as the care for aquatic genetic resources, i.e., interactions between public and private partners, and between different levels, scales and modes of governance. Governance then means systematic interactions in problem solving and opportunity creation and the care for the institutional frameworks which are needed to enable those involved in these activities to carry them out in an appropriate manner. Examples are given to illustrate how this conceptualization may be used for the governance of aquatic genetic resources.

Introduction

The concept of 'governance' is being used in different subdisciplines of the social sciences (March and Olsen 1989; World Bank 1989; Campbell et al. 1991; Hyden and Bratton 1992; Rosenau and Czempiel 1992; Leftwich 1994; Williams and Young 1994; Desai and Redfern 1995; Rhodes 1997; Pierre, in press). Although there are many differences in the way that it is defined and applied, its common elements are an emphasis on rules and qualities of systems, cooperation to enhance legitimacy and effectiveness of policies, and attention to new processes and public-private arrangements. The apparent success of the concept seems to be that it reflects the societal need for new initiatives based upon the realization of growing societal interdependencies. One form of governance is what may be called interactive or social-political governance. This perspective on governance takes different forms of social-political interactions as its central theme (Kooiman 1993; Kooiman and van Vliet 1995; Kooiman 1997; Kooiman et al. 1998; Kooiman, in press). This effort emphasizes the apparent need for new ways of solving societal problems or creating societal opportunities, not as public activities in themselves but by way of cooperation between public and private actors in concrete problem or opportunity situations. In a more abstract way, it focuses on the interaction between the state, the market and civil society.

With so many disparate uses, it is hardly surprising that various authors have defined governance in different ways. They include elements such as systems of rules at all levels of human activity, from the family to the international organization; processes through which conflicting or diverse interests may be accommodated and cooperative action may be taken; and self-organizing, interorganizational networks characterized by interdependence, resource exchange, rules of the game and significant autonomy from the state.

Social-political or interactive governance can thus be defined as all those interactive arrangements in which public as well as private actors participate in and aim at solving societal problems, or creating societal opportunities, and attending to the institutions within which these governing activities take place. The activities themselves, carried out within these arrangements, are called governing.

Societal Trends and the Changeable Nature of Governing Relations

Governance as a concept is receiving a lot of attention. This has its basis somewhere in societal development, and in particular, in growing or changing societal interdepencies at many levels and in many directions. No government is able to suggest any major plan without the participation of groups in society. Hardly any societal actor can change its resource base or the way it influences the market without somehow involving other actors, public or private. Most of the governance concepts that are now in use highlight aspects of this. One might say that this common element expresses itself quite well in the notion of long-term societal trends, such as processes of differentiation and integration, as fields of societal activities become more and more specialized.

The sciences are good example of this. Moreover, economic and social sectors have become more professionalized and hang together more. Processes such as these result in lengthening chains of interdependence or, phrased more dynamically, in lengthening chains of interaction (Kaufmann et al. 1986): chains that become increasingly institutionalized with multilevel, and multisectoral dimensions. These lengthening chains of interaction cause and require a multiplication of the number of parties participating in them, while the number of interactions among these parties also multiplies. Not only multilevel, but also intersectoral patterns of integration take place, which might be seen as answers to changing needs for collective action collective in the sense of public and private interactions, and not just of public responsibilities by themselves. This also applies to the sustainable use of genetic aquatic resources, where it is quite clear that safeguarding biodiversity, such as that agreed upon in the Convention on Biological Diversity (CBD), requires collective action at many levels and in many directions in which public as well as private partners participate.

As a result of these processes, the dividing lines between public and private sectors are becoming blurred, because of mutual dependencies. Interests are generally not just public or private, they are frequently shared. Responsibilities are becoming diffused among various societal actors and their relationships are changing. Hence, it is generally more appropriate in the context of such changing relationships to speak of shifting roles of government than of shrinking roles of government. A reshuffling of government tasks and a greater awareness of the need to cooperate with other societal actors does not render traditional government interventions obsolete. It merely implies a growing awareness of the limitations of traditional public command-and-control mechanisms. Responses to societal problems require broader sets of instruments. These instruments derive partly from market actors and partly from civil society parties.

Related developments take place in the sphere of nonprofit organizations (Perrault et al. 1997). This is expressed in the new and expanding roles of NGOs in many parts of the world, in the special interest groups becoming involved in governance issues, and in local community initiatives in many different forms and areas of governance (Willets 1996). This can be quite clearly seen in conservation issues, where the initiative for action is not coming primarily from public bodies, but from environmental organizations at all levels: in local initiatives and worldwide movements. Moreover, private enterprise increasingly acknowledges (or is being made to acknowledge) its societal responsibilities in areas such as environmental protection, although this is still more on the level of individual firms than on the level of industrial or commercial sectors as a whole.

Coping with the Diversity, Dynamics and Complexity of Societal Situations

The abovementioned conceptualization of social-political governance chooses three basic characteristics of modern societies to form a basis for further theoretical refinement. The underlying claim is that to understand what is going on in modern societal governance, in particular on the borders between the natural, the social, the economic and the political, one has to confront head-on issues that are highly diverse, complex and dynamic. To illustrate diversity, dynamics and complexity, some ideas are borrowed here from systems thinking: a system being a whole of entities which show more interrelations among themselves than with other entities, and that form the environment of the system. With this perspective, diversity is a characteristic of the entities which form the system and points to their nature and the degree in which they differ from each other. Complexity is an indicator for the architecture of the relations between the parts of a system, between the parts and the whole, and between the system and its environment. Dynamics applies to the tensions within a system and among systems. In the discussions on biodiversity there is a tendency to move away from conserving diversity merely at the species level, to looking at it as aspects of ecosystems of which diversity is one element, while also their dynamics and complexity have to be taken into consideration.

It is important to distinguish between these three characteristics, because each of them separately specifies particular and special aspects of societal phenomena and social-political governance. But the relationships between them are also of great importance, because they can become richer in substance and meaning in their mutual interrelationships; and because they can, separately and in conjunction, serve as basic elements in theory development. Anyone familiar with developments in fisheries biology, and more generally in ecology, will recognize that these concepts also play an important, but not always an agreed upon, role in these scientific disciplines.

The starting point of this governance conceptualization is that social-political phenomena and their governing, in terms of interactions, should be placed in the context of the diversity, dynamics and complexity of societies all over the world. These societies derive their strength from these characteristics, which present them continuously not only with opportunities but also with problems. Such opportunities and problems themselves are also complex, dynamic and diverse. After all, they reflect both the strong and the weak aspects of societies. This also applies, without doubt, to the conditions under which opportunities are created and used and problems formulated and solved. The ways in which societies are governed and the methods and techniques applied should, in principle, also be complex, dynamic and diverse, because otherwise their success will be a matter of chance rather than of purpose.

Separately, and in relation to each other, these three aspects are among the key building blocks of a theory on social-political governance and governability. Only by taking these three basic characteristics of modern societies seriously, can they be used in the governance of societies and the natural resources with which these societies interact in a 'modern' way; in other words, taking diversity, complexity and dynamics not only as aspects to be governed but also as main elements in a modern/contemporary mode of governance. This requires a closer look at the conceptualization of interactions as a central concept in which diversity, complexity and dynamics are related to each other.

Interactions and Governance

There seems to be a shift away from more traditional patterns, in which governance was basically seen as one-way traffic from those governing to those governed, towards a two-way traffic model in which aspects, qualities, problems and opportunities of both the governing system and the system to be governed are taken into consideration. Fisheries management shows examples of this. In the Netherlands and in the Shetlands, U.K., but also in other places, co-management schemes are applied in which fishers participate in activities such as allocation of quotas and planning of fisheries through the year, instead of having such measures placed upon them by governmental agencies from above (Kooiman et al. 1998). Such co-management schemes can be termed as forms of social-political governance when they are based upon broad and systematic interactions between those who are governing and those who are governed. This concept applies to public-public as well as public-private interactions and the way in which all of these are governed.

In addition to changes such as shifts from the public to the private sphere in terms of deregulation and privatization, there are other forms of more systemic interactions. These can be put under the headings of managing, steering and guiding. It is important to emphasize the bilateral and multilateral aspects of these modes of governance. They change the character of the position of the boundaries between state and society, which become increasingly permeable. Where government begins and society ends, or the other way around, becomes more diffuse. The borders between public and private responsibilities themselves become objects of interaction. Often, these interactions are based on the recognition of interdependencies. No single actor, public or private, has all knowledge and information required to solve complex, dynamic and diversified problems. No single actor has an overview that is sufficient to make the application of all needed instruments effective. No single actor has sufficient action with the potential to dominate unilaterally in a particular governance model. The governance of genetic resources is an example here. Many of the papers in this volume show that the developments are going so rapid (dynamics), their application in so many different directions (diversity) and the effects on existing modes of governance so fundamental (complexity) that cooperation between public and private actors seems to be inevitable, in order to arrive at an effective and equitable use and development of those resources.

The power of thinking, in terms of interactions, lies in its possibilities to conceptualize that everything hangs together with everything and that developments take place through interactions. In this sense, interaction provides insight into the mutual relationships within and between social-political problems and opportunities. It shows that the course and effects of actions and processes also depends on what others are doing or what occurs in other processes. With the help of the interaction concept, the social-political reality can be observed not only in terms of its differentiation, but also in terms of its integration. The analytical strength of this concept also lies in the fact that social-political phenomena can be observed by zooming in on interactions, and in identifying the multitude of those which are involved in a particular problem or opportunity.

A governance interaction then can be considered as a mutually influencing relationship between two or more entities, often public-private, but also between public entities themselves. In every interaction there are forces at work with tendencies to maintain existing relations or to change them. These tensions determine the dynamics of an interaction. In the characteristics of the entities between which the interactions occur, their diversity comes into being. Because of the specialization that is so prominent in modern societies, or because of cultural plurality, this diversity makes for special characteristics of modern governance. In the often overlapping interrelations between entities participating in interactions, the complexity of the governing world is realized. Interactions can take place at many societal levels: from those between individual actors to those between nations or states. They can also take many different forms: from cooperation and bargaining to competition and conflict.

Modes of Governance

The most 'chaotic' and fluid forms of social-political interactions, expressed in governance terms, are those of a self-governing character. Modern societies, particularly at the level of sectors, govern themselves. There are however differences between them in character and scope. Sectors that are dependent on public subsidies usually have a lower self-governing degree than those that finance themselves. With 'co' forms of governance, the central point lies in combined responsibilities for carrying out certain tasks. There is a certain degree of equality in the structure within which participating entities relate to each other. Autonomy of those entities remains an important characteristic of these modes of governance. Relinquishing autonomy is always only partial and contains mutual agreements, common rights and duties. Hierarchical or authoritative modes of governance are the most formalized forms of governing interactions, but although they seem to be one-sided top-down they remain interactions. Rights and duties are organized according to superordinate and subordinate responsibilities and tasks. In particular, the positive and negative sanctions attached to interventions have a highly formalized character and are surrounded by all kinds of political and juridical guarantees.

These three modes of governance can be found everywhere, and they are important by themselves. Thus it makes much difference if, in the governance of natural resources, the emphasis is on self-governance, which is the trend in many western European countries. Governments simply have not enough insight into the decisive factors that may have positive or negative effects on resource use within industries. Often, however, one finds mixes of the three modes. In the field of genetic resources, certain activities, such as the application of genetic techniques to humans, are authoritatively forbidden. Others, such as research and development of genetic opportunities, are explored in co-arrangements, while codes of conduct for firms and nonprofit institutes in the bioindustry can be looked at as forms of self-governance. Usually, different sectors of the society can be recognized by different mixes of these governance modes. This also differs from country to country. The laws protecting intellectual property rights are a good example of this.

Self-governance

From a theoretical perspective, a convenient starting point from which to consider the self-governing needs and capacities of social or social-political systems is autopoiesis (for recent overviews, see Dunsire 1996 and Brans and Rossbach 1997). This concept, originating from biology, is controversial but offers several entries into the way in which social and social-political systems govern themselves. There is a growing body of literature that applies autopoietic concepts, such as self-reference, self-organization and self-steering, to substantive areas such as law, economics, technology and politics. The most controversial issue about the characteristics borrowed from biology is that autopoietic systems are operationally or organizationally closed. This aspect is so important, because this closure is a central argument in explaining the failure of 'external' governing of systems such as law and economics.

The autopoietic character of social systems deserves interest in terms of governance. It is quite probable that systems 'see' only what they can interpret in their own terms or meaning, including communications from outside. This also applies to interactions with and interventions by other systems. The 'objective' qualities of acts of governing are not of primary importance; their only effect can be whatever 'meaning' the social systems attribute to them. If this meaning fits into what the governing is about, it might have effects. Otherwise, it will either be ignored, limited or exaggerated. Autopoietic systems can only be governed by their internal self-referential modes of organization and operation. This is what the autopoietic or self-organizing theory is about. Autopoiesis, especially when it is used in the broader sense of self-referentiality and related concepts, can be viewed as a starting point for theorizing on the self-governance of modern societies.

There are three important aspects to this: (1) the attention required for self-governance in modern societies; (2) the strengths and weaknesses of existing principles and practices of self-governance; and (3) the consequences of continuing societal differentiation and the way that self-governing can be part of modes of governance mixes. In practice, many self-governing activities have an informal character. They are based upon long traditions and often are not really controversial because they have no direct effects on other self-governing entities. Recently self-governance has come into public attention because of tendencies of governments to push societal sectors such as professions to be more active in self-governing activities; otherwise governments themselves will move in and do the job. The Code of Conduct of Responsible Fisheries (FAO 1995) is a good example. This code, which is voluntary, sets out the principles and international standards of behavior for responsible practices in fisheries with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for ecosystems and biodiversity. States and all those involved in fisheries are encouraged to apply and implement the code.

Co-governance

Co-governance is making use of organized forms of interactions for governing purposes. In social-political governance, these are key forms of 'horizontal' governing: parties co-operate, co-ordinate, communicate without a central or dominating governing actor. It is these particular forms of governance that seem to better equipped than other modes, such as self-governance or hierarchical ones, in diverse, dynamic and complex situations.

Conceptualizing co-governance can best start with the meaning of concepts such as coordination, cooperation and collaboration. There is abundance of literature using these concepts at different levels of societal organization, varying from interindividual collaboration to coordination at the level of markets, networks and hierarchies as general social mechanisms. For the purpose of this paper, which is to look at co-governing with regards to forms of societal interaction, it is important to establish a theoretical link between forms of co-activities as distinguished in the literature and the author's conceptualization of sorts and qualities of interactions and of the way in which diversity, dynamics and complexity of governing situations can be expressed in those terms.

At the microlevel of societal interactions, the analogous term is collaboration: an interaction taking place between actors, where these actors are individuals, and where the structural arrangements in which they work can be considered to be some kind of formal organizational arrangement, such as a (public-private) working group or project (Huxham 1996). Coordination is the term reserved for the mesolevel of societal interaction, in which the entities are organizations, i.e., the intentional level of 'doing things together', expressed in bi-, or multiple intra- and interorganizational arrangements of those interactions, and best seen in terms of sectors or subsectors of societal differentiation. At the macrolevel, societal interactions can be distinguished in terms of mechanisms or arrangements where one speaks of coordination within and between ' the' state, 'the' market, 'the' civil society. Using the term 'interaction' in this sense applies more to theoretical discussions on the extent to which these three societal institutions are in tune or not in tune, than to the ways in which they interact in practice. In the world of the conservation of aquatic resources, examples of interactions at all three levels come easily to mind. The efforts to collect biodiverse material in Brazil in collaboration between local fishermen and conservationists from Canada (Harvey, this vol.) is an example of such microinteractions. This entire conference is clearly an example of the coordination of research activities among institutions such as ICLARM, the FAO and others, at a mesolevel of interaction. The context in which this all takes place, such as the implementation of the Convention on Biological Diversity, is the macrolevel, the field upon which interactions in this field of interrelations are acted out.

These distinctions are no more than the beginning of describing modes of co-governance, but they are helpful in marshalling the relevant literature and practical experience. Such distinctions form the first step in identifying and understanding the factors that enable or control governing interactions at those levels. Certain arrangements, such as forms of collaboration or coordination between public and private actors or sectors are stimulated, or to the contrary hindered, within certain varieties of co-governance at the macrolevel. Only by an integrated look at the pros and cons of such arrangements and their mutual effects can a thorough insight be gained. Fortunately, recent interest in 'new institutionalism' is helping the discovery of many mutual forms of influence of different types of interactions at different societal levels and, as such, can contribute new knowledge about characteristics of different modes of co-governance in different societal contexts (March and Olsen 1989; DiMaggio and Powell 1991; Scott 1995; Hall and Taylor 1996; Lowndes 1996).

Networks as patterns of doing things together

There can be hardly any doubt that the emergence of mixed networks of public and private actors has to do with broad social developments. Growing social differentiation also engenders increasing dependencies. In this context, the emergence of policy networks is considered an important change in the political decision-making structure. Terms are used, in the context of networks, such as 'negotiation by governments' as a new model of social ordering between 'market' and 'state'; or as governance in a centerless society, with complex configurations of horizontal coordination and synchronization. Others consider the development of mixed public-private networks in terms of the need to solve social-political problems.

An example of the importance of such a network is seen in the area of biotechnology. In the biotechnology industry, the cooperation between firms and between firms and universities is considered essential for obtaining sustainable competitive advantage. Pooling of resources, finding complementary capabilities, and the time-consuming nature of the research are frequently mentioned as important reasons for such cooperation. The European Union (EU) tries to stimulate cooperation within the biotechnology industry through European-funded research programs that foster the formation of large research networks on biotechnology, in which partners from all parts of Europe are included. In addition, the EU tries to let the entire European biotechnology industry benefit from the knowledge generated within these research programs. One of the initiatives to enhance the diffusion of these scientific results is the establishment of "extended audiences", in the form of industrial platforms. This EU initiative has been readily taken up by industry and, at present, 13 industrial platforms exist, covering a variety of areas of biotechnological research (Degenaars et al. 1998).

Public-private partnerships

The public-private partnership (PPP), a specific form of social-political governance, has been prominent for some years (Kouwenhoven 1993). The growing interest in cooperation between public and private parties has been influenced by economic, social, political and cultural changes. As a consequence of this, the question is increasingly voiced whether certain issues could not be dealt with more effectively and efficiently through joint action by public and private parties, rather than by their acting separately? Such forms of cooperation are often referred to as PPPs.

The essence of PPPs is the synergetic effect that actors expect, i.e., greater effectivity and/or efficiency than from acting seperately. A prerequisite to the convergence of objectives is that they should be compatible. It is only then that private means can contribute to the solution of public problems, or public means can be used to react to commercial opportunities and threats. Likewise, a PPP distinguishes itself from similar arrangements by the preservation of the respective identities of the parties involved. It will be obvious then that PPPs are considered a specific mode of co-governance. An example of a PPP is 'The Environmental Action Plan Rijnmond' in The Netherlands (Kouwenhoven 1993). The Rijnmond area is one of the major industrial districts of The Netherlands, near the port of Rotterdam. In the seventies, the district was classified as a redevelopment area, because of its deplorable environmental quality, which was mainly caused by a high concentration of chemical plants. Within the framework of collective responsibility for the creation of a PPP, a contact group was formed in which representatives of the involved authorities, as well as trade and industry, took part. The parties agreed on a joint action plan, which offered possibilities for substantial improvement of the environmental quality in the district, as well as for considerable improvement of the commercial climate, with regard to the lifting of the status of redevelopment area. Synergetic effects were the know-how concerning the sources of pollution and the possibilities for adaptation within standards acceptable to industry, to be supplied by trade and industry.

Communicative governance

New patterns of governance stimulate learning processes that lead to cooperative behavior and mutual adjustment, so that responsibility for managing structural changes is shared by all or by the most involved actors. One such pattern of governance is described as 'communicative governance'. This is based on the image of complex problems in which problem-resolving capacities are distributed among autonomous but interdependent actors. In this type of governance, a form of rationality is presented in which social actors are considered 'reasonable citizens' (van Vliet 1993). This kind of rationality differs from the selfish, opportunistic profit- or benefit-maximizing kind, which is used in economic or public-choice theory. This call upon the 'reasonable citizen' aligns with the concept of communicative rationality, which is considered appropriate in complex problem solving as a substitution for instrumental, functional or strategic forms of rationality. Covenants, written forms of understanding between partners, are a good example of the use of communicative rationality. The covenant has become an important instrument in the 'target-group strategy' for implementing the Dutch national environmental policy plan. This strategy is designed to stimulate negotiation and deliberation between organized branches of trade and industry and government, and stresses that these groups share responsibility for environmental protection. Sustainable development combines a preventive and source-oriented approach to environmental problems. Such an approach cannot be implemented by governments making rules unilaterally, but depends on the cooperation of economic agents. The strategy thus represents a response to the serious enforcement problems and high administrative costs of the previous policy, which was implemented unilaterally by the government, and involved a costly loss of flexibility for the market sector. Advantages of covenants include the speed with which they can be established, their inherent flexibility, and most importantly their morally binding character and capacity to stimulate responsibility through the endorsement by stakeholders of commonly agreed standards. Covenants have been criticized by environmentalists for not being sufficiently binding on big business, which was thought to have excessive bargaining power over government. However, after a period of experimentation, covenants have become more formalized and institutionally embedded, and made more legally binding (Kooiman and van Vliet 1995).

Hierarchical governance

Intervention systems are the most classical and characteristic mode of governing interaction between the state and its individual citizens, groups or organizations. The most common and widely practiced forms are either by laws or by means of policies. There is hardly any societal activity that is not governed at least partly by one or more laws, or one or more policies. For almost any broader subject on almost every level of public involvement in social affairs, to have policy is standard practice. Often this involvement is closely linked with one or more forms of legal or administrative rules. These can be distinguished as separate forms of interventionist governance.

These hierarchical forms of governance have long historical roots and theorizing about them has particularly been influenced by Max Weber, especially by his studies on bureaucracy, which have been setting the stage for almost all theorizing on hierarchical/bureaucratic forms of coordination of social life (Weber 1925). However, most theorizing about hierarchical modes of governance has been and remains directed at organizations internally. Since the fall of most communist regimes, centrally controlled hierarchical modes of societal governance have become rare.

It seems important to build upon the above mentioned conceptualizations to theorize further about hierachical modes of governance, and to develop a coherent set of insights about the qualities and limitations of hierachical modes of governance in different societal problemsolving and opportunitycreating settings. Against this background, short introductions to the general properties of the most important forms of hierarchical governance follow.

Policies as interventionist systems

Policy aims at intervening in social-political situations in a rational manner on the basis of knowledge of causal relations but is, at the same time, part of these situations as context. Smith (this vol.) gives a detailed account of such a policy in the area of genetic resources and fisheries. He reviews thoroughly a number of major problems related to the current policies in this area. Mires (this vol.) discusses several aspects of the interactions between expert advice, administrative considerations and political pressures on the preparation and implementation of policies on aquatic genetic resources.

Recent developments in policy theorizing emphasize the institutional framework in which policies are prepared, developed and executed (Parsons 1995). This development can be characterized as the addition of the social to the political. In older theories, attention was strongly focussed on the governmental, public side of these processes. In recent theories, the social, interactional and private aspects receive more attention. One can call this a change from more 'closed' to more 'open' approaches towards policymaking. A 'blue revolution', as suggested by Entis (this vol.), implies policies that are more open than closed in character, if they are going to be effective.

Legal interventions

The state is factually and legally bounded in the choice, form and application of the means that it wants to use. The constitutional state requires the relations between state and citizens to be dominated by legal principles and rules. The more penetratingly the state intervenes in the private sphere, the more formal are its demands and guarantees. Consequently, the design and application of legal interventions are based on principles such as equality before the law, legal security, unity of the law and carefulness. Interventions by the state are subject to political scrutiny, which means consultation of social partners. This usually presents limitations to the scope of potential juridical interventions. Moreover, there is the growing interconnection of interventions by law on different levels of subnational, national and supranational regulation.

The grip of the state on social conditions has become a kind of handicap. In the course of intervention by legal means, limitations and disadvantages come into view. This is one of the reasons why legal interventions is coming under scrutiny and deregulation is one possible outcome. As stated by Correa (this vol.), it would be an overestimation of the potency of patent law if one considered it an appropriate instrument to regulate research which is dangerous (or unacceptable for other reasons) to certain groups of humans. Human curiousity could not be hampered by the fact that patent protection were not available if such research promised an interesting result. However, if the legislator is of the opinion that certain technical knowledge should be held only under limited conditions, it is up to that legislator to enact appropriate legislation.

Mixes of Modes of Governance

Social-political (collective) problem solving and collective opportunity creation in complex, dynamic and diverse situations are public as well as private, governmental and market challenges. They present sets of profit as well as nonprofit making activities. At one time one party takes the lead in governance, in another situation it is another. The growing number of social-political challenges call, however, for shared responsibilities and for 'co-arrangements'. For solving social-political problems and creating social-political opportunities, thorough and combined public and private insights into the diversity, dynamics and complexity of social-political questions and the conditions in which these questions arise are indispensable. In simple terms, it is usually the private (market) part of a sector that carries the responsibility for the governance of the primary interactions taking place in it. It is the task of private nonmarket parties, as nonprofit organizations (such as producers' and consumers' organizations, environmental and scientific organizations) to take care of the governance of the more organized interactions that accompany these primary processes. It is the task/responsibility of public organizations to ensure that problems and opportunities within and around the primary and secondary processes and structures of these sectors will take place according to principles and rules which reflect the common and broader system/society-wide interests connected with these processes.

All this expresses itself in different mixes of public, public-private and private forms of interactions, organized in the three modes earlier outlined. Little is known about the qualities or defects of these mixes. In the context of this paper, it can only be assumed that, on the basis of analyses made so far, the mix of self- and co-governing is hardly explored whereas the mix of co- and hierarchical and the mix between self and hierarchical governing are somewhat better known. An analysis of the mix of all three is still at an exploratory stage.

Conclusion: Governance and Aquatic Genetic Resources

Modern societies are characterized by continuing processes of differentiation and specialization. Those processes create opportunities for these societies but they also create problems. New and more traditional modes of governance have been explored in this paper, with the aim of solving such problems or stimulating those opportunities. To what extent can the governance concept and the ideas developed around it contribute to the governance of aquatic genetic resources?

It will be clear that the subject, aquatic genetic resources, is a diverse, dynamic and complex phenomenon in itself. According to the arguments developed in this paper, for the governance of aquatic genetic resources to be effective and legitimate, it should also have these characteristics. The governance approach described here has as its central focus the interactions taking place between social systems. Starting with the continuous interaction processes, through which human actions acquire their irreversible and unpredictable character, affords some kind of understanding of the diversity, complexity and dynamics of social-political governance situations. It is necessary in this context, for governments and their social partners to define their mutual responsibilities jointly and continuously. This requires a growing awareness of the implications of the different modes of governance, including the capacities of social systems for self-governance, co-governance and authoritative top-down governance. Each mode can contribute in its own way and as part of governability in a broad sense.

Pragmatic criteria, such as a willingness to be open to differences, willingness to communicate, and willingness to learn, are important for coping with diversity, dynamics and complexity. They are, however, not sufficient to bring about the necessary integration between social systems. Rather, substantive criteria are also needed to establish the basis upon which these systems are willing and able to interact with each other and to accept each other's boundaries.

What does all of this mean for the governance of aquatic genetic resources? By taking diversity, dynamics and complexity and their mutual relationships as a starting point, a governance model for aquatic genetic resource systems comes into view, in which these systems and the bodies governing them are consciously, explicitly and purposefully interrelated. The governance bodies as well as the aquatic genetic resources systems themselves are diverse, dynamic and complex. These entities themselves need order, but nothing can change without dynamics. They need similarity to enable communication, but they need diversity to gain new insights. They need standards to reduce uncertainty and risk, but they need complexity to solve problems and create opportunities. In this volume, many of these aspects are thoroughly discussed. The task ahead is to bring insights from these studies together in the perspective of their governance qualities. This could involve the following:

- *Creation of interactions between public and private parties, at all levels of governance of aquatic genetic resources, and the interaction between those levels.* This means that experiences will be tested in the different contexts that are characteristic for those levels, and that the results of those tests will be available to all involved, at the micro-, meso- and the macrolevel of governance.
- *Acknowledgement of the mutual dependencies of public and private parties in the development and implementation of governance measures, because of the diverse, dynamic and complex character of genetic aquatic resource systems.* This means that governments, market parties and NGOs must recognize that none of them is able to handle alone the issues raising out of the governance of these resources, but forms of continuous interaction between them are essential.
- *Systematic exploration of the three governance modes, self governance, co-governance and hierarchical governance and their mixes, to enhance the effectiveness and legitimacy of the governance of aquatic genetic resources.* This means that, through information exchange, such as the one becoming available within the context of the Convention on Biological Diversity, all positive and negative experiences with any of these three governance modes or their mixes will be evaluated on the basis of effectivity and legimitacy criteria.
- *Experimentation with co-modes of governance and stimulation of forms of and conditions for cooperative ways of governance.* From the theoretical reasoning in this paper and based on empirical work carried out in this field, it seems that this governance mode is of particular value for the conservation and sustainable use of natural resources, including aquatic genetic resources.

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Discussion

Kapuscinski: Are people in your area of work interacting with systems ecologists, on 'co'-approaches to the management of complex systems?

Kooiman: Well, I see myself a bit like a servant here. We tried to apply these approaches to fisheries in Europe. From this experience, the theory progressed further. Before, the options were only governmental, 'self' or 'co'. The best starting point might be 'what can the actors implement themselves?' Look at self-governance first, then if this does not work, try 'co'- arrangements, then, if these are not adequate, finally go to legislation. Traditionally, it has been done the other way around. Whenever you start with legislation, you will then need repair, repair, and more repair legislation! Better to try out self-governance or co-arrangements.

Pullin: Those who have seen the booms and busts of fisheries and aquaculture over the years can appreciate that legislation by itself does not work. But it's also hard to be optimistic about the capacity of most fishers and fish farmers to engage in much self-regulation. How could this be turned around, so that the rapid depletion of a resource for aquaculture and fisheries becomes the exception rather than the norm? Could you not combine these three approaches rather than taking a first approach, then a second approach and legislation as the last resort? Also, the prevailing power structure is very important for determining who does what–or who is allowed to do what.

Kooiman: Well, you start with a primary interaction with the system and then broaden it to a societal level. The traditional approach has been top-down rather than bottom-up. A bottom-up approach is often preferable. You can certainly combine the three modes. There is a certain capacity for self-governance. To this can be added professional codes, etc. It can be a mixture. We looked at fish in Europe. Where is it going? 85% goes to the supermarkets–so maybe the supermarkets are the governing body of a chain. There is a lot of interaction in the chain between fish processors and supermarkets, but the fishers stay out of this. Also, civil society takes part in governance, through the markets. A big change is taking place here. For example, in Norway, some environmental NGOs are, by law, going to be partners. The trick might be to balance the powers in a particular interaction or system. This might be much more efficient than trying to punish one partner.

Bartley: You said that governments can't do much in genetics because of the speed with which this field is progressing. Because it is developing fast, a government, like that of the US, tends to say 'stop'; for example, there is a ban on human cloning and on the use of marijuana for medical research. The same thing applies to transgenic fish. The government tends to become overwhelmed and then stops everything. How do you see this? It may be necessary, but not all that good.

Kooiman: This is important for the recommendations of our meeting. Self- and co-governance can work best in areas that are relatively unstructured. It is difficult for them to work: if 200 years of legislation are already present. Genetics is a new field. There are a lot of openings. I learned today that it took about 20 years for the parties in plant genetics to realize how interdependent they are. This realization could come earlier for aquatic genetic resources. Market parties are very important here. In natural resources management, market parties are often considered to be enemies. In a whole societal perspective, the market parties shift the dynamics. It is very crude for the government to simply come in with regulations–although maybe that's all that can be done in some circumstances. It is difficult, for example, for a government to put a ban on consumers consuming something. This can only work for a short while.

Developing Sui Generis *Options for the Protection of Living Aquatic Resources of Indigenous and Local Communities*

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ABSTRACT

Indigenous and traditional peoples have increasingly become the focus for research aimed at the development of new products for the improvement or discovery of medicines, agricultural products, body and skin preparations, natural oils, essences, dyes and insecticides. An increasing number of these "new or natural" products is coming from aquatic resources. Indigenous and traditional peoples have long been targets for expropriation of their music, arts, crafts, and images that are often inspired by or represent rivers, streams, springs, the sea, and the life and resources that are associated with aquatic ecosystems. Trade and science, however, have removed materials, ideas, knowledge, expressions of culture–and genetic resources–from their social and spiritual contexts to convert them nto objects for research or commercialization. This is seen by indigenous and traditional peoples as violations of the spiritual base from which all knowledge and life emanates.

For most indigenous and traditional peoples, all creation is sacred and inseparable from the "secular" aspects of life. Spirituality is the highest form of consciousness, and spiritual consciousness is the highest form of awareness. In this sense, a dimension of traditional knowledge is not local knowledge, but knowledge of the universal as expressed in the local: nature's organizing principles may be encoded as stories, myths, or songs about fish, water spirits, or landscapes. Thus, knowledge of the environment–including aquatic ecosystems–depends not only on the relationship between humans and nature, but also between the visible world and the invisible spirit world.

Intellectual property rights (IPRs) have become important to global economic, environmental and commercial debates on aquatic resources in part because of the massive perceived potential for biotechnology and development of medicines, agricultural products, body and skin preparations, natural oils, essences, dyes and insecticides from aquatic resources traditionally used by indigenous peoples, traditional societies and local communities. Yet, IPRs favor industrialized nations rather than bioculturally rich, developing nations. There are some remote hopes that existing Western legal instruments and structures can be adapted to enhance conservation of aquatic biodiversity and empowerment of indigenous, traditional and local communities. This paper argues that any such attempts will need to combine 'bundles of rights' from a wide range of international legally binding and nonbinding agreements to guide newly emerging systems of international law.

The CBD, and related UNCED agreements, call for access to, protection of and benefit sharing from the use and wider application of traditional technologies and aquatic resources. However, neither enforcement mechanisms, nor, indeed, even general agreement on what to enforce, has appeared on the international scene. Existing legal and nonlegal mechanisms provide some of the ideological groundwork for protection of indigenous and traditional peoples, but it has become increasingly obvious that *sui generis* options for collective rights are needed. These must be developed to replace IPRs with protective mechanisms that are built more upon human rights and environmental concerns than upon economic considerations.

Development of *sui generis* options provides opportunities for new dialogues, increased recognition of Indigenous peoples and their knowledge, new codes of ethics and standards of conduct, socially and ecologically responsible business practices, holistic approaches to sustainability, and alternative concepts of property, ownership and value. Replacement of IPRs–guided by a rights-based traditional resource rights process–can serve to catalyze this dialogue, and, indeed, promote a global consensus on how to enhance biological and cultural diversity. No matter how good any *sui generis* option might become, however, they can never replace recognition of the right to self-determination of indigenous peoples, and support of their own projects, programs and strategies to manage and conserve and enhance traditional use of and respect for aquatic resources.

Introduction

Indigenous and traditional peoples have increasingly become the focus for research aimed at the development of new products for the improvement or discovery of medicines, agricultural products, body and skin preparations, natural oils, essences, dyes and insecticides; an increasing number of these "new or natural" products is coming from aquatic resources (Chadwick and Marsh 1994). They have long been targets for expropriation of their music, arts, crafts, and images that are often inspired by or represent rivers, streams, springs, the sea, and the life and resources that are associated with aquatic ecosystems. Trade and science, however, have removed materials, ideas, knowledge, expressions of culture–and genetic resources–from their social and spiritual contexts to convert them into objects for research or commercialization. This is seen by indigenous and traditional peoples as violations of the spiritual base from which all knowledge and life emanates.

For most indigenous and traditional peoples, all creation is sacred and inseparable from the "secular" aspects of life. Spirituality is the highest form of consciousness, and spiritual consciousness is the highest form of awareness. In this sense, a dimension of traditional knowledge is not local knowledge, but knowledge of the universal as expressed in the local: nature's organizing principles may be encoded as stories, myths, or songs about fish, water spirits, or landscapes. Thus, knowledge of the environment–including aquatic ecosystems–depends not only on the relationship between humans and nature, but also between the visible world and the invisible spirit world (see Posey and Dutfield 1997; Posey 1999).

According to Opoku (1978), the distinctive feature of traditional African religion is that it is:

> "A way of life, [with] the purpose of... order[ing] our relationship with our fellow men and with our environment, both spiritual and physical. At the root of it is a quest for harmony between man, the spirit world, nature, and society. Thus, the unseen is as much a part of reality as that which is seen–the spiritual is as much a part of reality as the material. In fact, there is a complementary relationship between the two, with the spiritual being more powerful than the material. The community is of the dead as well as the living. And in nature, behind visible objects lie essences, or powers, which constitute the true nature of those objects".

Indigenous and traditional peoples frequently view themselves as guardians or stewards of harmony and equilibrium–the central concepts that link life, land and society. Chief Oren Lyons (1999) explains how biodiversity for his Haudenosaunee people is expressed not as relationships and obligations to some external objects that possess life, but rather to kin and family–or "all our relations". Suzuki (1999) called this the "Sacred Balance" and argued that science is less sophisticated than indigenous knowledge because science still sees nature as being components (to use a term of the Convention on Biological Diversity) for human use and exploitation. Science with its quantum mechanics methods, says Suzuki, can never address the universe as a whole; and it certainly can never adequately describe the holism of indigenous knowledge and belief. In fact, technology has used the banner of scientific 'objectivity' to mask the moral and ethical issues that emerge from such a functionalist, anthropocentric philosophy.

Strathern (1996) makes this clear when discussing the ethical dilemmas that are raised (or avoided) when embryos are 'decontextualized' as human beings to become objects/subjects of scientific research. Just as genetic and transgenic research on human embryos deeply offend the religious and humanistic sensitivities of many from industrialized societies, aquatic genetic research and reduction of species and ecosystems to mere production systems for human exploitation are repugnant concepts to many indigenous and traditional peoples.

Traditional Ecological Knowledge of Aquatic Resources

The Convention on Biological Diversity (CBD) recognizes in Article 8j the central role for successful *in situ* conservation of "knowledge, innovations and practices" of "indigenous and local communities embodying traditional life styles" (see below). Scientists refer to such "knowledge, innovations and practices" with a confusing array of terms and acronyms: traditional ecological knowledge (TEK), local knowledge (LK), indigenous knowledge (IK), traditional knowledge (TK), indigenous knowledge systems (IKS), indigenous resource management systems (IRMs), local community systems (LCSs) and more. These complicated acronyms are in part due to the difficulties in defining "indigenous" and "traditional" as described elsewhere in this paper (see also Posey and Dutfield 1997). For the purpose of this paper, these terms have roughly the same meaning and are referred to as TEK.

TEK is far more than a simple compilation of facts (Gadgil et al. 1993; Johnson 1992). It is the basis for local level decisionmaking in areas of contemporary life, including natural resource management, nutrition, food preparation, health, education, and community and social organization (Warren et al. 1995). TEK is holistic, inherently dynamic and constantly evolving through experimentation and innovation, fresh insight and external stimuli (Suzuki and Knudson 1992; Slikkerveer 1999). It also embraces information about location, movements and other factors explaining spatial patterns and timing in aquatic ecosystems, including sequences of events (e.g., fish catches, marine mammal sightings, aquatic blooms), cycles (e.g., fish migration, spawning, tidal changes, lunar influences) and trends (e.g., decrease in catches, early thaws, rainfall patterns, changes in migration or spawning patterns).

Although TEK is likely to be spiritually based, it is also usually highly pragmatic and utilitarian (Chambers 1999). The Gwich'in of Northwestern Canada, for example, organize their seasons around social events linked to prime fishing times and preparation, preservation and utilization of different species (Raygorodetsky 1997). Ruddle and Johannes (1985) document how long-term, empirical knowledge of the environment is incorporated into more effective resource management strategies by numerous coastal communities. Toledo (1991) likewise detailed the "essentially utilitarian character" of the P'urhepecha of Lake Patzcuaro (Mexico) in their "operational steps" toward efficient and effective hunting and fishing. Kalland (1994a, 1994b) found the same circumstances with Japanese whalers. Kalland (1998) states:

> "In order to hunt whales successfully it is necessary not only to acquire skills in navigation, shooting and handling of meat, but also to acquire detailed knowledge on migratory, mating and feeding behavior of various species of whales. The whalers have learnt to take account of such natural phenomena as tides, currents, winds, wave patterns, water temperature and coloring. They are also keen observers of fish and bird behavior."

A basic characteristic of TEK is that it is directly linked to specific sites that form the core of individual and group identity. A hydropower project in Quebec, for example, was successful in preserving fish populations, but disastrous in its conservation of fishing spots and meeting places that had served as the foci of Chisasibi Cree identity for generations (Roué and Nakashima 1994). Projects to build dams and lakes might even increase fish populations, but a Cherokee medicine woman, Alice Benally, sees such developments as ruinous to the sacred medicinal plants, which were an integral part of the submerged earth:

> "If we are to make our offerings at a new place, the spiritual beings would not know us. We would not know the land and the land would not know us." (Wood and Vannette quoted in Whitt 1999).

Nowhere is the link between place, culture and knowledge more apparent than with the dreaming-places of the aboriginal peoples of Australia. As James Galarrwuy Yunupingu, Chairperson of the Northern Land Council, explains: "My land is mine only because I came in spirit from that land, and so did my ancestors of the same land. My land is my foundation" (Galarrwuy Yunupingu 1995; see also Benet 1999). Here, the term 'land' does not just mean terrestrial places, but lakes, shoreline, islands, reefs and underwater sites

(H. Morphy, pers. comm.). H. Morphy (pers. comm.) has also recorded that former dreaming sites, left beneath the ocean after rising post-glacial sea rises, are still revered by aboriginal elders.

It is misleading to state that indigenous and traditional peoples always have a conservationist ethic or that traditional practices always lead to the conservation of resources (Chambers 1999). Johannes and Ruddle (1993) observed that in indigenous societies, environmentally destructive practices coexisted, with efforts to conserve natural resources–just as in all other societies. Indigenous peoples themselves shun the romantic views of many western observers. For example, Peteru (1999) asserts that Western Samoans have a primarily utilitarian view of their environment that now provokes ecological damage in the islands. Two native American scientists, Pierotti and Wildcat (1999) warn that:

"Those wanting to embrace the comfortable and romantic image of the Rousseauian "noble savage" will be disappointed. Living with nature has little to do with the often voiced "love of nature," "closeness to nature," or desire "to commune with nature" one hears today. Living with nature is very different than "conservation" of nature. Those who wish to "conserve" nature still feel that they are in control of nature, and that nature should be conserved only insofar as it benefits humans, either economically or spiritually. It is crucial to realize that nature exists on its own terms, and that non-humans have their own reasons for existence, independent of human interpretation."

Lynge (1999) emphasizes that one of the basic differences between traditional hunters and urban conservationists is that the latter fear, not love, nature. As he pointed out, "good nature management" depends upon "the recognition of the interdependent wholeness of humanity", which, in turn, is based upon a respect for life that must be taken to preserve lives. This view is fundamental to his assertion that Inuit have the basic right to take sea mammals and that in so doing, they are respecting, not destroying, a sacred commodity.

Many indigenous and traditional peoples live sustainably from the resources available to them:

"In contrast to the specialized mode of biological resource use in modern economies, where comparatively few resources are perceived and recognized as having production value, under the indigenous view all of the components of natural landscapes are directly or indirectly useful or usable resources. This aspect alone tends to favor a conservationist attitude towards the environment. Moreover, it seems clear that the multiple use strategy of indigenous communities is an effective mechanism for preserving and even increasing biological diversity by increasing habitat heterogeneity" (Toledo 1991).

Thus, effective strategies for conservation of aquatic resources must support local communities and protect their traditional ecological knowledge. Unfortunately, few indigenous peoples have the legal authority to protect their own resource rights and are powerless to prevent outside exploitation. This uncontrolled open- access situation can mean that the only "rational" behavior by communities is to join in the unsustainable exploitation of the dwindling resource base (Chambers 1999). Recognizing locally based property rights, on the other hand, gives both an incentive and a means for the involvement of indigenous, traditional and local peoples in effective aquatic resource conservation.

Who are Indigenous Peoples?

Over the past 20 years, indigenous peoples have become the focus of increasing interest and international debate. The United Nations has been a primary forum for these discussions through the United Nations Economic and Social Council (ECOSOC) Working Group on Indigenous Populations, which has developed the Draft Declaration on the Rights of Indigenous Peoples (see Appendix I for the full text). Indigenous and traditional communities also figure prominently in the Earth Charter (Posey and Dutfield 1996), the Commission on Sustainable Development (Posey et al. 1996), Agenda 21 (Posey et al. 1996) and the CBD (see also Posey and Dutfield 1996).

Although defining 'indigenous' has proven problematic for international organizations (Clay 1991), indigenous peoples themselves offer several definitions. For example, the World Council of Indigenous Peoples provides the following definition:

"Indigenous peoples are such population groups who from ancient times have inhabited the lands where we live, who are aware of having a character of our own, with social traditions and means of expression that are linked to the country inherited from our ancestors, with a language of our own, and having certain essential and unique characteristics which confer upon us the strong conviction of belonging to a people, who have an identity in ourselves and should be thus regarded by others" (WCIP 1993).

A definition of indigenous peoples that has gained broad international acceptance is that of the 1989 International Labour Organisation (ILO)'s Convention 169 Concerning Indigenous and Tribal Peoples in Independent Countries (Posey et al. 1996) which is the only international legal agreement specifically on indigenous peoples. It states that people are considered indigenous if they are:

"a) tribal peoples in (independent) countries whose social, cultural and economic conditions distinguish them from other sections of the national community, and whose status is regulated wholly or partially by their own customs or traditions or by special laws or regulations
b) peoples in (independent) countries who are regarded as Indigenous on account of their descent from the populations which inhabited the country, or a geographical region to which the country belongs, at the time of conquest or colonization or the establishment of present state boundaries and who, irrespective of their legal status, retain some or all of their own social, economic, cultural and political institutions."

In addition, ILO 169 establishes another important principle in stating that:

"**Self-identification** [present author's emphasis] as Indigenous or tribal shall be regarded as a fundamental criterion for determining the groups to which the provisions of this convention apply." [Article 1.2]

The "s" in peoples in the phrase 'indigenous peoples' is very significant, because it implies collective rights as ethnic nations. These rights are subsumed under the right to self-determination, that includes rights to land, territory and resources. Most Nation States have resisted recognition of self-determination and subsequently, the term 'peoples' (Clay 1991, 1994; Kingsbury 1992a, 1992b,1994). Most official UN documents use "people", or the even weaker terms "populations" or "communities" that imply lack of collective rights altogether.

Indigenous peoples interpret the right to self-determination to include rights to tangible and intangible cultural, scientific and intellectual resources. The 1994 Statement from the International Consultation on Intellectual Property Rights and Biodiversity, organized by the Coordinating Body of Indigenous Peoples of the Amazon Basin (COICA) states:

"All aspects of the issue of intellectual property (determination of access to natural resources, control of the knowledge or cultural heritage of peoples, control of the use of their resources and regulation of the terms of exploitation) are aspects of self-determination [present author's emphasis]. For Indigenous peoples, accordingly, the ultimate decision on this issue is dependent on self-determination." (Posey and Dutfield 1996, Appendix 9)

The UN Conference on Environment and Development (UNCED) has produced a number of international agreements that highlight the importance of indigenous peoples and their role in the conservation and sustainable use of the components of biological diversity (Posey 1990; Mead 1994. For example, Agenda 21 devotes an entire Chapter (26) to "Recognising and Strengthening the Role of Indigenous People and their Communities". Item 26.4b proposes that governments should:

"adopt or strengthen appropriate policies and/or legal instruments that will protect indigenous intellectual and cultural property and the right to preserve customary administrative systems and practices."

The Preamble of the 1992 Convention on Biodiversity Diversity (CBD) also recognizes the:

"close and traditional dependence of many Indigenous and local communities embodying traditional lifestyles on biological resources, and the desirability of sharing equitably arising from the use of traditional knowledge, innovations and practices relevant to the conservation of biological diversity and the sustainable use of its components."

Note that the question of self-determination is avoided all together by the CBD, which only refers to "indigenous and local communities", Article 8j of the CBD, which is specifically concerned with *in situ* conservation through collaboration with indigenous and local communities, calls on States to:

> "respect, preserve and maintain knowledge, innovations and practices of Indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote the wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices."

In CBD Article 18.4, knowledge, innovations and practices are referred to as "traditional and indigenous technologies". This elevates "knowledge, innovations and practices" to a level equivalent to industrial technologies, and presumably, makes them subject to the relevant agreements on transfer, access and IPR protection. Indigenous peoples are anxious about these provisions. On the one hand, recognition of traditional knowledge as technology elevates indigenous knowledge to an internationally recognized category; on the other hand, indigenous technologies are subsumed under laws which uphold Nation State sovereignty and endorse IPRs.

Thus, the CBD encourages: (1) *in situ* conservation utilizing knowledge, innovation and practices of indigenous and local communities embodying traditional lifestyles; and (2) wider use and application of indigenous technologies. This amounts to a global call to extricate aspects of knowledge from its systems (cultural) context, while providing only IPRs as mechanisms for protection and equitable benefit-sharing. It should not be of any surprise, therefore, that indigenous peoples are suspicious of the CBD and its expansion of Nation State sovereignty over their knowledge and genetic resources, especially given that IPRs are the only mechanisms specifically mentioned to protect indigenous and local communities (Gray 1990, 1991a, 1991b; Mead 1994).

Intellectual Property Rights and Ownership of Knowledge

Existing intellectual property rights (IPRs) are viewed by indigenous peoples as not adequate to implement "appropriate protection measures" (Posey 1990). According to the Statement from the 1994 COICA Regional Meeting on Intellectual Property Rights and Biodiversity in Santa Cruz, Bolivia:

> "For indigenous peoples, the intellectual property system means legitimization of the misappropriation of our peoples' knowledge and resources for commercial purposes [Therefore]...there must be appropriate mechanisms for maintaining and ensuring rights of Indigenous Peoples to deny indiscriminate access to the resources of our communities or peoples and making it possible to contest patents or other exclusive rights to what is essentially Indigenous." (Posey and Dutfield 1996; Appendix 9: 2 and 16)

Posey and Dutfield (1996) found IPRs to be problematic for the following reasons (Posey et al. 1996):

- They are intended to benefit society through the granting of exclusive rights to "natural" and "juridical" persons or "creative individuals", not collective entities such as indigenous peoples (Boyle 1996). As the Bellagio Declaration (in Boyle 1996) puts it:

  "Contemporary intellectual property law is constructed around the notion of the author as an individual, solitary and original creator, and it is for this figure that its protections are reserved. Those who do not fit this model–custodians of tribal culture and medical knowledge, collectives practicing traditional artistic and musical forms, or peasant cultivators of valuable seed varieties, for example–are denied intellectual property protection."

- They [Indigenous peoples, traditional societies, and local communities] cannot protect information that does not result from a specific historic act of "discovery". Indigenous knowledge is transgenerational and communally shared. Knowledge may come from ancestor spirits, vision quests, or orally-transmitted lineage groups. It is considered to be in the "public domain" and, therefore, unprotectable.

- They cannot accommodate complex nonwestern systems of ownership, tenure and access. IPR law assigns authorship of a song to a writer or publishing company that can record or publish as it sees fit. Indigenous singers, however, may attribute songs to the creator spirit and elders may reserve the right to prohibit its performance, or to limit it to certain occasions and to restricted audiences.

- They serve to stimulate commercialization and distribution, whereas indigenous concerns may be primarily to prohibit commercialization and to restrict use and distribution. According to the 1994 COICA Statement:

  "For members of indigenous peoples, knowledge and determination of the use of resources are collective and inter-generational. No indigenous population, whether of individuals or communities, nor the government, can sell or transfer ownership of resources which are the property of the people and which each generation has an obligation to safeguard for the next."

- They recognize only market economic values, failing to consider spiritual, aesthetic, or cultural–or even local economic–values. Information or objects may have their greatest value to indigenous peoples because of their ties with cultural identity and symbolic unity.

- They are subject to manipulation to economic interests that wield political power. *Sui generis* protection has been obtained for semi-conductor chips and "literary works" generated by computers, whereas indigenous peoples have insufficient power to protect even their most sacred plants, places, or artefacts.

- They are expensive, complicated, and time-consuming to obtain, and even more difficult to defend.

"Patents are perhaps the most famous IPRs and discussions usually degenerate into the legal quagmire of patentability. Patents are of very limited interest to most Indigenous Peoples because of difficulties in documenting 'inventions' and identifying individual inventors. Since indigenous knowledge is considered in the 'public domain', then 'uniqueness' is also problematic. Even if technical requirements for patents were satisfied, costs of filing, maintaining, monitoring, legally implementing and enforcing would be prohibitively expensive for most indigenous groups (Colchester 1994). Thus, from the perspective of Indigenous Peoples, traditional and local communities, patents are fundamentally **immoral** because they 'inevitably mitigate against those groups that are already politically and economically marginalised." (Posey and Dutfield 1996)

Other IPR instruments may be of more limited benefit to indigenous and local communities than patents. For example, know-how and trade secrets have potentially greater applicability, but also entail specialized legal advice and corresponding expenses. Appellation of origin and trademarks are relatively accessible IPR tools and can be effectively applied to products coming from indigenous lands or produced under indigenous auspices or licensing agreements (Posey and Dutfield 1996).

Copyright is easily obtained and is helpful in the protection of written texts, works of art and databases. Enforcement and monitoring of copyright can be difficult, time-consuming and costly. Scientists regularly depend upon copyright for protection of their own works and are increasingly extending that protection through co-publishing with indigenous collaborators. Copyright-like mechanisms are being attempted in some countries with Community Inventories of useful plant varieties and species. Inventories may be kept by the community under strict rules of access, or published to put registered materials into the public domain in hopes of impeding patent applications by others.

Sui Generis Options and Traditional Resource Rights

It has become increasingly clear that IPRs must be replaced with alternatives, generally known as *sui generis* options because they must be developed especially to meet the unique needs of indigenous and local communities. Despite the considerable international debate on the need for such options, there is little consensus on what they would encompass. Traditional resource rights (TRR) have been proposed as a strategy towards the development of appropriate *sui generis* systems for the protection and enhancement of indigenous and local communities (Posey et al. 1996). TRR is more of a process than a product. It is a framework for development of multiple systems and 'solutions' that reflect the diversity of contexts where *sui generis* systems are required (Posey 1994; Posey and Dutfield 1996).

'Traditional resources' are meant to include tangible and intangible assets and attributes deemed to be of value to indigenous and local communities. Resources describe all that sustain communal identity, express history, are manifest in nature and life, sustain the pride of unique heritage, maintain a healthy environment, and from which emerge sacred and spiritual values. 'Traditional' does not describe antiquity, but rather the established and respected social processes of learning and sharing knowledge that are unique to each indigenous culture. Traditional resources, therefore, can include plants, animals, and other material objects that have sacred, ceremonial, heritage, or esthetic and religious qualities, as well as economic and social values.

TRR emerge from four processes: (1) identifying 'bundles of rights' expressed in existing moral and ethical principles; (2) using rapidly evolving 'soft law' based on legally non-binding agreements, declarations and resolutions which recognize customary practice and; (3) harmonizing existing legally binding international agreements signed by Nation States; and (4) equitizing to provide marginalized indigenous, traditional and local communities with favorable conditions to impact on all levels and aspects of policy planning and implementation.

Bundles of rights

Expressions of rights can be found in a variety of places, including legally binding instruments, nonlegally binding agreements, statements and principles of international institutions, declarations and manifestos of nongovernment and peoples' organizations, codes of conduct of professional societies and businesses, and recognized local, regional or national practice. Many countries already have flexibility, built into their laws to accommodate ethnic, social, economic, and religious differences of citizens. The mechanisms that afford flexibility are guides to how new laws can evolve and where TRR can be applied nationally. Thus, by gleaning these sources and analyzing points of accommodation, certain basic overlapping principles, or bundles of rights, can be discerned. They are called 'bundles' because principles are frequently overlapping and synergistic (i.e., mutually supporting). Some basic 'bundles' are:

- human rights (individual and collective);
- right to self-determination;
- land and territorial rights;
- right to development;
- environmental integrity rights;
- religious freedom;
- prior informed consent;
- intellectual property rights;
- cultural heritage rights;
- collective rights; and
- right to privacy.

A guide to bundles of rights and to some major international agreements in which they are expressed can be found in Table 1. Some are enshrined in legally binding international agreements and are theoretically supported and enforceable by international law. Others have no legal basis but, because they come from respected sources and have broad support, may have great influence on political discussions and development of legal instruments. The lack of adequate national and international law on the environment, access and transfer of genetic resources, and protection of traditional knowledge and genetic resources, means that credible nonlegal sources with political support can significantly influence the development of *sui generis* systems. Given the current urgency and demand for such systems, the evolution of law from customary practice and informal sources–sometimes called 'soft law'–is nebulous and multifaceted, but rapid.

Soft law

Whereas treaties take the form of documents signed by governments that agree to be bound by their contents, customary law evolves over time, becoming universally accepted through continuous practice. During this process, the elements that influence, and even catalyze, the evolution of international law are sometimes referred to as 'soft law'. These elements include, *inter alia*, declarations of principles, codes of practice, recommendations, guidelines, standards, charters, resolutions, etc. that lack legal status, but enjoy strong expectations that their provisions will be respected and followed by the international community.

For example, the International Society for Ethnobiology has undertaken a 10-year consultation with indigenous and traditional peoples-as well as with its extensive international membership–to establish 'principles for equitable partnerships' (WGTRR 1997). The main objective of the process was to es-

Table 1. Traditional resource rights.

Category	Supporting agreements	
	Legally binding	Not legally binding
Human rights	ICESCR, ICCPR, CDW, CERD, CG, CRC, NLs	UDHR, DDRIP, VDPA
Right to self-determination	ICESCR, ICCPR	DDRIP, VDPA
Collective rights	ILO169, ICESCR, ICCPR	DDRIP, VDPA
Land and territorial rights	ILO169, NLs	DDRIP
Right to religious freedom	ICCPR, NLs	UDHR
Right to development	ICESCR, ICCPR, ILO169	DDHRE, DDRIP, DHRD, DICED, VDPA
Right to privacy	ICCPR, NLs	UDHR
Prior informed consent	CBD, NLs	DDRIP, DICED
Environmental integrity	CBD	DDHRE, DICED, RD
Intellectual property rights	CBD, GATT, UPOV, WIPO, NLs	
Neighboring rights	RC, NLs	
Right to enter into legal agreements, such as contracts and covenants	NLs	
Cultural property rights	UNESCO-CCP, UNESCO-WHC, NLs	
Right to protection of folklore	NLs	UNESCO-WIPO, Unesco-F
Right to protection of cultural heritage	UNESCO-WHC, NLs	UNESCO-PICC
Recognition of cultural landscapes	UNESCO-WHC	
Recognition of customary law and practice	CBD, ILO169, NLs	DDRIP
Farmers' rights		FAO-IUPGR

Legend:

CBD, UN *Convention on Biological Diversity* (1992) – 140 states parties as of 28 April 1996.

CDW, UN *Convention on the Elimination of All Forms of Discrimination Against Women* (1979) – 138 states parties as of 31 December 1994.

CERD, UN *Convention on the Elimination of all Forms of Racial Discrimination* (1966) – 142 states parties as of 31 December 1994.

CG, UN *Convention on the Prevention and Punishment of the Crime of Genocide* (1948) – 116 states parties as of 31 December 1994.

CRC, UN *Convention on the Rights of the Child* (1994) – 168 states parties as of 31 December 1994.

DDHRE, UN *Draft Declaration of Principles on Human Rights and the Environment* (1994).

DDRIP, UN *Draft Declaration on the Rights of Indigenous Peoples* (formally adopted by the UN's Working Group on Indigenous Populations in July 1994).

DHRD, UN *Declaration on the Human Right to Development* (1986).

DICED, *Draft International Covenant on Environment and Development* (1995).

FAO-IUPGR, *International Undertaking on Plant Genetic Resources* (1987 version).

GATT, *Final Document Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations* (1994).

ICCPR, UN *International Covenant on Civil and Political Rights* (1966) – 129 states parties as of 31 December 1994.

ICESCR, UN *International Covenant on Economic, Social and Cultural Rights* (1966) – 131 states parties as of 31 December 1994.

ILO169, International Labour Organisation *Convention 169 Concerning Indigenous and Tribal Peoples in Independent Countries* (1989) – 7 states parties.

NLs, national laws.

RC, *Rome Convention for the Protection of Performers, Producers of Phonograms and Broadcasting Organisations* (1961) – 47 states parties as of 31 December 1994.

RD, Rio Declaration (1992).

UDHR, *Universal Declaration of Human Rights* (1948).

Unesco-CCP, *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property* (1970) – 79 states parties as of 1 January 1994.

UNESCO-F, Recommendations on the Safeguarding of Traditional Culture and Folklore (1989).

UNESCO-PICC, Declaration on the Principles of International Cultural Cooperation.

UNESCO-WHC, *Convention Concerning the Protection of the World Cultural and Natural Heritage* (1972) – 135 states parties as of 1 January 1994.

UNESCO-WHC, *Convention Concerning the Protection of the World Cultural and Natural Heritage* (1972) – 135 states parties as of 1 January 1994.

UNESCO-WIPO, *Model Provisions for National Laws on Protection of Expressions of Folklore Against Illicit Exploitation and Other Prejudicial Actions* (1985).

VDPA, UN *Vienna Declaration and Programme of Action* (1993).

WIPO, World Intellectual Property Organisation (administers international IPR agreements, such as: the *Paris Convention for the Protection of Industrial Property* (1883, revised most recently in 1967) – 129 states parties as of 31 December 1994; *Berne Convention for the Protection of Literary and Artistic Works* (1886, revised most recently in 1971) – 111 states parties as of 31 December 1994; *Madrid Agreement Concerning the International Registration of Trademarks* (1891, revised most recently in 1967) – 43 states parties as of 31 December 1994; *Lisbon Agreement for the Protection of Appellations of Origin and their International Registration* (1958, revised most recently in 1967) – 17 states parties as of 31 December 1994; *Patent Cooperation Treaty* (1970) – 77 states parties as of 31 December 1994.

tablish terms under which collaboration and joint research between ethnobiologists and communities could proceed based upon trust, transparency and mutual concerns. A list of these principles can be found in Appendix I.

Historically, soft law has been influenced mostly by legal, NGO, and business interests. Traditional resource rights, must however, be guided by indigenous, traditional and local peoples, who have their own diverse regimes to regulate access to and control over knowledge and resources. Indigenous and traditional systems are frequently more sophisticated than those based on intellectual property rights or national sovereignty:

> "Indigenous peoples possess their own locally-specific systems of jurisprudence with respect to the classification of different types of knowledge, proper procedures for acquiring and sharing knowledge, and the rights and responsibilities which attach to possessing knowledge, all of which are embedded uniquely in each culture and its language." (Four Directions Council 1996).

The Four Directions Council (1996) also warns that:

> "Any attempt to devise uniform guidelines for the recognition and protection of Indigenous peoples' knowledge runs the risk of collapsing this rich jurisprudential diversity into a single 'model' that will not fit the values, conceptions or laws of any Indigenous society. A better approach would be for the international community to agree that traditional knowledge must be acquired and used in conformity with the customary laws of the peoples concerned."

Thus an important aspect of conservation of cultural diversity is the maintenance of customary law and practice including diversity of traditional jurisprudence systems. Guiding principles for any *sui generis* system would inevitably have to follow those established in the Draft Declaration on the Rights of Indigenous Peoples developed by the UN Working Group on Indigenous Populations. The Draft Declaration on the Rights of Indigenous Peoples (DDRIP) is the most important statement of basic requirements for adequate rights and protection. Over a period of nearly two decades, the DDRIP has been developed guided by hundreds of indigenous representatives in consultation with the UN Working Group on Indigenous Populations of the Geneva Human Rights Centre. It is broadranging, thorough and reflects one of the most transparent and democratic processes yet to be seen in the United Nations. Table 2 summarizes some of the principles affirmed by the DDRIP. The complete text is found in Appendix II.

Harmonization

Government representatives in international fora are frequently unaware of commitments made by their nation in other forums. Environment and development issues, for example, are discussed independently of parallel discussions on human rights. Genetic resource access and transfer agreements are negotiated with little or no coordination with trade and commerce representatives. Food security and biodiversity conservation are debated at the same time, but in cities on different continents. As a result, most nations find little need to 'harmonize' their many agreements to present a consistent, integrated international position. A holistic approach to environment and sustainable development requires that such a harmonization process take place, and that the foundation for this process be international human rights principles and laws. Harmonization is not just desirable, it is necessary. Article 8 (*in situ* conservation) of the CBD, for example, cannot be successfully implemented without integrating human rights principles. Unless a rights-driven approach is utilized to guarantee equity, the CBD, as well as FAO and WTO, will become targets of derision and protest from Indigenous peoples and local communities.

Equitizing

Equity is not something granted by words in a Convention. The current imbalance of power and money means that real equity can only be achieved through proactive efforts by government and non-government organizations to insure effective participation of Indigenous and traditional peoples in all phases of the political and implementing process. These efforts are known as 'equitizing', and mean that funding should be provided and support given for adequate and effective participation of Indigenous peoples, traditional societies, and local communities in all international forums where issues that affect them are discussed. This same equitizing support

Table 2. Some principal rights affirmed by the Draft UN Declaration on the Rights of Indigenous Peoples, as agreed upon by the members of the Working Group on Indigenous Populations, at its eleventh session, 1993.

- Right to self-determination, representation and full participation.
- Recognition of existing treaty arrangements with Indigenous peoples.
- Right to determine own citizenry and obligations of citizenship.
- Right to collective, as well as individual, human rights.
- Right to live in freedom, peace, and security without military intervention or involvement.
- Right to religious freedom and protection of sacred sites and objects, including ecosystems, plants, and animals.
- Right to restitution and redress for cultural, intellectual, religious or spiritual property that is taken or used without authorization.
- Right to free and informed consent (prior informed consent).
- Right to control access and exert ownership over plants, animals and minerals vital to their cultures.
- Right to own, develop, control and use the lands and territories, including the total environment of the lands, air, waters, coastal seas, sea-ice, flora and fauna and other resources which they have traditionally owned or otherwise occupied or used.
- Right to special measures to control, develop and protect their sciences, technologies and cultural manifestations, including human and other genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs and visual and performing arts.
- Right to just and fair compensation for any such activities that have adverse environmental, economic, social, cultural or spiritual impact.

should be provided at national, regional and local levels. UNESCO could play a major role in this important process by providing forums for discussions of *sui generis* options of rights by indigenous and traditional peoples. It could also assist in the important task of developing dialogue between policymakers, legal experts, scientists, and community leaders.

Conclusions

Intellectual property rights (IPRs) have become important to global economic and commercial debates on aquatic resources in part because of the massive perceived potential for biotechnology. Yet, IPRs favor industrialized nations rather than bioculturally rich, developing nations. There is some hope that existing western legal structures can be adapted to enhance conservation of aquatic biodiversity and empowerment of Indigenous, traditional and local communities. Any such attempts will need to combine 'bundles of rights' from a wide range of agreements to guide newly emerging systems of international law.

The CBD, and related UNCED agreements, call for access to, protection of and benefit sharing from the use and wider application of traditional technologies and aquatic resources. However, neither enforcement mechanisms, nor, indeed, even general agreement on what to enforce, has appeared on the international scene. Existing legal and nonlegal mechanisms provide some of the ideological groundwork for protection of Indigenous and traditional peoples, but it has become increasingly obvious that *sui generis* options for collective rights are needed. These must be developed to replace IPRs with protective mechanisms that are built more upon human rights and environmental concerns than upon economic considerations.

Development of *sui generis* options provides opportunities for new dialogues, increased recognition of indigenous peoples and their knowledge, new codes of ethics and standards of conduct, socially and ecologically responsible business practices, holistic approaches to sustainability, and alternative concepts of property, ownership and value. Replacement of IPRs, guided by a rights-based traditional resource rights process can serve to catalyze this dialogue, and, indeed, promote a global consensus on how to enhance biological and cultural diversity. No matter how good any *sui generis* option might become, however, it can never replace recognition of the right to self-determination of indigenous peoples, and support of their own projects, programs and strategies to manage and conserve aquatic resources.

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Appendix I

Principles for 'Equitable Partnerships' Established by the International Society for Ethnobiology

- **Principle of Self-Determination:** This principle recognizes that indigenous peoples have a right to self-determination (or local determination for traditional and local communities) and that researchers shall as appropriate acknowledge and respect such rights. Culture and language are intrinsically connected to land and territory, and cultural and linguistic diversity are inextricably linked to biological diversity; therefore, the principle of self-determination includes: (i) the right to control land and territory; (ii) the right to sacred places; (iii) the right (to own/determine the use of/accreditation, protection and compensation for) knowledge; (iv) the right of access to traditional resources; (v) the right to preserve and protect local language, symbols and modes of expression; and (vi) the right to self-definition.
- **Principle of Inalienability:** This principle recognizes the inalienable rights of indigenous peoples and local communities in relation to their traditional lands, territories, forests, fisheries and other natural resources. These rights are both individual and collective, with local peoples determining which ownership regimes are appropriate.
- **Principle of Minimum Impact:** This principle recognizes the duty of scientists and researchers to ensure that their research and activities have minimum impact on local communities.
- **Principle of Full Disclosure:** This principle recognizes that it is important for the indigenous and traditional peoples and local communities to have disclosed to them (in a manner that they can comprehend), the manner in which the research is to be undertaken, how information is to be gathered and the ultimate purpose for which such information is to be used and by whom it is to be used.
- **Principle of Prior Informed Consent and Veto:** This principle recognizes that the prior informed consent of all peoples and their communities must be obtained before any research is undertaken. Indigenous peoples, traditional societies and local communities have the right to veto any program, project, or study that affects them.
- **Principle of Confidentiality:** This principle recognizes that indigenous peoples, traditional societies, and local communities, at their sole discretion, have the right to exclude from publication and/or to be kept confidential any information concerning their culture, traditions, mythologies or spiritual beliefs and that such confidentiality will be observed by researchers and other potential users. Indigenous and traditional peoples also have the right to privacy and anonymity.
- **Principle of Active Participation:** This principle recognizes the critical importance of communities to be active participants in all phases of the project from inception to completion.
- **Principle of Respect:** This principle recognizes the necessity for western researchers to respect the integrity of the culture, traditions and relationship of indigenous and traditional peoples with their natural world and to avoid the application of ethnocentric conceptions and standards.
- **Principle of Active Protection:** This principle recognizes the importance of researchers taking active measures to protect

and enhance the relationship of communities with their environment and thereby promote the maintenance of cultural and biological diversity.

- **Principle of Good Faith:** This principle recognizes that researchers and others having access to knowledge of indigenous peoples, traditional societies and local communities will at all times conduct themselves with the utmost good faith.
- **Principle of Compensation:** This principle recognizes that communities should be fairly, appropriately and adequately remunerated or compensated for access and use of their knowledge and information.
- **Principle of Restitution:** This principle recognizes that, where as a result of research being undertaken, there are adverse consequences and disruptions to local communities, those responsible for all undertaking of research will make appropriate restitution and compensation.
- **Principle of Reciprocity:** This principle recognizes the inherent value to western science and humankind in general from gaining access to knowledge of indigenous peoples, traditional societies and local communities and the desirability of reciprocating that contribution.
- **Principle of Equitable Sharing:** This principle recognizes the right of communities to share in the benefits from products or publications developed from access to and use of their knowledge and the duty of scientists and researchers to equitably share these benefits with indigenous peoples.

Appendix II

Un Draft Declaration on the Rights of Indigenous Peoples

As Agreed upon by Members of the Working Group on Indigenous Populations at Its Eleventh Session, 1993

Affirming that Indigenous Peoples are equal in dignity and rights to all other peoples, while recognizing the right of all peoples to be different, to consider themselves different, and to be respected as such,

Affirming also that all peoples contribute to the diversity and richness of civilizations and cultures, which constitute the common heritage of humankind,

Affirming further that all doctrines, policies and practices based on or advocating superiority of peoples or individuals on the basis of national origin, racial, religious, ethnic or cultural differences are racist, scientifically false, legally invalid, morally condemnable and socially unjust,

Reaffirming also that Indigenous Peoples, in the exercise of their rights, should be free from discrimination of any kind,

Concerned that Indigenous Peoples have been deprived of their human rights and fundamental freedoms, resulting, *inter alia*, in their colonization and dispossession of their lands, territories and resources, thus preventing them from exercizing, in particular, their right to development in accordance with their own needs and interests,

Recognizing the urgent need to respect and promote the inherent rights and characteristics of Indigenous Peoples, especially their rights to their lands, territories and resources, which derive from their political, economic and social structures, and from their cultures, spiritual traditions, histories and philosophies,

Welcoming the fact that Indigenous Peoples are organizing themselves for political, economic, social and cultural enhancement and in order to bring an end to all forms of discrimination and oppression wherever they occur,

Convinced that control by Indigenous Peoples over developments affecting them and their lands, territories and resources will enable them to maintain and strengthen their institutions, cultures and traditions, and to promote their development in accordance with their institutions, cultures and traditions, and to promote their development in accordance with their aspirations and needs,

Recognizing also that respect for Indigenous knowledge, cultures and traditional practices contributes to sustainable and equitable development and proper management of the environment,

Emphasizing the need for demilitarization of the lands and territories of Indigenous Peoples, which will contribute to peace, economic and social progress and development, understanding and friendly relations among the nations and peoples of the world,

Recognizing in particular the right of Indigenous families and communities to retain shared responsibility for the upbringing, training, education and well-being of their children,

Recognizing also that Indigenous Peoples have the right freely to determine their relationships with States in a spirit of coexistence, mutual benefit and full respect,

Considering that treaties, agreements and other arrangements between States and Indigenous Peoples are properly matters of international concern and responsibility,

Acknowledging that the Charter of the United Nations, the International Covenant on Economic, Social and Cultural Rights and the International Covenant on Civil and Political Rights affirm the fundamental importance of the right of self-determination of all peoples, by virtue of which they freely determine their political status and freely pursue their economic, social and cultural development,

Bearing in mind that nothing in this Declaration may be used to deny any peoples their right of self-determination,

Encouraging States to comply with and effectively implement all international instruments, in particular those related to human rights, as they apply to Indigenous Peoples, in consultation and cooperation with the peoples concerned

Emphasizing that the United Nations has an important and continuing role to play in promoting and protecting the rights of Indigenous Peoples,

Believing that this Declaration is a further important step forward for the recognition, promotion and protection of the rights and freedoms of Indigenous Peoples and in the development of relevant activities of the United Nations system in this field,

Solemnly proclaims the following United Nations Declaration on the Rights of Indigenous Peoples:

ARTICLES

Part I

1. Indigenous Peoples have the right to the full and effective enjoyment of all human rights and fundamental freedoms recognized in the Charter of the United Nations, the Universal Declaration of Human Rights and international human rights law.
2. Indigenous individuals and peoples are free and equal to other individuals and peoples in dignity and rights, and have the right to be free from any kind of adverse discrimination, in articular that based on their indigenous origin or identity.
3. Indigenous Peoples have the right of self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development.
4. Indigenous Peoples have the right to maintain ana strengthen their distinct political, economic, social and cultural characteristics, as well as their legal systems, while retaining their rights to participate fully, if they so choose, in the political, economic, social and cultural life of the State.
5. Every Indigenous individual has the right to a nationality.

Part II

6. Indigenous Peoples have the collective right to live in freedom, peace and security as distinct peoples and to full guarantees against genocide or any other act of violence, including the removal of indigenous children from their families and communities under any pretext. In addition, they have the individual rights to life, physical and mental integrity, liberty and security of person.
7. Indigenous Peoples have the collective and individual right not to be subjected to ethnocide and cultural genocide, including prevention of and redress for:

(a) Any action which has the aim or effect of depriving them of their integrity as distinct peoples, or of their cultural values or ethnic identities;

(b) Any action which has the aim or effect of dispossessing them of their lands, territories or resources;

(c) Any form of population transfer which has the aim or effect of violating or undermining any of their rights;

(d) Any form of assimilation or integration by other cultures or ways of life imposed on them by legislative, administrative or other measures;

(e) Any form of propaganda directed against them.

8. Indigenous Peoples have the collective and individual right to maintain and develop their distinctive identities and characteristics, including the right to identify themselves as indigenous and to be recognized as such.
9. Indigenous Peoples and individuals have the right to belong to an indigenous communitys or nation, in accordance with the traditions and customs of the community or nation concerned. No disadvantage of any kind may arise from the exercise of such a right.
10. Indigenous Peoples shall not be forcibly removed from their lands or territories. No relocation shall take place without the free and informed consent of the indigenous peoples concerned and after agreement on just and fair compensation and, where possible, with the option of return.
11. Indigenous Peoples have the right to special protection and security in periods of armed conflict. States shall observe international standards, in particular the Fourth Geneva Convention of 1949, for the protection of civilian populations in

circumstances of emergency and armed conflict, and shall not:

(a) Recruit Indigenous individuals against their will into the armed forces and, in particular, for use against other Indigenous Peoples;
(b) Recruit Indigenous children into the armed forces under any circumstances;
(c) Force Indigenous individuals to abandon their lands, territories or means of subsistence, or relocate them in special centers for military purposes;
(d) Force Indigenous individuals to work for military purposes under any discriminatory purposes.

Part III

12. Indigenous Peoples have the right to practice and revitalize their cultural traditions and customs. This includes the right to maintain, protect and develop the past, present and future manifestations of their cultures, such as archaeological and historical sites, artifacts, designs. ceremonies, technologies and visual and performing arts and literature, as well as the right to the restitution of cultural, intellectual, religious and spiritual property taken without their free and informed consent or in violation of their laws, traditions and customs.
13. Indigenous Peoples have the right to manifest, practice, develop and teach their spiritual and religious traditions, customs and ceremonies; the right to maintain, protect and have access in privacy to their religious and cultural sites; the right to the use and control of ceremonial objects; and the right to the repatriation of human remains. States shall take effective measures, in conjunction with the indigenous peoples concerned, to ensure that indigenous sacred places, including burial sites, be preserved, respected and protected.
14. Indigenous Peoples have the right to revitalize, use, develop and transmit to future generation their histories, languages, oral traditions, philosophies, writing systems and literatures, and to designate and retain their own names for communities, places and persons. States shall take effective measures, whenever any right of indigenous peoples may be threatened, to ensure this right is protected and also to ensure that they can understand and be understood in political, legal and administrative proceedings, where necessary through the provision of interpretation or by any other appropriate means.

Part IV

15. Indigenous children have the right to all levels and forms of education of the State. All Indigenous Peoples also have this right and the right to establish and control their educational systems and institutions providing education in their own languages, in a manner appropriate to their cultural methods of teaching and learning. Indigenous children living outside their communities have the right to be provided access to education in their own culture and language. States shall take effective measures to provide appropriate resources for these purposes.
16. Indigenous Peoples have the right to have the dignity and diversity of their cultures, traditions, histories and aspirations appropriately reflected in all forms of education and public information. States shall take effective measure, in consultation with the Indigenous Peoples concerned, to eliminate prejudice and discrimination and to promote tolerance, understanding and good relations among Indigenous Peoples and all segments of society.
17. Indigenous Peoples have the right to establish their own media in their own languages. They also have the right to equal access to all forms of non-indigenous media. States shall take effective measures to ensure that State-owned media duly reflect indigenous cultural diversity.
18. Indigenous Peoples have the right to enjoy fully all rights established under international labor law and national labor legislation. Indigenous Peoples have the right not to be subjected to any discriminatory conditions of labor, employment or salary.

Part V

19. Indigenous Peoples have the right to participate fully, if they so choose, at all levels of decision making in matters which may affect their rights, lives and destinies through representatives chosen by themselves in accordance with their own procedures, as well as to maintain and develop their own indigenous decisionmaking institutions.
20. Indigenous Peoples have the right to participate fully, if they so choose, through procedures

determined by them, in devising legislative or administrative measures that may affect them.
States shall obtain the free and informed consent of the peoples concerned before adopting and implementing such measures.

21. Indigenous Peoples have the right to maintain and develop their political, economic and social systems, to be secure in the enjoyment of their own means of subsistence and development, and to engage freely in all their traditional and other economic activities. Indigenous Peoples who have been deprived of their means of subsistence and development are entitled to just and fair compensation.
22. Indigenous Peoples have the right to special measures for the immediate, effective and continuing improvement of their economic and social conditions, including in the areas of employment, vocational training and retraining, housing, sanitation, health and social security.
Particular attention shall be paid to the rights and special needs of indigenous elders, women, youth, children and disabled persons.
23. Indigenous Peoples have the right to determine and develop priorities and strategies for exercising their right to development. In particular, Indigenous Peoples have the right to determine and develop all health, housing and other economic and social programs affecting them and, as far as possible, to administer such programs through their own institutions.
24. Indigenous Peoples have the right to their traditional medicines and health practices, including the right to the protection of vital medicinal plants, animals and minerals. They also have the right to access, without any discrimination, to all medical institutions, health services and medical care.

Part VI

25. Indigenous Peoples have the right to maintain and strengthen their distinctive spiritual and material relationships with the lands, territories, waters and coastal seas and other resources which they have traditionally owned or otherwise occupied or used, and to uphold their responsibilities to future generations in this regard.
26. Indigenous Peoples have the right to own, develop, control and use the lands and territories, including the total environment of the lands, air, waters, coastal seas, sea-ice, flora and fauna and other resources which they have traditionally owned or otherwise occupied or used. This includes the right to the full recognition of their laws, traditions and customs, land-tenure systems and institutions for the development and management of resources, and the right to effective measures by States to prevent any interference with, alienation of or encroachment upon these rights.
27. Indigenous Peoples have the right to the restitution of the lands, territories and resources which they have traditionally owned or otherwise occupied or used; and which have been confiscated, occupied, used or damaged without their free and informed consent. Where this is not possible, they have the right to just and fair compensation. Unless otherwise freely agreed upon by the peoples concerned, compensation shall take the form of lands, territories and resources equal in quality, size and legal status.
28. Indigenous Peoples have the right to the conservation, restoration and protection of the total environment and the productive capacity of their lands, territories and resources, as well as to assistance for this purpose from States and through international cooperation. Military activities shall not take place in the lands and territories of Indigenous Peoples, unless otherwise freely agreed upon by the peoples concerned. States shall take effective measures to ensure that no storage of hazardous materials shall take place in the lands and territories of Indigenous Peoples. States shall also take effective measures to ensure, as needed, that programs for monitoring, maintaining and restoring the health of Indigenous People, as developed and implemented by the peoples affected by such materials, are duly implemented.
29. Indigenous Peoples are entitled to the recognition of the full ownership, control and protection of their cultural and intellectual property.
They have the right to special measures to control, develop and protect their sciences, technologies and cultural manifestations, including human and other genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs and visual and performing arts.

30. Indigenous Peoples have the right to determine and develop priorities and strategies for the development or use of their lands, territories and other resources, including the right to require that States obtain their free and informed consent prior to the approval of any project affecting their lands, territories and other resources, particularly in connection with the development, utilization or exploitation of mineral, water or other resources. Pursuant to agreement with the Indigenous Peoples concerned, just and fair compensation shall be provided for any such activities and measures taken to mitigate adverse environmental, economic, social, cultural or spiritual impact.

Part VII

31. Indigenous Peoples, as a specific form of exercising their right to self-determination, have the right to autonomy or self-government in matters relating to their internal and local affairs, including culture, religion, education, information, media, health, housing, employment, social welfare, economic activities, land and resources management, environment and entry by non-members, as well as ways and means for financing these autonomous functions.
32. Indigenous Peoples have the collective right to determine their own citizenship in accordance with their customs and traditions. Indigenous citizenship does not impair the right of Indigenous individuals to obtain citizenship of the States in which they live. Indigenous Peoples have the right to determine the structures and to select the membership of their institutions in accordance with their own procedures.
33. Indigenous Peoples have the right to promote, develop and maintain their institutional structures and their distinctive juridical customs, traditions, procedures and practices, in accordance with internationally recognized human rights standards.
34. Indigenous Peoples have the collective right to determine the responsibilities of individuals to their communities.
35. Indigenous Peoples, in particular those divided by international borders, have the right to maintain and develop contacts, relations and cooperation, including activities for spiritual, cultural, political, economic and social purposes, with other peoples across borders.

    States shall take effective measures to ensure the exercise and implementation of this right.
36. Indigenous Peoples have the right to the recognition, observance and enforcement of treaties, agreements and other constructive arrangements concluded with States or their successors, according to their original spirit and intent, and to have States honor and respect such treaties, agreements and other constructive arrangements. Conflicts and disputes which cannot otherwise be settled should be submitted to competent international bodies agreed to by all parties concerned.

Part VIII

37. States shall take effective and appropriate measures, in consultation with the Indigenous Peoples concerned, to give full effect to the provisions of this Declaration. The rights recognized herein shall be adopted and included in national legislation in such a manner that Indigenous Peoples can avail themselves of such rights in practice.
38. Indigenous Peoples have the right to have access to adequate financial and technical assistance, from States and through international cooperation, to pursue freely their political, economic, social, cultural and spiritual development and for the enjoyment of the rights and freedoms recognized in this Declaration.
39. Indigenous Peoples have the right to have access to and prompt decision through mutually acceptable and fair procedures for the resolution of conflicts and disputes with States, as well as to effective remedies for all infringements of their individual and collective rights. Such a decision shall take into consideration the customs, traditions, rules and legal systems of the Indigenous Peoples concerned.
40. The organs and specialized agencies of the United Nations system and other intergovernmental organizations shall contribute to the full realization of the provisions of this Declaration through the mobilization, *inter alia*, of financial cooperation and technical assistance. Ways and means of ensuring participation of Indigenous Peoples on issues affecting them shall be established.

41. The United Nations shall take the necessary steps to ensure the implementation of this Declaration including the creation of a body at the highest level with special competence in this field and with the direct participation of Indigenous Peoples. All United Nations bodies shall promote respect for and full application of the provisions of this Declaration.

Part IX

42. The rights recognized herein constitute the minimum standards for the survival, dignity and well-being of the Indigenous Peoples of the world.
43. All the rights and freedoms recognized herein are equally guaranteed to male and female Indigenous individuals.
44. Nothing in this Declaration may be construed as diminishing or extinguishing existing or future rights Indigenous Peoples may have or acquire.
45. Nothing in this Declaration may be interpreted as implying for any State, group or person any right to engage in any activity or to perform any act contrary to the Charter of the United Nations.

Institutional Factors Relating to Aquatic Genetic Resources

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ABSTRACT

Various international mechanisms have come into existence to consider the problems of conservation of genetic resources and biological diversity. These have drawn attention to the issues and have provided moral authority for actions at regional and national levels. While there is a need for action at the regional level to conserve and to manage transboundary species in both inland and marine waters, such mechanisms have been slow to arise and are generally ineffective. The real power to manage and conserve natural resources lies with national authorities. While there have been real changes in attitude to these issues in the last decade, the persistence of complex social interactions between the various government and nongovernment interests has made definition of policies difficult. Solutions to the current confusion lie in clear assignment of responsibility and in education. Three major issues dominate debates at all levels: (1) equity and trade; (2) preservation as opposed to use; and (3) financing national and international initiatives. There is a clear need for more coherent approaches to policymaking on these issues by the rationalization of institutions at international, regional and national levels.

Introduction

This conference draws attention to the genetic and biodiversity aspects of the two major domains in fisheries-capture fisheries and aquaculture. In both sectors, threats are perceived to long-term human well being from shorter-term strategies aimed at providing more food for current populations. Many of the concerns are moral, aesthetic, social and economic. At the same time, the increase in fishing power and human capacity to impact fish stocks and aquatic environments seriously, together with a growing capability to modify organisms genetically, can pose threats to the sustainability of resources. In general, the capacity of present technology to intervene and to influence the genetic makeup of individual organisms, populations and ecosystems has seemingly far outstripped the capacity of societies to interpret, to assimilate and to control these advances. While much of the current dialogue is devoted to trying to resolve concerns which often impinge on morality and public value systems, urgent decisions are also required on a number of biological issues which have potentially permanent detrimental consequences. Concerns seem to resolve themselves into three broad categories: (1) concerns as to the fate of individual organisms, communities and ecosystems; (2) concerns as to impacts on human diet and health; and (3) concerns as to how to share the benefits of the emerging technologies.

At the level of the global environment, such concerns were the driving force behind the convening in 1992 of the United Nations Conference on the Environment and Development and the formulation of its Agenda 21, in particular Chapters 15 (Conservation of biodiversity) and 17 (Protection of the oceans) (United Nations 1993). At the same time, the Convention on Biodiversity was being formulated and accepted to provide guidelines for the conservation of biodiversity (UNEP 1994). In the field of fisheries, the parlous states of most of the world's inland and marine living aquatic resources, together with the polemics surrounding certain types of aquaculture have led to a series of international initiatives. These culminated in the formulation and acceptance by the FAO Committee on Fisheries (COFI) of a Code of Conduct for Responsible Fisheries (FAO 1995a). FAO had been pursuing an independent course for a number of years prior to these processes in that it had set up a Commission on Plant Genetic Resources in 1983 to provide a global forum for discussions. In response to the growing concerns of member countries about other forms of agricultural biodiversity and genetics this Commission was changed in 1996 into the Commission on Genetic Resources for Food and Agriculture (CGRFA).

The meetings of these various bodies revealed the inadequacies of existing political approaches and institutions for addressing the various issues involved. That this inadequacy exists is hardly surprising as concerns about biodiversity and genetics are extremely recent, having emerged as issues only in the last twenty years or so. Impatience and cynicism at the apparent slowness of reaching decisions in the international fora and at the vacillation often shown in these bodies is thus probably misplaced. Essentially, humanity is attempting to come to grips with extremely complex issues that strike at the base of many of the institutions that have been developed historically relating to natural resources, food and the landscape. Part of the response has been for a proliferation of fora driven by the need for new approaches to deal with new problems, the impotence of existing mechanisms and conflicts among interests. This paper explores existing frameworks for the governance of aquatic genetic resources and the needs for future international and national mechanisms if the various concerns are to be adequately addressed.

Institutions

International

The major world conferences mentioned above cannot be viewed as institutions in themselves. Two bodies have, however, emerged from them as the major international fora for discussion of these issues: The CGRFA and the Conference of Parties to the Convention on Biological Diversity (CBD). Each of these maintains a Secretariat, one operating under FAO and the other under a Secretariat within the United Nations Environment Programme (UNEP). Each Secretariat has been assigned a significant data gathering function. The main role of the original conferences was to heighten international and national awareness of problems, and to recommend frameworks for further action. Subsequent meetings have a more important function in setting guidelines and promoting international agreements. With the exception of the CBD, these are not legally binding on their signatories.

During the international debate on these topics, two main polarizations emerged which are now central to the process:

a) The question of equity is central to both bodies, particularly with regard to the relative roles of developing and developed countries. Although intangible benefits such as biodiversity may be shared aesthetically as part of the common human heritage, it is more usual to view such sharing in terms of money. The common view, derived mainly from the use of plants by humans is that the developing world, as the main center of biodiversity, is supplying the majority of the genetic material whereas the developed world is supplying the bulk of the technological know-how. Until now, developed countries have reaped the major part of the financial benefit from these transactions and mechanisms are advocated, and actively sought, to ensure a better distribution. This has led to prolonged debate on, and eventually acceptance of, farmers' rights to remuneration for traditional crops developed within particular communities and the right to remuneration for countries from which genetic material is exported for development. The emphasis on financial benefits is leading to a shift in public fora away from conservation towards trade. This carries with it the threat of conflicts among the CBD, the CGRFA and the World Trade Organization (WTO) and Trade Related Intellectual Property Systems (TRIPs), in that the attempts to limit movements of organisms and genetic material by the CBD may be interpreted as hindering free trade in genetic commodities (Kapuscinski this vol.).

b) The deeper moral issue of use against conservation or preservation is central to the whole philosophy of sustainability, which has matured during this history of consultation. This tension is mainly internal to countries where the viewpoints of different national pressure groups are encapsulated in the Ministries responsible for the Environment and those responsible for agricultural production. Nevertheless, there is also an element of North-South tension here too, in that the developed countries are perceived to be attempting to impose conservationist policies on countries that need to expand their agricultural sectors at the expense of the natural environment as part of their development. This debate has been, to a certain extent, crystallized in various international fora. The Conferences of Parties (COPs) to the CBD, for example, were initially composed of delegations drawn mainly from the Ministries of the Environment, and were also attended by environmentally-oriented nongovernment organizations (NGOs). This carried with it the risk of an overly conservationist attitude in the COPs. The CGRFA, and other FAO bodies such as the Committee on Agriculture to which the CGRFA reports, are attended primarily by Ministries of Agriculture, this time with a risk of bias to the utilizationist view. Fortunately, good sense is prevailing with the inclusion of agro-biodiversity issues in the COPs, of sustainability issues in the activities of FAO, and of trade in meetings of the CBD and of the CGRFA.

The Consultative Group on International Agricultural Research (CGIAR) comprises sixteen agricultural research centers which contribute through their research to promoting sustainable agriculture for food security in the developing countries. All CGIAR centers have genetics as part of their agendas. Two centers in particular address these issues, the International Plant Genetic Resources Institute (IPGRI) for plants in general and the International Center for Living Aquatic Resources Management (ICLARM) for aquatic animals.

Other agencies exist, within and outside the United Nations system, which have strong interests in the conservation of biological resources and which usually argue heavily for their conservation, rather than for the utilization-based scenarios of FAO. These include the United Nations Environment Programme (UNEP), the World Conservation Union (IUCN), the World Wide Fund for Nature (WWF), as well as Greenpeace and other pressure groups. A second group of organizations is concerned more with utilization of genetic resources, including the WTO (formerly the General Agreement on Tariff and Trade [GATT]), or with ownership such as the World Intellectual Property Organisation (WIPO) and the Union Internationale pour la Protection des Obtentions Végétales (UPOV) (see, for example, the 1961 International Convention for the Protection of New Varieties of Plants [UPOV 1992]).

Consideration of plants has been paramount in the development of philosophies on genetic resources. FAO had been active for some years, through its Commission on Plant Genetic Resources, before the major world conferences mentioned above, and has now developed a wide range of mechanisms under its ([CGRFA]) including:

- the International Undertaking on Plant Genetic Resources;
- the International Fund for Plant Genetic Resources
- a Global Plan of Action for the Conservation and Sustainable Utilisation of Plant Genetic Resources for Food and Agriculture;
- a regular Report on the State of the World's Plant Genetic Resources for Food and Agriculture;
- a World Information and Early Warning System on Plant Genetic Resources (WIEWS);
- the International Network of *Ex Situ* Collections under the Auspices of FAO;
- a Network of *In Situ* Areas under the Auspices of FAO;
- an International Code of Conduct for Plant Germplasm Collecting and Transfer; and
- a Draft Code of Conduct on Biotechnology and Crop Related Networks.

The CGRFA is now required by the Conference of FAO to establish suitable mechanisms for considering issues relating to the genetic resources of domestic animals and aquatic animals. Because of the enormous markets for seeds and horticultural varieties and the relative ease of tracking these commodities, the private sector has also long been highly commercialized. International private sector NGOs such as the International Seed Testing Association (ISTA) and the International Seed Trade Federation/International Association of Plant Breeders (FIS/ASSINSEL) together with national groupings ensure recognition of and compensation for breeders' rights. As new fishes, naturally bred or genetically modified, appear in aquaculture there will be a need for similar structures to protect breeders and developers. This implies that attempts will be made to apply to aquatic animals many of the mechanisms and institutions that have been developed for plants, either by directly absorbing aquatic genetic resource interests within existing plant or livestock genetic institutions or by establishing homologous institutions for aquatic animals.

Relative to this, aquaculture, fisheries and their target species are in a peculiar situation, as has been discussed at three meetings (FAO/UNEP 1981; FAO 1993; Pullin and Casal 1996). First, the question of equity with respect to genetic diversity has not yet arisen to any serious degree in aquaculture and fisheries. Domesticated strains of aquatic animals are not common and the few that do exist are usually spread through the user communities without question. Taking the various strains of common carp (*Cyprinus carpio*) as examples, recompense has been sought neither for their developers nor for the countries of origin of the founder populations of products that are now widely used in aquaculture. Had this species been a plant, the developers would have built active compensation into the breeding and dissemination programs from the start. Second, there is the question of conservation of the fish stocks that are exploited by capture fisheries. Many marine and inland stocks are now recognized as overfished to the point that damage at the community, species and subspecies (stock) levels are all documented (FAO 1995b, 1997). Solutions require improved management techniques, but these have proved difficult to apply because of entrenched economic and social interests. Third, there exist attempts at fisheries rehabilitation or enhancement involving the movement of genetic material, sometimes of alien species or genotypes, which may in itself hasten the loss of remaining native genetic resources. Each of these domains requires different approaches and institutions and parallels may be drawn here between aquaculture and agriculture and between capture fisheries and forestry.

International agencies have played a valuable role in development of present attitudes to aquatic biodiversity and genetics by: (1) drawing international and national attention to the problems; (2) providing fora for debate; (3) gathering data and developing broad conceptual frameworks suitable for further development: (4) negotiating precise agreements at the international level; (5) providing a major framework for setting up networks and; (6) providing a moral sanction for the implementation of these principles. These efforts have culminated in recent years in the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stock Agreement, and in the Code of Conduct for Responsible Fisheries (FAO 1995a).

Many aquatic species are transboundary in that they occur in several countries or migrate between national jurisdictions in the sea and in international lakes and rivers. Such species need consensual management by the various countries involved. However, governments have been generally reluctant to assign legislative capacity to supranational groupings. Furthermore, many of the groupings that already exist, such as the major river basin commissions, concentrate on power generation or navigation as their primary objectives and rarely consider fisheries. The need has been recognized in recent years for more formalized structures such as regional fishery bodies and river or lake basin authorities, with greater powers to regulate environmental quality, fishing effort, stocking rates, etc. Very real powers are now being exercised by supranational economic groupings such as the European Union (EU) which can impose regionally regulations on agriculture, aquaculture and fisheries [see for example Council Regulation (EC) No. 2100/94 of 24 July on Community Plant Variety Rights (European Union 1994). Some lake basin commissions, such as the Great Lakes Commission of North America and the Commission for Lake Constance, function well as fishery regulators. Such bodies also act as valuable foci for debate and, through their economic power, can influence products and policies in nations exporting natural products to them.

National

Whatever the achievements of the international institutions the results of their deliberations remain but formulae of words until they are implemented at the national level. The power to legislate and to enforce remains a national prerogative unless assigned to some regional management authority as discussed above; for example, The UK Plant Varieties Act of 1997 (UK 1997) which empowers breeders of ornamental plants to exact fair compensation for their work. Unfortunately, however, fragmentation of opinion, the sheer number of players and the confrontational nature of much national politics make the reaching of consensus, which is translatable into legislation, exceedingly difficult.

The mechanisms and degree to which pressures are exerted in various countries depends much on their political status. Countries with strong central government will find it easier to impose conformity to an established line. However the growing number of countries with greater political freedom have greater problems in formulating and implementing national policies. In such countries, governments are usually obliged to reconcile a range of conflicting interests with their own chances of re-election, thereby reducing their effectiveness.

At the national level, questions of biodiversity no longer affect only the animal and plant production sectors and those concerned with the conservation of wildlife and the environment. They involve instead the whole of the national economy, in that the influences of many sectors apparently far removed from the natural resource, such as mining, power generation or urbanization, now appear as the prime sources of damage and threats to biodiversity. There is, thus, an immediate economic conflict between those wishing to 'develop' the landscape and those wishing to maintain it and its life forms intact. Conservation law must therefore entrain all sectors of the economy by education, motivation and, where necessary, enforcement of regulations, with penalties for noncompliance. For aquatic species, their environments, and for fisheries and aquaculture, it is now clear that the major constraints in both inland and inshore marine sectors arise from externally applied pollution and habitat degradation. A second and newly emergent factor is the power of the consumer. Here, public perceptions of what is safe or acceptable to eat or wear influence fisheries and aquaculture both in the nature of their products and in the ways in which they are obtained. In this instance, public perceptions are especially vulnerable to pressure groups, often small but highly vocal, that may bring about decisions which are not always in the best short- or long-term public interest.

At the official level, national diversity of opinion arises from an extension of arguments between preservation and use. Ministries of Agriculture, Transport or Industry emphasize utilitarian approaches to the environment whereas Ministries of Environment, Wildlife, etc. are more conservationist. In recent years, the power of this conservationist element has increased to a point where much of agriculture and fisheries risk being regulated by these interests. This may be acceptable in societies where there is currently a surplus of food. It is, however, an extremely dubious practice where human populations are inadequately nourished or where conservationist strategies can be tempered with more moderate approaches to satisfying human demands.

Governments in their turn are influenced by a formidable array of special interest groups or NGOs. These may choose to operate outside the formal framework of government mechanisms, using the law as a tool to impose their views. Examples of this are numerous including: (1) the banning of tuna imports to the USA from countries not guaranteeing safe capture methods; (2) the banning of imports and sale of shrimp raised through coastal aquaculture methods that harm the environment (mangrove destruction); (3) the prosecution of anglers in Germany for cruelty; and (4) public doubts as to the safety of genetically modified organisms (Bartley 1998).

Many of the views on which these actions were based are well-founded and it would be a mistake to dismiss as trivial sentiments that can move a considerable body of public opinion, affect commerce and the directions which legislation takes. Here it should be remembered that it is usually easier to pass a motion into law than to have it removed from the statute books when it proves inappropriate. Some groups seek to use the law to protect their interests as originators of new strains or as owners of traditional material. Such individuals are often not influential on their own but may band together into associations powerful enough to protect their interests,

Finally, it is the individual citizens of a nation who are most affected by policy and who contribute to it through their opinion. Individuals are at the same time (1) consumers who regulate the market and its products by setting the limits of what they will accept; (2) producers who grow or catch aquatic organisms, develop strains and seek to earn a living through their produce or their royalties; and (3) polluters placing their imprint on the landscape through their lifestyles. National institutions aim ultimately at sustainable supply of the needs of individuals for healthy food and at limiting the damage to the natural resources that food production and other human usage may cause.

Consensus is understandably elusive given the diversity of opinion that continues to exist in each country with regard to the aims and aspirations of its citizens concerning the natural environment, development priorities, attitudes to food and health and to the many technical problems within the realm of genetic technology and biodiversity. The current levels of debate are an inevitable part of the democratic process and as such are desirable provided that all voices may be heard and considered.

Fig. 1 gives a generalized framework classifying the various international and national institutions having a remit or interest in the field of aquatic genetic resources and biological diversity.

Conclusions

The present fragmented approach to conservation and management of aquatic genetic resources is inadequate to the needs of society and to the living world. There is a definite need, even in developed economies, to promote dialogue among all interested parties, from which an educated consensus can emerge. At the international level, this will happen, hopefully at the COPs of the CBD and meetings of its related bodies (particularly its Subsidiary Body for Scientific, Technical and Technological Advice), and at the CGRFA and its subsidiaries as all gain experience. However, many countries lack the range of institutions necessary to establish such dialogues because of financial and educational constraints.

Part of the reason for the present fragmented approach is, perhaps, that the information base is so incomplete as to permit completely different interpretations by the major protagonists. For example, estimates of extinction rate vary widely among authorities, evaluations of the impacts of transgenics in human food are highly inadequate, the social effects of adoption of new strains remain under investigated and the means to reduce fishing effort equitably are heavily contested. There is, therefore, little ground upon which consensus can be built. Given these current difficulties and uncertainties, there is a definite need for improved information collection, interpretation and dissemination. Much of the responsibility for this should continue to reside in the major international and regional organizations, through their own activities and through the establishment of networks to encourage national and individual participation. At the same time, improved collaboration between the conservationist and utilizationist viewpoints should be promoted and some rational basis should be sought to encourage trade whilst protecting rare and endangered species.

Responsibility at the national level should reside in the competent government authorities and academic institutions, with industry and commerce also encouraged as major players. However, two recent trends influence the level at which decisions are being taken. On the one hand, the trend to create international economic integrating mechanisms will shift responsibility to the supranational level. Conversely, the trend to devolve decisionmaking and executive power to the local level within nations will increase local participation. In either eventuality, there appears to be a slow eroding of the role of central national government, which will require the evolution of new types of institution. To a certain extent, the fragmentation of decisionmaking may bring considerable advances in flexibility and adaptability to local circumstance. At the same time, however, the diversity of opinion and level of awareness on global issues will complicate the situation. Here too, there is need for a mechanism for discussion and consensus-building among such groupings, without which, consistent, long-term policies will fail to emerge.

Three major types of institutions are required:

- Institutions that are responsible for the conserva tion and management of living aquatic resources. These should be responsible not only for the regulation of the fisheries and allied management practices, such as stocking and rehabilitation, but also for the control of other users of the resource. Such institutions would have roles of beyond formal regulatory bodies for fisheries, extending instead across the whole field of natural resource management. For example, if the northwestern United States and Canada implemented comprehensive protection measures for salmon conservation and use, this would impact on power generation, logging, and urban and agricultural water supply, and would fundamentally change the viability of Seattle, one of the fastest growing cities in the USA.
- Institutions that are responsible for the fair and equitable development, distribution and use of

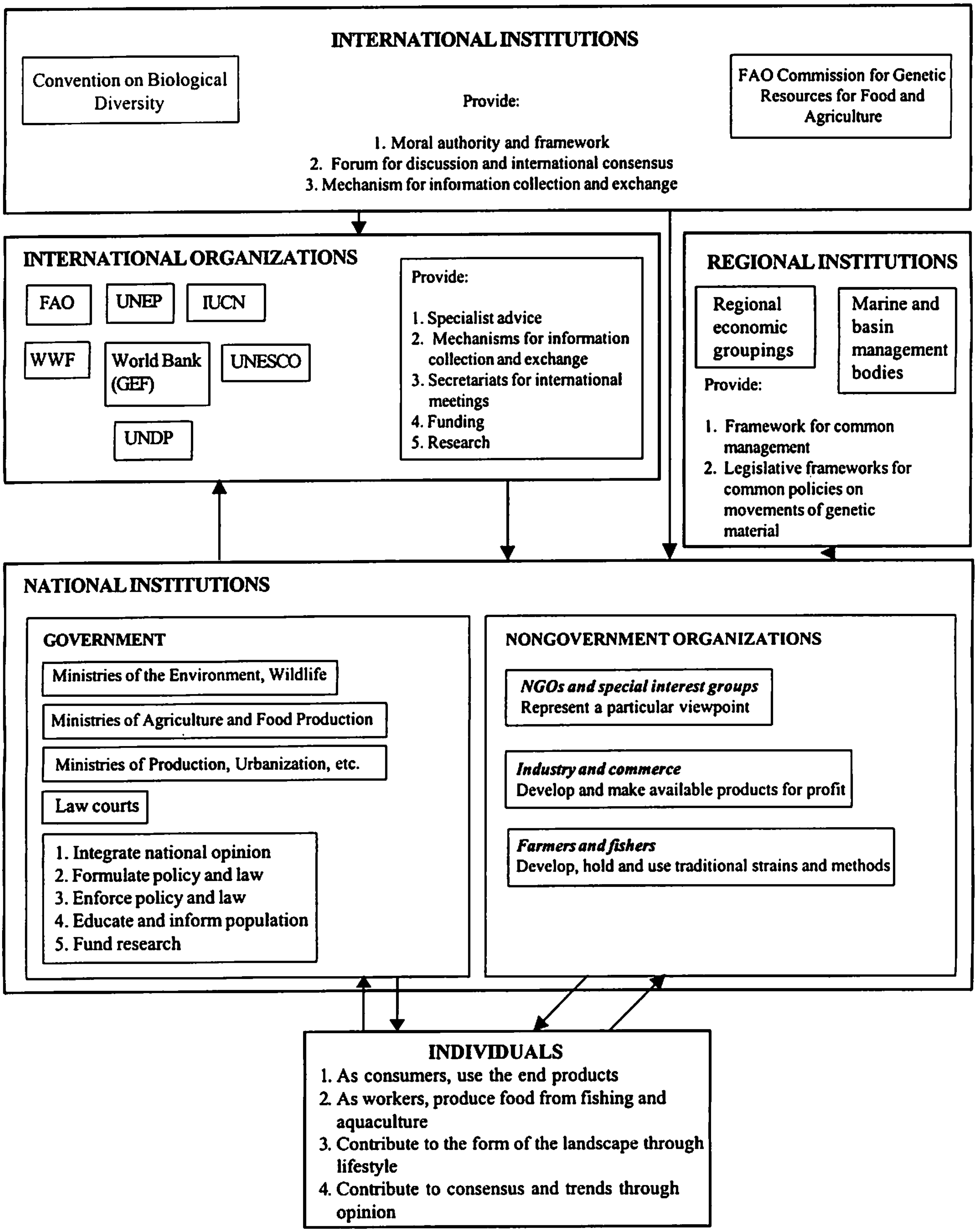

Fig. 1. Generalized framework classifying the various international and national institutions having a remit or interest in the field of aquatic genetic resources and biological diversity.

farmed strains of aquatic organisms, strains and genetically modified aquatic organisms. At the international level, a range of organizations are emerging which aim to regulate trade in these products, for example the FAO Code of Conduct for Responsible Fisheries has a section on trade, the WTO interests itself in fisheries commodities and the CBD is working on fair and equitable markets for genetic commodities. At the national level, institutions with similar mandates should build on a combination of the principles of farmers' and breeders' rights and should also be linked to institutions responsible for *in situ* and *ex situ* conservation. Some of these mechanisms already exist for plants, not only in the public (government) sector but also in the private sector where consortia of breeders collectively seek to protect their rights. Less formal local expertise residing in 'wise persons' who are frequently protagonists and representatives in local communities should also be incorporated into the system. At present, relationships between various levels (government, legal, private and communal, etc.) are far from clear. Even developed economies are still negotiating mechanisms whereby such rights can be defined and enforced. Aquaculture, in particular, has many lessons to learn in this respect and should be encouraged to explore whether it should merge its interests with those plant or domestic livestock groups or should develop its own parallel institutions.

- Institutions that are responsible for research and for information gathering and exchange. Normally these will be associated with formal international (such as the CGIAR centers) and national (universities and research institutes) institutions. However, there is a growing trend for industry and to commerce to develop and commercialize new varieties and products.

Clearly, many countries will need assistance in setting up the required institutions and in the establishment of educational and public awareness programs. The CBD seeks to assure funding for such developments. This in itself has some dangers, as the advice sought and given under these provisions will probably be biased towards the conservationist approach. There is at present no counterbalancing fund to enable the agricultural aquaculture and fisheries sectors to develop environmentally sound approaches. Given the weakness of even the developed countries in this respect, it may also prove difficult to locate an adequate supply of specialists to deliver the advice and programs of education that are needed at all levels to build up expertise for the future.

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Discussion

Correa: First, you said that international fora reflect the differences that exist at national level. My impression is that, today, for developing countries, international developments have a very strong influence on national activities. In this area, most developing countries are just reacting to the developments in international fora. Very few have the infrastructure and the people with skills to have a proactive position on these issues. There might be only a few countries in each region – for example, Brazil and Colombia in Latin America, two to four countries in Africa, India and Malaysia in Asia, etc.–but most developing countries are essentially just following what is happening. In Latin America, most governments do not have the officials needed to deal with so many issues simultaneously.

Second, I would also like to comment on the WTO. It has to have a very central role, because the system of negotiating there is influencing the whole international scenario. The World Trade Organization (WTO) has a business approach: quid pro quo. Its discussions have large implications for all countries, especially developing countries. In this framework, developed countries are able to bargain for access to markets and for environmental conservation, etc. These negotiations influence a wide range of other negotiations which are not directly related to trade.

Third, you mentioned that, for plant biodiversity, there has been developed a 'constituency.' There is a need to build such a constituency for aquatic genetic resources. There have been 'constituency builders' for plant genetic resources – Cary Fowler was one. All the groups that you mentioned should be brought together to create a strong constituency for aquatic genetic resources.

Welcomme: I agree with you completely.

A. Gupta: You refer to the experience of the plant people. However, experience is like a rear view mirror. It shows the path travelled but not the way to move forward. So, I would suggest caution in interpreting what has been done with plants. For example, FAO undertaking can be interpreted as a great success or as a great failure. This depends which side of the debate you stand on. Therefore, large negotiation–based strategies which might achieve not a single change in the way that business is done - might not be the best approach for late entrants into this particular field.

Another point, which you mentioned with reference to Europe, is that states are moving towards more and more federal structures. This is happening in India. FAO and other international organizations will have to work out how to deal with these new 'nodes' of seeking information and making decisions. We should think about a 'distributed information' approach which does not require a national node to be the only point of dispersal. InterNet technology makes this accessible. Democratization of knowledge is the essence – in as many languages as possible.

Fowler: Centralized decisionmaking is not just taking place inside centralized governments, it is also taking place in some of the biggest democracies in the world, where the decisionmaking is very limited and arbitrary and personalized in many ways. Biodiversity policies are being negotiated in numerous intergovernmental settings, from the Convention on Biological Diversity (CBD), to FAO, to the WTO and the World Intellectual Property Rights Organization. Government policies in each of these fora may actually be determined by a single person in a single ministry, without reference to other ministries, or broader concerns. Another point is that, at first, in the CBD and FAO, representation came mainly from ministries of environment, agriculture, etc. This is now shifting and ministries of foreign affairs are now sending representatives to these meetings. There is very little coordination of policy at the national level and so different fora have come to represent different interests, both internationally and nationally. So, if you look at the CBD, FAO, WTO, UPOV, and the CGIAR, etc., you will find that for areas with overlap in their mandate, there is almost no overlap in policymaking at the national level. Different people represent their governments and give conflicting views.

Welcomme: On your last point, I completely agree. On the comparison with plants, I did not mean just the formal mechanisms that are being addressed through the International Plant Genetic Resources Institute (IPGRI) and through the FAO mechanisms. I meant the people who are at the cutting edge of trading, buying and selling. I don't think that we should necessarily adopt the agribusiness approach of the big seed companies. To my view, the garden plants are a much closer analogy.

Pullin: It seems to me that 'seed supply' in aquaculture is being concentrated into fewer and fewer hands–in other words, it is beginning to mirror seed supply in agriculture. This is where a lot of genetic resources are going to be: in the hands of a few seed suppliers. I have not really understood why so many fish farmers have chosen to give the job of raising their seed to someone else, but that is the way that things have gone. Your analogy with garden plants is useful here. For example, rose breeders organizations can be private sector institutions which control, ultimately, the genetics of the industry.

Agricultural Research and the Art of Public Awareness

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ABSTRACT

Public awareness can be a valuable tool for mobilizing support for agricultural research. The importance of public awareness and educational programs has been recognized in a number of international agreements and conventions relating to environment and development. However, this has not translated into adequate support for these programs at the national or international levels. To be effective, a public awareness campaign should have clear objectives and target audiences and should be backed by simple, direct messages. The International Plant Genetic Resources Institute (IPGRI) provides an example of a global effort to raise awareness of the benefits of agricultural biodiversity among policymakers in developing countries. The IPGRI effort uses a range of tools and an approach that targets the media, NGOs and governmental officials, and builds coalitions with advocacy groups and other organizations sharing similar goals. The result is an effective and cost-efficient means of building support and understanding for genetic resources conservation.

Introduction

The great American humourist Mark Twain, who held strong views on every subject, had this to say about public opinion:

"We all do no end of feeling and we mistake it for thinking. And out of it we get an aggregation, which we consider a boon. Its name is public opinion. It is held in reverence. It settles everything. Some think it is the voice of God" (Twain 1900).

A journalist and publisher himself and a keen–if cynical–observer of human nature in the second half of the 19th Century, Twain was well aware of the power of the spoken and written word to inspire human emotions and action. Obviously he was not the first person to recognize the influence of language. Ever since human beings first learned to communicate, they have been drawn–sometimes without knowing why–to people who could touch them through spoken expression. Throughout history, the world's great leaders have had one thing in common: they have known how to take a complex message and communicate it in such a way that even the most simple-minded citizens could understand and be moved by it. Politics, the press, the world of advertising: these sectors exist and prosper because they have learned how to inspire those feelings that people mistake for thinking and Twain calls that 'public opinion'.

There are causal links between awareness, understanding, behavioral change and sustainability that are logical and self-evident, if sometimes difficult to measure. Nevertheless, until fairly recently, the agricultural research community did not fully appreciate the potential for public awareness to create greater support for its work. The feeling seemed to be that if the research products were good enough, they would sell themselves.

Public awareness smacked of self-promotion; it was a bit tacky and it certainly was not scientific. In the early heady days of agricultural research, good research products did sell themselves. But the harsh 1990s' realities have changed all that.

Following a period of sustained growth in the late 1980s, overseas development assistance (ODA) has stagnated and even declined in recent years. The prospects for future improvements are dim. Most analysts foresee a continued decline in ODA as a consequence of domestic budgetary stringency. In addition, consistent with geopolitical developments, resources are being redirected from the traditional aid focus–the developing countries of the South–to new areas such as Eastern Europe, the countries of the former Soviet Union, South Africa and the Mediterranean Basin (CGIAR 1995).

The remarkable growth of the Internet around the world has transformed us from a society of information providers into a society of communicators. The use of the Internet, in particular by nongovernmental organizations (NGOs), to create communication networks is giving rise to a new value system based on open debate and transparency. At the same time, as the lines between national, regional and international development concerns have started to blur, there has been a move to seek common solutions to global problems. Multilateral approaches to problem solving are terrifically complex–not to mention expensive–hence the need for broad popular support for scientific and development activities is particularly important.

International Policy Support for Public Awareness and Education

The public response to an initiative is based on an understanding of the circumstances that prompted that initiative, its likely impact and the potential consequences of doing nothing. Now, factors such as the world's mounting economic and development challenges and the establishment of global programs to address them, the revolutionary potential of the communications field to effect global change, and greater competition for fewer resources have prompted scientists and policymakers alike to consider how they might better promote the impact of their own work.

One consequence of this has been that the rash of international conventions, agendas and plans, which have emerged from the United Nations meetings held over the past several years, have all recognized public awareness as an important tool for mobilizing support for development initiatives.

An entire chapter of Agenda 21, an action plan arising from the United Nations Conference on Environment and Development (UNCED), is devoted to 'Promoting Education, Public Awareness and Training.' Chapter 36 outlines a number of activities that countries might undertake to meet these objectives, noting that:

> "public awareness and education are...critical for promoting sustainable development and improving the capacity of the people to address environment and development issues...and for achieving...skills and behavior consistent with sustainable development and for effective public participation in decision-making" (Robinson 1993).

Education, as defined by Agenda 21, describes a long-term process of developing how people think in order to change human behavior and lifestyles in ways that will support sustainable development. Awareness raising on the other hand, is generally a short-term activity with very specific audiences, objectives and messages. Its goal is to influence the state of knowledge of a target audience in order to promote rapid change in perception and action.

The United Nations Educational, Scientific and Cultural Organization (UNESCO)–the lead agency for the implementation of Chapter 36–recently reviewed the progress that has been made in addressing this aspect of the Agenda 21 program in the five years since UNCED. The review found that improved access to communications technologies, the impact of the mass media, globalization, and the evolution of the 'information society' have supported the implementation of Agenda 21 in these areas. Nevertheless, the review noted that environmental public awareness was still unsatisfactory. It concluded that the public education programs called for by Agenda 21 should ideally be developed by coalitions of scientists and communicators; however, until now, the flow of appropriate information from the specialist generators of the information to the nonspecialist users has been less than satisfactory.

The review also found that the political will needed to reorient human behavior towards sustainable development is still lacking. The importance of education

Today, there are more than 1 300 and the number continues to grow (FAO 1998).

While progress has been significant, there is no room for complacency. According to the FAO report, most countries do not currently have facilities for the long-term *ex situ* conservation of plant genetic resources. A large number of national genebanks were apparently built without sufficient provision for ongoing financial support. Some of these genebanks have now closed and others are in a state of deterioration. The report notes that "there are many...(genebanks)...that are perhaps incapable at present of performing the basic conservation role of a genebank (FAO 1998)". It is clear that more needs to be done to convince governments to stand by their commitments to conserve plant genetic diversity.

Established in 1987, IPGRI's public awareness program aims to promote the conservation and use of plant genetic resources at the local, national, regional and international levels, in support of the institute's goals. The program has three objectives:

- To raise awareness of the role of genetic resources in sustainable development and food security in order to influence policy at all levels;
- To inform current and potential partners of genetic resources policy issues, developments and activities worldwide; and
- To enhance the capacity of partners to build and sustain financial and institutional support for their genetic resources activities.

National policymakers are priority targets of IPGRI's public awareness program. As IPGRI is particularly committed to supporting genetic resources efforts in less developed countries, so the institute's public awareness activities are particularly directed towards policymakers in these countries.

The program uses four major strategies for trying to influence government action to conserve genetic resources. The first strategy is to gain media attention for issues relating to agricultural biodiversity. In developed countries, the media is an important vehicle for reaching government officials, who regularly read newspapers and magazines, watch television and listen to the radio. Even when the press is controlled by the government, as in many countries around the world, it is still capable of reaching a massive audience and generally provides credibility to an issue or institution.

The second strategy used by IPGRI is to enlist the support of nongovernmental organizations to rally for effective policy solutions. At the national, regional and international levels, NGOs play an important role in generating awareness and action, especially where policymaking is concerned. In many countries, NGOs have become a significant force in promoting conservation objectives and the rights of traditional indigenous groups. Coalition building with NGOs requires careful compromise: often, IPGRI and its NGO partners will not be on the same side of every issue. However, the fact that the members of the coalition can put aside most of their differences and agree to come together to promote a common message sends a very powerful signal about the importance of that message.

The third strategy of IPGRI's public awareness program is to reach and educate policymakers directly. This strategy requires knowledge of the political processes operating in a target country and an understanding of the government's pet political interests. Linking genetic resources issues to these interests is a key to making them more appealing and politically desirable to policymakers.

The final strategy is to provide national institutions with appropriate tools and technologies for use in their own information efforts. These institutions are generally well placed to identify key target audiences and to assess the public awareness needs in their countries; what they often lack are the necessary tools and skills for carrying out this work. The tools–and the messages they convey–may have to be adapted to reflect national priorities and circumstances. However, it is likely that many generic messages–such as the importance of genetic diversity and the interdependence of countries with regard to genetic resources–will prove useful in supporting national public awareness strategies and activities.

In the long-term, IPGRI seeks to enhance the capacity of national programs to use communications as a tool for securing sustainable financial and institutional support for their genetic resources activities. This approach will encourage self-sufficiency among partners and will lessen their reliance on external sources of support and thus their vulnerability. As well as through training, building communications capacity will involve fostering an "information sharing culture" among IPGRI's partners. This will include promoting a better understanding of the value and impact of their work and the importance of public awareness in the field of plant genetic resources conservation and use.

The types of product developed by IPGRI for awareness raising depend on the messages and the audience. IPGRI's web site provides a comprehensive account of the activities of the Institute and its partners. News releases, brochures, posters, fact sheets, displays, and other materials are disseminated to target audiences in various languages. The information needs of NGOs are addressed through seminars and fact sheets on specific topics of interest to them, as well as through other products intended for a wider audience. The magazine *Geneflow* reaches journalists, NGOs and policymakers throughout the world.

Conclusions

Public awareness is an important tool for mobilizing popular opinion and for generating and sustaining appropriate action and political and funding support within countries and globally. An awareness raising campaign should have clearly defined objectives and audiences and be based on clear and concise messages.

There is a tremendous scope for rationalizing efforts to raise awareness of agricultural research issues. Many international and intergovernmental organizations active in agricultural research have established public awareness programs. Building links between such programs saves time and money and avoids the duplication of effort. It also lends considerable strength to a public awareness campaign. While the primary objective of any public awareness program is to support institutional goals–a particular concern at a time when research priorities are under review and competition for funds is fierce–in every case they must start by informing public understanding of the issues underlying their work. For organizations with common research interests, an approach to public awareness that emphasizes sharing basic messages, tools and technologies could be an effective and cost efficient way to inform and influence popular understanding of the importance of their work.

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Discussion

Raymond: I want to try a couple of things. I need a volunteer. Roger!

Pullin: Very happy!

Raymond: Tell me, what do you do – tell me about your job.

Pullin: I manage a research program.

Raymond: What sort of research do you do?

Pullin: Myself? – very little.

Raymond: You're not very helpful! What is the research concerned with?

Pullin: Fish genetics.

Raymond: And what are fish genetics?

Pullin: The differences between individual fish, populations of fish, species of fish – a whole hierarchy of levels.

Raymond: And why is that important?

Pullin: Because it determines how they get along in the world and what they and their progeny can contend with, now and in the future.

Raymond: But why should I care about that? I don't really like fish! I'm sort of a 'meat person'. So, why should I support your research program?

and public awareness has received greater recognition in the years since UNCED, but this has not translated into the guaranteed long-term funding that is necessary to ensure a secure basis for public support and action to achieve development goals.

Article 13 of the Convention on Biological Diversity (CBD) also treats the subjects of public awareness and education. The CBD calls upon Parties to undertake activities that will develop public awareness and education about biodiversity at the national level and to cooperate at the international level to strengthen public awareness and education (UNEP 1994). Both the Conference of the Parties (COP) to the CBD and its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) have consistently emphasized the importance of public awareness and education to underpin development efforts.

At the fourth meeting of the COP in May 1998, the Parties stressed that the chief responsibility for the implementation of Article 13 lies with governments. International efforts can only support and supplement the work carried out by countries, not substitute for it. In Decision IV/10 B., the COP resolved that public awareness and education issues should become an integral component of all sectoral and thematic items under its program of work (Convention on Biological Diversity 1998). It invited UNESCO to consider launching a global initiative on biological diversity education, training and public awareness. Other United Nations bodies, in particular the United Nations Environment Programme (UNEP), and relevant international and regional organizations, were asked to support this initiative and to further develop their information dissemination and public awareness activities in support of the CBD's work.

The CBD's stress on national responsibilities for public awareness and education and its call for international cooperation in support of those efforts are reinforced by Global Plan of Action for the Conservation and Use of Plant Genetic Resources, the World Food Summit Plan of Action, the United Nations Framework Convention on Climate Change, and other international instruments dealing with environmental issues. But despite these international commitments to awareness raising, the general public still has much to learn about environment and development issues. Only about 20% of the general population are somewhat knowledgeable about science. That is not likely to change until people come to understand the impact that ignorance and inaction can have on their lives. That should be the goal of development communicators.

Ideally, all research institutes would have a dedicated public awareness program with adequate and secure funding and expertise of the specialists. Nevertheless, despite a growing recognition of the role that public awareness can play in generating support for research efforts, it is still underfunded. And when budgets are threatened, one of the first departments to suffer is information. These cuts are astonishingly short sighted. If an organization cannot tell the world what it is doing, how can it expect the world to lend its support?

Practical Public Awareness

The first step in the establishment of an effective public awareness effort is to identify a specific objective for that effort. The objective might be, for example, increased funding for a research activity or a national commitment to support biodiversity conservation. The next step is to discover the people and processes that are critical to meeting that objective. If the goal is to influence national policies regarding biodiversity conservation, for example, it will be necessary to understand how environmental, agricultural and development policies are determined and by whom. This can vary widely from country to country as can the roles and relative influence of the media, pressure groups and other stakeholders on the policymaking process. The target audience for a public awareness program that is aimed at influencing policy should include the groups and individuals whose goodwill and support are important to the people who make that policy.

Having identified the target audiences, the next step is to consider their distinct and often different interests and concerns. Consider the viewers of CNN, the readers of a technical journal, *Time* magazine, the *New Scientist* or *National Geographic*, Members of Parliament or the local gardening club. Each of these groups might have an interest in agricultural research but the type of information they want and their levels of sophistication are likely to vary widely.

There can also be a great difference of interests within audience groups. Donors are often key targets for public awareness efforts. Some donor organizations are largely driven by self-interest when they fund research. For these, the principal motivation is 'doing well by doing good.' Others are driven more by altruism. In this case, their continued willingness to invest in research will depend on their confidence that it offers a greater contribution to development than alternative investments.

The most basic and fundamental rule of public awareness is **Know the Audience.** The interests of the target audience (and of the individuals and subgroups within that audience) will dictate their information needs, which will in turn determine the most appropriate public awareness messages and the best tools for communicating those messages.

The most effective communicators put themselves in the shoes of the people they want to reach and try to imagine the sorts of issues they care about. Future Harvest is an example of a public awareness campaign that takes this approach. An initiative of the Consultative Group on International Agricultural Research (CGIAR), Future Harvest is concerned with the role that agricultural research plays in the lives of everyday people. Too often, the public and policymakers think of research as the means to produce a tastier tomato or an earlier maturing bush bean. While people generally recognize that such improvements are a good thing, they are unlikely to be inspired by better beans and tomatoes because they do not see how they relate to the things they really care about. The central message of Future Harvest is that improved agriculture, as a result of research, has much wider social benefits–peace, prosperity, environmental protection, health, and the alleviation of human suffering. By relating these messages to people's concerns, public awareness efforts such as Future Harvest can capture their attention.

Keeping the peoples' attention is the next task. The challenges posed by the global issues of poverty, hunger, population growth, and environmental degradation are enormously complex as is the research needed to address them. An effort to raise awareness of the importance of agricultural research will not succeed if it is based on sophisticated and intricate concepts and, so far, researchers have not been terribly successful at translating these concepts into simple and basic messages. This is in direct contrast to the simple and straightforward (if often unjustified) attacks on research by its critics, e.g., "Genetically engineered plants contaminate the environment and reduce biological diversity." Not surprisingly, these attacks are often believed because they are easier to understand.

Simple language does not mean simple thinking. It shows consideration for the audiences who lack technical knowledge and expertise. Dense, complicated sentences filled with jargon, acronyms and abstractions may seem scholarly and authoritative (and are second nature to many scientists), but if the audience does not understand the technical terms being used, they are nothing more than wasted words.

Box 1. Keys to communicating an effective message.

1. Keep your message to three points.
2. Don't use jargon or acronyms. Use clear, concise language.
3. "Humanize" your message by relating it to the lives of your audiences.
4. Use examples whenever possible.
5. Be passionate. Project your conviction in the truth of your message.
6. Relax, be yourself and have fun!

Raising Awareness of Plant Genetic Resources

The International Plant Genetic Resources Institute (IPGRI) is the world's largest international institute devoted to the study and promotion of plant genetic diversity. Its aim is to advance the conservation and use of genetic resources for the benefit of present and future generations of people. IPGRI's principal goal is the establishment of strong national systems for genetic resources conservation, in order that countries can meet their own needs and can contribute to developing effective global genetic resources systems.

The years since the UNCED have seen a significant growth in recognition among governments around the world of the value of conserving and using plant genetic diversity. This recognition has resulted in the development of international, regional and national agreements governing the conservation, use and exchange of plant genetic resources and the establishment of national priorities, plans and programs to implement them. According to the FAO's Report on the State of the World's Plant Genetic Resources, in 1985, 50 countries had national plant genetic resources programs and 25 had national committees. By 1996, these figures had grown to 74 and 59. More striking still is the growth in the number of genebanks over roughly the same period. At the end of the 1970s, there were just over 50 genebanks located in countries around the world.

Pullin: Because I would hope that you have some concern for living things, whether you eat them or not.

Raymond: Ok, but say that you are looking to me to fund your program – and there are an awful lot of living things that are important. Why should I choose yours over anything else?

Pullin: Because otherwise you might not have any fish to talk about for very much longer – in some parts of the world.

Raymond: Ok! Sorry to have put you on the spot like this, but I always take this approach. I wanted to get from you, in about 20 seconds, the message as to why it is important; why I should care? Why is it a development issue? How can it help people in developing countries?

Pullin: Well, when I was doing research in university, the only headline that I generated in 10 years was "British boffin puts fish on the pill" (Laughter).

Raymond: That's good! Just take away the message that, in the outside world, you are not talking to members of your 'club' any longer. You cannot expect the public to understand your jargon and your acronyms.

Harvey: I've been working seriously on public awareness and I'm sure that what everybody here does is extremely interesting. I'm sure that most people here have been approached by a writer or a reporter who wants to write up their work. They know that our work and our lives are interesting and that there is a lack of connection between these and the public. There need to be better fora for people like us to talk to writers and other professional communicators. A few years ago, I got some funds to prepare a short publication for lay readers called *The salmon survival guide*. We did not attach much importance to it at the time, but we have now distributed 72 000 copies. Every sector and all stakeholders asked for copies. In the last few months, I've started to write a local newspaper column in the travel section. So I can write about 800 words on, say, a trip to Brazil. People are always interested in travel, and I can work in something about migratory fish, and people read it and are interested. We should all be writing and searching out the writers who are looking for material.

Mires: Well, I've been approached by journalists on particular issues, but then they always say "Well, what's the 'title' – how do we 'title' it?" In making the title, professionals are inclined to dramatize, and the more you do this, the more you get away from the truth.

Raymond: Professionals are trying to communicate the excitement and importance of something to people who didn't know it was important.

A. Gupta: Some of the best successes that we have achieved in communication have been through competitions: competitions among children, public administrators, agriculture department people, rural working people, etc. This generates tremendous awareness because people begin to see things which are different. It is also important to relate to everyday experiences. We have stalls at cultural fairs and people come and see our databases and things. So here is a fair about knowledge. It is important to bring these things to people, not just to talk in scholarly meetings to the 'converted ones.' Finally, why could not popularize media, like films, be used to popularize topics like different cuisines, like people dying for conservation causes, etc.? This would then become a part of public consciousness.

Entis: Our company is clearly a subject for communications with various media. It is very important to know who you are speaking with. Remember that reporters are representatives of the media and have agendas–and those agendas might not be your agendas. So think about what they have in mind when they are talking to you. I was once interviewed by a British reporter at the height of the Bovine Spongiform Encephalopathy (BSE) in cattle crisis. He asked me whether there was any relationship between BSE and what we were doing with transgenic fish which were then being grown in Scotland. I spent about 15 minutes explaining the background, with as little as possible on molecular biology, to show that our work had absolutely nothing to do with BSE. The next day, the headline was "Gene company denies link to mad trout disease." (Laughter). So let this be a lesson!

Leria: I think that everyone here is aware of the need for education and public awareness. However, I'm not sure that it is the scientific community that is mainly to blame for not getting the message across. Whose fault is it when something happens like the example that we just heard? The message is given, but the person is not prepared to receive it. We cannot expect the mass media to be fully conversant with all of science, but there should be some specialization to help to get the correct message out. What is your view on that?

Raymond: The journalist is simply interested in a story. That is his or her agenda and you have to keep that in mind. There are short- and long-term approaches to this whole thing and these are mirrored in the concepts of 'Education' (which is long-term) and 'Awareness Raising' (which is short-term). Hopefully, if countries take their obligations under the Convention of Biological Diversity seriously, and institute national curricula, then 20 to 40 years from now, policymakers will be well acquainted with these issues and journalists will have grown up exposed to these curricula. Then the job will be much easier because it will involve communicating to people who already have a basis of knowledge. But in order to establish policy frameworks today, it is essential to communicate ideas in the simplest possible way.

Pullin: But the journalist is the interface here, and the journalist is not accountable for saying things that are wrong. We had an unfortunate experience at ICLARM with a journalist sent to us by the United Nations Development Programme to report on the GIFT tilapia. This person made 10 serious factual errors, including saying the fish were pink! (which they are not). There is no accountability here and it is sometimes difficult for a scientist to deal with this interface.

Entis: I face this a lot, because we deal with giving out information on controversial issues. I always request that the journalist submit the article to me for comments (not for editorial change) before it is published.

Froese: They won't always do that.

Raymond: Journalists usually work under extreme pressure and deadlines.

Welcomme: If we have a really serious message to convey, we should use professional communicators.

Raymond: Such persons are rare in most organizations. Information is usually the first area for which funding is cut.

Kapuscinski: In knowing your audience it is important to realize that there are multiple audiences and that they have their own ideas about what they want to know about. Public awareness is like extension or outreach and, to be successful, there must be a two-way dialogue. The scientists and communicators need, periodically, to ask their multiple audiences 'What do you want to know about?" The long-term implication is that this influences research and what you want to share through public awareness. When I first worked in extension, I was aware of an undercurrent of elitism which implied that technical experts know what are the most important things to communicate to everybody. It took a long time for me to develop relationships with different users and to seek their input.

Raymond: I agree, There are multiple audiences and it requires constant 'pulse taking': identify your most important audiences, and avoid an elitist attitude.

Froese: When you have something very important to communicate, consider publication in *Nature* or *Science* and this will then be picked up and reported well in other journals for the public. Second, communicators should be more active in approaching scientists to tell them that they have something really important to get across. Third, use humor to get the message out.

Adaptive Biosafety Assessment and Management Regimes for Aquatic Genetically Modified Organisms in the Environment

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ABSTRACT

Scientists have recently integrated relevant knowledge from the life sciences to develop decision support tools for case-specific assessment of hazards posed by releasing genetically modified organisms (GMOs) into the environment. Although these decision-support tools are an essential component of biosafety efforts, they do not cover all the elements of an effective biosafety regime. This paper addresses biosafety more broadly. National biosafety regimes are seriously limited in their ability to assess the ecological and social impacts of transboundary movements of GMOs in a global economy. For aquatic GMOs (including freshwater, brackishwater and marine species), national biosafety regimes alone cannot prevent or mitigate inadvertent transboundary movements posed by the widespread spatial and temporal connectivity of aquatic ecosystems. To avoid social and ecological failures of natural resource policies that are focused too narrowly on single resources, we propose the adoption of adaptive biosafety assessment and management regimes, for implementation at local, national and international levels of governance. This approach assumes that, because human knowledge about complex social-ecological systems will always be incomplete, there will be some surprises about unintended effects of released GMOs. Adaptive biosafety regimes emphasize ongoing learning from experience through interdisciplinary and transparent formulation of biosafety goals, assessment of potential hazards, design and implementation of specific biosafety policies, and ongoing monitoring for unintended effects of GMOs. We recommend an international system for liability and compensation, an international registry of diagnostic DNA markers for any traded GMO, and an international network of aquatic genetic integrity areas that would be off-limits to GMOs.

Introduction

The development of genetically modified organisms (GMOs) bearing novel genotypes and expressing novel phenotypes is a major achievement of modern biotechnology and promises to provide a variety of benefits in agriculture and other areas of human enterprise. Terms other than GMOs, such as genetically engineered and living modified organisms (GEOs and LMOs), have been used to name novel organisms produced through the application of modern biotechnologies. Each name bears a certain degree of ambiguity and is contested by different groups of people (see Penman this vol.). Research and development of aquatic GMOs–including freshwater and marine species–is an area of major activity that promises to benefit aquaculture in many ways (Hew and Fletcher 1992; Kapuscinski and Hallerman 1994). In fact, transgenic fish are likely to be among the first transgenic vertebrates to be commercialized for human food production (Anon. 1996; Entis 1997).

Owing to their novel genotypes and phenotypes, the anticipated large-scale dissemination and use of ecologically competent GMOs pose a variety of risks to the environment and to the human food supply (reviewed in ABRAC 1995; Rissler and Mellon 1996; Scientists' Working Group on Biosafety 1998). A large number of potential trait modifications raise questions about the effects of GMOs on ecosystems and human health and welfare (reviewed in Scientists' Working Group on Biosafety 1998). The challenge for biotechnology developers, consumers, policymakers and scientists is to find a balance between applications that are clearly beneficial and applications that are potentially detrimental to human health and the environment (Klinger 1998).

In many national and international negotiations on biosafety policy, there are competing views about the environmental risks of GMOs. A major factor fueling this debate is the scarcity of risk assessment experiments conducted under ecologically realistic conditions. In a number of recent experiments that had ecologically realistic designs, scientists detected unexpected and adverse effects of the GMO on other organisms. Most of the examples of ecologically appropriate tests involve crop systems because this is by far the most dominant arena of development and commercialization of GMOs in agriculture. Beneficial insects that fed on insect prey reared on transgenic insect-resistant crops exhibited increased mortality and reduced developmental time (Birch et al. 1996/7) and reproductive problems and reduced longevity (Hilbeck et al. 1998). Holmes et al. (1998) found adverse effects of an ethanol-producing transgenic microbe on wheat plants grown in sandy soils. Following reports of spontaneous hybrids and backcrosses between transgenic oilseed rape and its weedy relative, *Brassica campestris*, under field conditions (Jørgensen and Andersen 1994), Mikkelsen et al. (1996) found that transgenic, herbicide-tolerant weedlike plants, exhibiting high fertility and the same morphology and chromosome numbers as in the weedy relative, were produced in field experiments where transgenic, herbicide-tolerant, interspecific hybrids were grown together with the weedy relative. Bergelson et al. (1998) found that genetic engineering can substantially increase the probability of transgene escape, heightening the risk of producing weedy or pest populations of wild relatives. In field studies, herbicide-resistant *Arabidopsis thaliana* produced by gene transfer of a resistance allele outcrossed to wild relatives roughly 20 times more often than ordinary mutants expressing the same mutant allele as the transgenic plants.

Scientists have recently integrated relevant knowledge from the life sciences (genetics, physiology, ecology, public health, nutrition, etc.) to develop decision-support tools for case-specific assessment of potential hazards posed by releases of GMOs into the environment (ABRAC 1995; Klinger 1998; Scientists' Working Group on Biosafety 1998). In cases where the user identifies a specific biosafety hazard, these decision-support tools aim for a common goal of biosafety, but provide the user flexibility in the choice of appropriate risk management measures. Although they are an essential component of biosafety efforts, particular technical decision-support tools are not intended to cover all the elements of a comprehensive biosafety regime.

The importance of biosafety regimes to the conservation and sustainable use of biodiversity is recognized in the Convention on Biological Diversity. Its Article 14 calls upon each contracting party to require environmental impact assessments of proposed projects "that are likely to have significant adverse effects on biological diversity with a view to avoiding or minimizing such effects". Furthermore, Article 19.3 calls for parties to consider the need for and modalities of a protocol setting out procedures in the field of safe transfer, handling, and use of living modified organisms that may have an adverse effect on biodiversity and its components. At the second meeting of the Conference of the Parties in November 1995, delegates established an open-ended ad hoc Working Group on Biosafety (BSWG) to elaborate modalities of a biosafety protocol. Negotiations have been difficult and protracted, primarily due to the conflicting nature of proposed alternatives for different elements of the protocol (BSWG 1999). The ideas presented in this paper are based on current understanding of human-environment interactions, understanding that is critically important in these negotiations.

This paper addresses biosafety regimes broadly. Its point of departure is to learn from the documented failures of twentieth century policies that focused on management of single renewable natural resources in the environment. Biosafety regimes that are too narrow in their scope of environmental and social analyses will end up repeating these historical errors. Therefore, we propose a framework for biosafety regimes, called adaptive biosafety assessment and management. This framework stresses that one should expect surprises about unintended effects of GMOs because humans will never fully resolve crucial uncertainties about future behavior of complex social-ecological systems. To maximize learning and adaptive responses from experience, biosafety regimes should therefore emphasize interdisciplinary and publicly transparent assessments and monitoring of the effects of GMOs on interconnected social and environmental systems.

Lessons from Living Renewable Resource Management in the Twentieth Century

Much of the past and present management of renewable living resources has aimed at controlling a single species or single component of an ecosystem. Often the goal has been to increase or to maintain the productivity of a fish, tree, crop or other species of economic interest. These management policies typically consider very narrow temporal and spatial scales of assessment and management. This has generated a vicious cycle of focusing on a single problem, implementing a quick fix for the problem, and eventually experiencing unintended consequences (Senge 1994). Fig. 1 illustrates this cycle of fixes that backfire. A parallel path for biosafety would focus assessment and management primarily on the GMO itself while downplaying the variability in biophysical conditions in the accessible environments which, in turn, influence the environmental effects of a particular GMO. It would rely on data about performance of a given GMO in a limited number of production systems and environmental surroundings and would ignore the possibility of post-release evolutionary changes in offspring of fertile GMOs and changes in environmental conditions.

Many of the narrowly focused renewable resource policies of this century have failed to meet their objectives (Holling 1978; Gunderson et al. 1995). Two examples from the annals of fisheries management illustrate the types of mistakes that biosafety programs should try to avoid.

Pacific salmon in the Columbia River Basin

In the Columbia River Basin of North America, "the belief that humans could tinker with one part of nature (reproduction of salmon) and obtain expected results has turned out to be simplistic" (Committee on

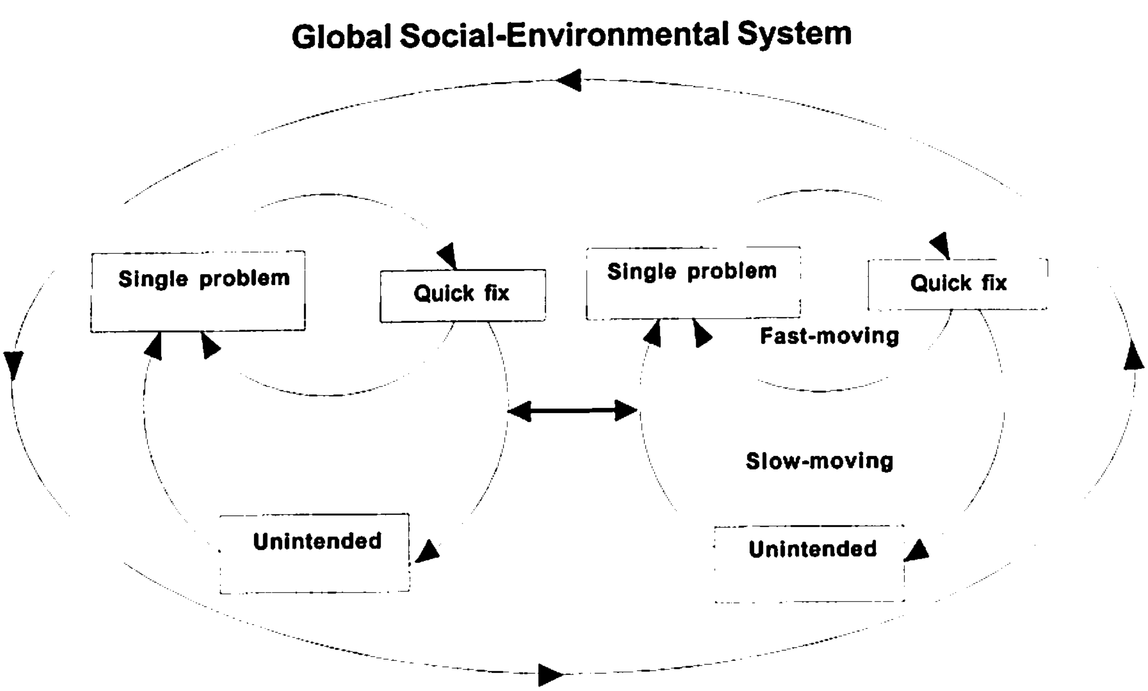

Fig. 1. The cycle of "fixes that backfire", the term carried by Senge (1994), when assessment and management of human actions in the environment focus narrowly on single problems at the expense of integrated systems analysis and on fast variables at the expense of slow variables.

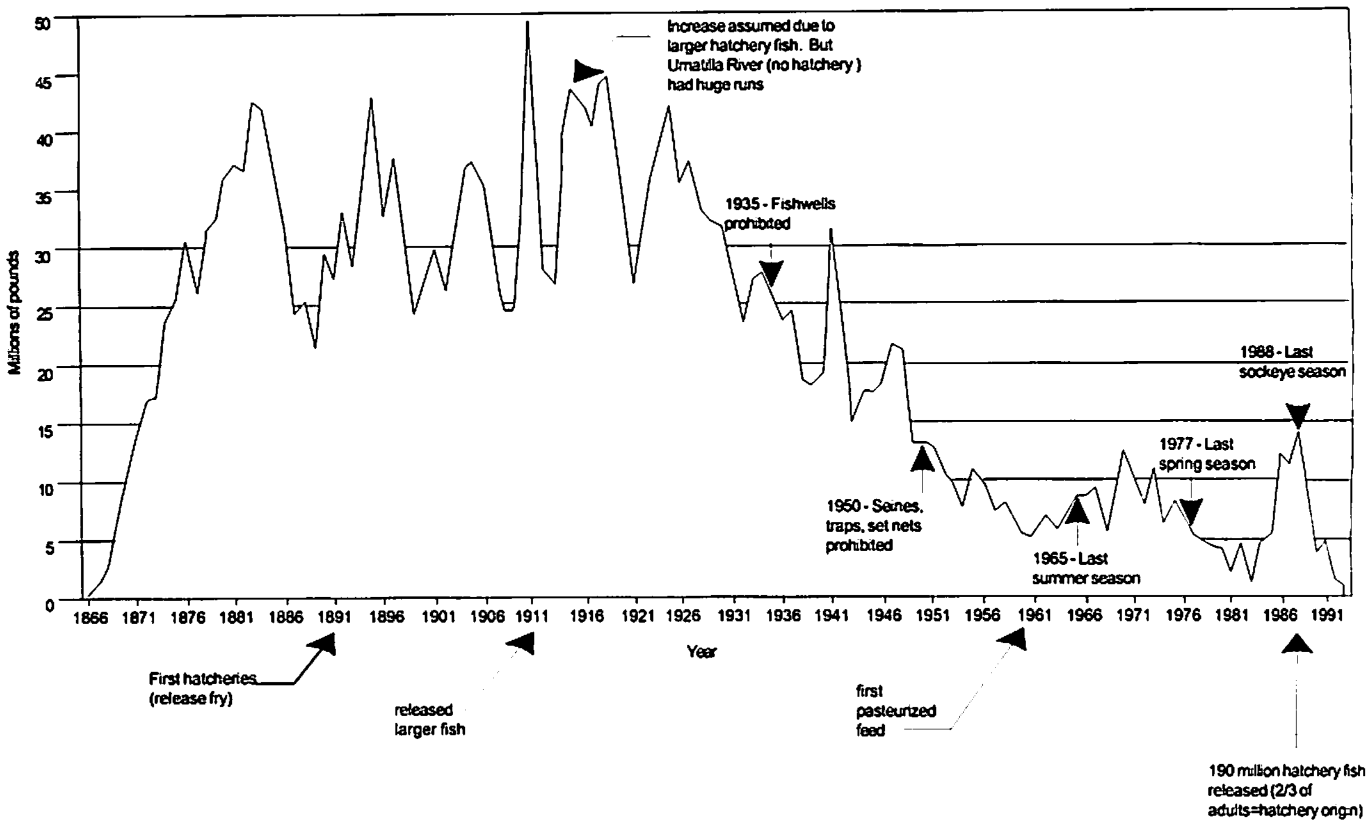

Fig. 2. Commercial landings (pounds) of salmon and steelhead in the Columbian River, 1886-1993. Reprinted with permission from: Upstream: salmon and society in the Pacific Northwest. 1996. National Academy of Sciences, National Academy Press, Washington, D.C.

Protection and Management of Pacific Northwest Anadromous Salmonids 1996). An extensive hatchery program was put in place to mitigate the negative impacts of various human activities on salmon, particularly the construction of large dams. But releases of ever increasing numbers of Pacific salmon (*Oncorhynchus* spp.) from hatcheries failed to stabilize or to increase yields of salmon from capture fisheries in the Basin (Fig. 2). In the early 1900s, tens of millions of small fry were released annually from Columbia River hatcheries, but declining catches discouraged hatchery managers and stimulated them to rear fish to a larger size before release. The assumption was that larger fish would survive better in the wild. When catches increased in 1914, fishery managers were quick to conclude that this was due to the first releases of larger hatchery fish. However, large numbers of adults returned at the same time to the Umatilla River, a tributary of the Columbia, where no hatchery fish had been released. In retrospect, it is impossible to rule out that, if there had been no releases of larger hatchery fish, catches nevertheless might have increased around 1914 due to other changes in the ocean or in freshwater habitats.

From the 1950s to the present, increased reliance on hatchery propagation has failed to counteract dramatic declines in salmon numbers in the Columbia Basin and nearby coastal waters. Technological improvements, such as feeding pasteurized and formulated diets to hatchery fish, could not stem the declines. Among the many unintended consequences, hatchery practices have contributed to losses of genetically distinct, local populations through stock transfers and the interbreeding of different broodstocks (Committee on Protection and Management of Pacific Northwest Anadromous Salmonids 1996).

Releases of hatchery salmon have led to additional unintended genetic, behavioral, and ecological changes in wild populations. Selective breeding in hatcheries has changed the spawning-run timing and age at sexual maturity in some populations (reviewed by Campton 1995). An interesting example is the case of coho (*O. kisutch*) salmon hatcheries in the lower Columbia River where improvements in hatchery diets and disease control in the 1960s triggered an unforeseen chain of events (Flagg et al. 1995). These improvements in

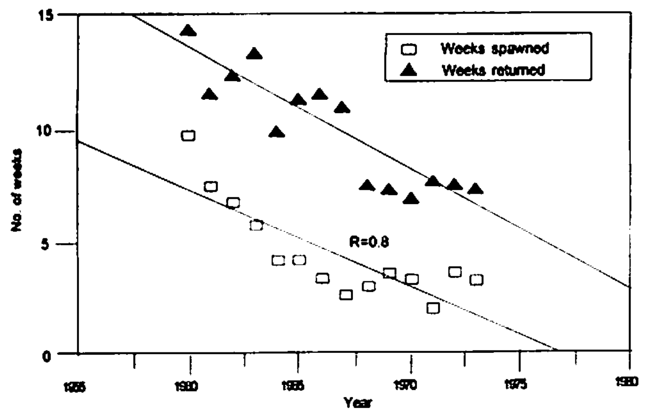

Fig. 3. Reductions in time of spawning and time of adult returns for coho salmon at five Washington Department of Fisheries resulting from preferential mating of early returning adults. Reprinted with permission from: The effects of hatcheries on nature coho salmon populations in the lower Columbian River, p. 366-375. *In* H.L. Schramm, Jr. and R.G. Piper (eds.) Uses and effects of cultured fishes in aquatic ecosystems. Am. Fish. Soc. Symp. 15. Bethesda, Maryland.

husbandry increased the survival of hatchery coho salmon and yielded larger numbers of adults returning to the hatcheries than were needed to spawn and to fill the egg capacity of available incubators. Knowing that larger hatchery-raised coho salmon survived better after release than did smaller salmon, hatchery managers spawned exclusively early returning adults so that the eggs would hatch early and allow maximum growth before releasing fish to the wild. This led to a rapid and dramatic narrowing in the period of adult returns and spawning (Fig. 3). These altered spawning regimes have produced feral hatchery coho salmon that spawn before native fish. This earlier spawning time exposes the redds (nests) of feral hatchery fish to more scouring floods in the fall. Fry hatching from these earlier seeded redds are likely to emerge before natural food supplies are abundant. This concern is supported by another study showing that hatchery-propagated subyearling coho displaced the wild coho in a stream probably due to competition between the larger hatchery fish and the smaller wild juveniles (Nickelson et al. 1986). Hatchery-adult returns in this study also exhibited a large shift from late to early spawners; but early spawners contributed very little successful natural reproduction, so fewer offspring were in the stocked stream than would have been produced if the initial stocking of hatchery fish had not occurred.

Hatchery propagated fish also pose a threat to wild populations due to the effects of domestication selection. Domestication selection is natural selection imposed by artificial rearing conditions such as environmental conditions in a hatchery or fish farm. Domestication generally results in increased fitness in the artificial environment but decreased fitness in natural environments (Price 1984; Kohane and Parsons 1988). The concern is that frequent interbreeding between partly domesticated and wild individuals could place a genetic load on the offspring, reduce individual fitness, and thus depress the wild population (Dobzhansky 1970; Hartl 1988). Numerous studies have attributed domestication selection as the cause of significant differences between hatchery propagated and wild fish in physiological and behavioral traits (see papers reviewed by Campton 1995; Berejikian et al. 1996). A common observation has been that hatchery produced fish exhibit greater aggression and swimming activity, raising the concern that wild offspring produced by hatchery x wild fish matings will exhibit increased vulnerability to predators and increased mortality in the wild (Johnsson and Abrahams 1991; Mesa 1991; Ruzzante 1994). Furthermore, observed differences in reproductive behavior between hatchery and wild fish have contributed to large declines in the breeding success of hatchery coho salmon compared to wild fish in stream environments (Fleming and Gross 1992; 1993).

As Columbia was transformed into an industrial river, salmon abundance and biodiversity in the basin declined precipitously. Today, two-thirds of returning adult salmon are of hatchery origin. Native Americans, whose livelihoods and cultures revolved around the salmon runs, have experienced dramatic social, economic and environmental changes (Committee on Protection and Management of Pacific Northwest Anadromous Salmonids 1996; Lee 1993, 1995). Commercial and recreational fishers and fishing-dependent businesses and communities have also suffered unwanted effects. A dominant and unfortunate feature of these changes has been ongoing social and political conflict regionally and nationally. These changes have also fueled political actions on the part of commercial fishers and greatly complicated diplomatic negotiations over the Pacific Salmon Treaty between the United States and Canada.

Nile perch in Lake Victoria

The case of Nile perch (*Lates niloticus*) in Lake Victoria provides another good example of unintended consequences of focusing on a single species of economic interest. Nile perch was introduced into Lake Victoria in the 1950s and early 1960s to convert so-called 'trash' haplochromines into more desirable table fish and to attract tourism by providing a sport fishery (Ribbink 1987; Miller 1989; Kudhongnia et al. 1992). Barlow and Lisle (1987) argued that the real reason for the introduction of Nile perch was to create sport fisheries. Before the introduction of the Nile perch, haplochromines comprised 30-40% of the weight of all fish landed and were consumed by the local people bordering the lake, but not by Europeans who preferred the larger fishes.

Within two decades of its introduction, Nile perch induced dramatic ecological changes in the lake. Two thirds of the 300 known cichlid taxa existing in the lake are now either extinct or thought to be extinct (Riedmiller 1994; Wanink and Goudsward 1994; Lowe-McConnell 1996). Nile perch predation on haplochromines simplified trophic levels and has been linked to the recent algal blooms observed in the lake (Goldschmidt et al. 1993).

Other dimensions of the unintended consequences of Nile perch introduction have been deforestation and the marginalization of local communities. As the perch became the dominant species in the lake, representing almost 80% of all catches, subsistence fishing was substituted by commercial fishing. Traditionally fish catches, mainly haplochromines and tilapias, were sundried. Because of the Nile perch's large size and the oily nature of its flesh, sundrying had to be substituted by smoking which, in turn, contributed to deforestation (Miller 1989; Riedmiller 1994). Although the introduction of refrigerated vans and freezing plants facilitated the export of fresh perch weighing more than 1 kg, this has not reduced deforestation. Between 1984 and 1991, for example, the number of kilns used for smoking of perch increased from 10 to over 50 (Riedmiller 1994).

Fresh perch exports have particularly affected the fish-trading women, who traditionally held the smoking and sundrying occupations. The export of fresh perch weighing more than 1 kg limited the volume of fish traded locally, leading to increased competition among women to buy fish that are not exportable. Fishers now prefer to sell their Nile perch catches to freezing plants rather than give it to their fish-trading wives (Stoneman 1990). This raises questions about how the role of women has changed within such households.

The dominance of Nile perch in Lake Victoria also has permanently altered the social relations of production in communities bordering Lake Victoria and negatively affected the livelihoods of people in local communities. Nile perch fetches only one-third of the price per pound of the native cichlids (Dudley 1994). Furthermore, catching Nile perch requires boats and gear which are beyond the means of local fishers. The local fishers are therefore being driven out of business as the fishery is concentrated in the hands of wealthier people who can afford these new tools (Riedmiller 1994). In addition, although dramatic increases have been observed in fish catches since the introduction of the Nile perch, fish consumption by people in local communities has not changed. Much of the Nile perch is exported to large cities, the Middle East and Europe (Riedmiller 1994).

Insights from failures in natural resource management

In the cases of failure examined, the processes of policy formulation, implementation and outcomes were considered to be sequential and evaluation was reduced to examining how far the original objectives had been achieved. In other words, the decisionmakers conceptualized policies as essentially linear and assumed that the object of policy analysis (i.e., species of economic interest) was situated in a fairly constant environmental-social system. These assumptions, have been however, challenged by major theoretical shifts and empirical studies in both ecological and social sciences. The 'new' ecological understanding, which emphasizes disequilibria and instability, has fundamentally altered the conventional ecological wisdom that depicted nature as tending towards stability or near-equilibrium and has asserted the inherent unpredictability of the biophysical environment (e.g., Holling 1982, 1995).

The tendency of contemporary management systems to separate policy formulation, implementation and outcomes as distinct and sequential phases of natural resource management has also been challenged by recent work in the social sciences. Long and Long (1992), for instance, have shown that policy 'outcomes' often result from factors that are not directly linked to the implementation of a particular policy. Often neglected are the important ways in which various actors reinterpret and transform policies during the implementation phase. That is, by confining implementation research "to the study of top-down planned interventions by governments, development and private institutions" (Long and Long 1992), past development policies failed to recognize the active role played by local groups in formulating their own programs of development that may contradict the interests of governments, and consequently shape the outcome of a given policy prescription. Long and Long (1992) asserted the need to go beyond the oversimplified conceptualization of policies as the "execution of an already specified plan of action with expected outcomes" and reconceptualize it "as ongoing, socially constructed and negotiated process."

These major theoretical shifts, in both ecological and social science, have led to a major rethinking of the problems that environmental policies attempt to solve (Holling 1995). They also underscore the inescapable limits to our ability to predict coevolutionary responses of social and ecological systems to human perturbations (Norgaard 1994). This new understanding has the following important implications for the design of biosafety policies:

- Interdisciplinary and integrated modes of assessment and monitoring are needed for understanding effects of GMOs in the environment.
- Biosafety assessment should pay careful attention to temporal factors. It should focus on interactions between fast phenomena (e.g., escape of GMOs into the immediate environment due to failure of confinement measures) and slow phenomena (e.g., adaptive evolution of GMOs in the environment, delayed transboundary movement of released individuals or propagules leading to unexpected establishment of a new GMO population far away from the locations of production, trade, or use). Furthermore, monitoring should focus on long-term, slow changes in driving variables (e.g., decadal changes in upwelling conditions in coastal waters that would affect the survival and dispersal of released marine GMOs).
- Biosafety assessment should also pay careful attention to spatial connections. The widespread connectivity of aquatic ecosystems combined with increased international trade of living aquatic organisms in a global economy imply a tremendous increase in the likelihood of unintentional transboundary movements of aquatic GMOs into distant ecosystems.
- Biosafety policies that ignore the evolutionary potential of GMOs in the environment and the coevolution, through feedback interactions, of human societies and the environment will fail (Norgaard 1994). Ignoring these interactions and system properties will lead to perpetual surprise, safety failures and tremendous social distrust.

For example, it is a challenge to design biosafety policies that can adequately address the potential for adverse environmental problems occurring decades after transgenic marine fish escape from an aquaculture operation and arrive in a distant coastal marine bay. Biosafety regimes need to prepare for situations in which invading transgenic fish breed in the new habitat, interact with the resident biota, possibly evolve increased fitness in response to natural selection, and displace native biota through mechanisms such as hybridization, competition and predation.

Cross-Scale Issues Posed by Transboundary Movements

Some of the developments and uses of GMOs will go forward solely within the boundaries of a sovereign nation state. Nation states, therefore, have the primary role and responsibility to oversee the safe development, transfer, handling, use and disposal of GMOs occurring wholly within their political boundaries. Not surprisingly, there is active development and debate of national biosafety policies in many nation states. With respect to oversight of aquatic GMOs, Kapuscinski and Hallerman (1994) analyzed the status of aquatic biotechnology policy in the United States and recommended congressional options for filling identified gaps. Hallerman and Kapuscinski (1995) summarized the status and gaps in national policies for a small number of countries. Additionally, the Fishery Resources and Aquaculture Service of FAO has commissioned a review of national biotechnology policies relevant to uses of aquatic GMOs in aquaculture. Bartley and Hallerman (1995) summarized the results of a questionnaire that gathered background information for this ongoing review.

National biosafety regimes alone are inadequate for addressing the biosafety challenges posed by transboundary movements of GMOs. In an increasingly global economy, dramatic increases in transboundary movements of GMOs can be expected, as a result of international transport and trade. As commercialization of aquatic GMOs increases, so will their transboundary movements through transfers between different facilities of transnational public or private organizations and through trade.

Unintended transboundary movements of GMOs pose the most difficult biosafety challenge. There will probably be significant increases in unintended transboundary movements as uses of GMOs increase across a growing variety of production systems and environmental settings. Either intentional or accidental releases of GMOs into the environment within a nation state will sometimes lead to dispersal of the GMO to suitable environments that lie outside the political boundaries of the originating nation state. This presents an enormous biosafety challenge with respect to taxa and life stages of GMOs that disperse easily. Examples include many microorganisms; seeds, spores, and other small propagules of different taxa; and the great majority of aquatic GMOs (Scientists' Working Group on Biosafety 1998).

Large-scale uses of aquatic GMOs present a high likelihood of unintended transboundary movements because of the tremendous connectivity among natural bodies of water. The transboundary nature of coastal and open marine waters is readily apparent. Perhaps less apparent is the prevalence of freshwater ecosystems that cross political boundaries (Biswas 1994). Nearly 47% of terrestrial areas of the world, excluding Antarctica, fall within international water basins, ranging from a high of 60% in Africa and South America to a low of 40% in North and Central America. Forty-four countries have at least 80% of their total area within international freshwater basins, including 20 in Africa, seven in Asia, 13 in Europe, and four in Latin America. A 1970s estimate counted 214 international rivers and lake basins, representing a 20% increase over the 1950s estimate. The value for the 1990s is probably even higher given the breakup of the former Soviet Union.

Political boundaries become irrelevant for addressing the impacts of aquatic GMOs once these enter suitable ecosystems with direct and indirect connections to transboundary waters. A suitable ecosystem is defined as one in which survival of the aquatic GMO is possible (ABRAC 1995). Survival poses the possibility that the GMO will interact with other aquatic biota, reproduce, and even disperse to other accessible and suitable ecosystems. Table 1 illustrates the variety of natural and unintentional human-mediated routes of dispersal for aquatic GMOs. Sole reliance on national or even regional biosafety regimes will be inadequate to address the resulting transboundary issues.

Components of Adaptive Biosafety Assessment and Management

We propose a framework of adaptive biosafety assessment and management as inspired by the work of Holling (1978) and his colleagues. This framework is equally relevant at all levels of political jurisdiction, from the local community to the national and international. Social understanding about safe versus dangerous applications of biotechnology and the robustness of conclusions drawn from biosafety assessments will increase if adaptive policies are implemented at all these levels. Adaptive policies require adequate mechanisms for information exchange and coordination of regulatory oversight across these different levels.

Adaptive biosafety assessment and management are based on the recognition that knowledge of the societal-environmental systems into which GMOs will enter is always incomplete and therefore surprises regarding actual effects are inevitable (Lee 1989). Biosafety regimes cannot, therefore, be decomposed simply into separate phases of knowledge generation (or research), policy design and implementation. Nor can adaptive biosafety be reduced to a single passage through these different phases. Rather, adaptive biosafety regimes involve a continual learning process that requires integrated consideration of and iterative passes through all phases. Specific biosafety policies should be designed and implemented to maximize learning from experience. This calls for the integration of environmental, social and economic dimensions of biosafety issues into all phases of adaptive biosafety assessment and management. Without such integration, biosafety regimes are doomed to failure (Holling 1978).

Adaptive biosafety regimes also need to be transparent to the general public, and to engage civil society at critical points in decisionmaking. Implementation

Table 1. Possible routes of local and global dispersal that many aquatic genetically engineered organisms (GEOs), like their microbial plant or animal relatives, are likely to follow after intentional or unintentional release, and during transport of people and goods. These examples of organisms dispersing by the various routes are not exhaustive: from Scientists' Working Group on Biosafety (1998).

I. **Hitchhiking on human-created forms of transport**

- **shipping at sea and on large lakes and rivers**
- **via ballast water and sediments**, e.g., marine larvae, shellfish, fish, arthropods, microorganisms, molluscs, algae
- **on all the surfaces and crevices of boats below the water line**, e.g., marine larvae, shellfish, fish microorganisms,sedentary marine organims, arthropods, molluscs, algae
- **on surfaces above the water line**, e.g., bacteria, bacterial and fungal spores, plant seeds
- **floating oil and gas drilling platforms**, e.g., variety of marine organisms
- **aircraft**, e.g., microorganisms, seeds, insects and other terrestrial arthropods
- **ground transport (including agricultural equipment such as tractors)**, e.g., live plants, seeds, small mammals, microorganisms insects and other terrestrial arthropods, pollen, many soil organisms and seeds when bulk soil, manure, and compost is transported
- **recreational boats and equipment**, e.g., freshwater fish and invertebrates, aquatic plants, algae, microorganisms
- **containers used to transport live organisms**, e.g., plants, fungi, seeds, fish, insects, bait buckets with fish or invertebrates
- **containers used to transport food**, including live organisms travelling with frozen foods, seeds within fresh fruits and vegetables, grain crop seeds
- **transport of crop seeds, cuttings, and nursery stock**, e.g., microorganisms, insects
- **on and in human bodies or clothing**, especially bacteria, fungi, small seeds and viruses
- **trash/refuse/garbage**, e.g., microorganisms, insects
- **navigation canals allowing active dispersal of mobile organisms**, e.g., fish, aquatic invertebrates, and plants
- **transfers of water between municipalities and regions, for domestic and industrial use and irrigation**, e.g., microorganisms, protozoa, viruses

II. **Natural routes of dispersal**

- **flowing water**, e.g., microorganisms, fish, algae, aquatic insects, arthropods, molluscs
- **subsurface flowing waters**, e.g., soil, microorganisms and invertebrates, cave organisms
- **on waterfowl and shorebirds**, e.g. microorganisms, small invertebrates, caught fish, plant seeds.
- **terrestrial vertebrates, especially mammals (fur)**, e.g., seeds, pollen, small invertebrates
- **terrestrial and flying insects**, (flies, bees, ants), e.g., seeds, pollen, seeds, microorganisms mites
- **rafting on logs and larger floating "islands" broken away from shorelines, on lakes, rivers and seas**, e.g., many kinds of terrestrial organisms
- **ocean and lake currents**, e.g. multicellular and unicellular algae, larger aquatic plants, invertebrates larvae, fish, microorgaisms
- **atmospheric circulation with subsequent deposition as rain, snow and dry fall**, e.g., bacterial and fungal cells and spores, pollen, airbornes plant seeds
- **autonomous locomotion**, e.g., flying, walking, and swimming organisms
- **tornados, cyclones, hurricane, floods**, e.g. microorganisms, seeds, insects, birds, fish shellfish, aquatic plants

of the various stages of the adaptive cycle need to involve decisionmakers, appropriate disciplinary specialists, methodologists, people with experiential knowledge about the social and environmental conditions, and all affected parties. This kind of civic engagement in the development of the knowledge base and implementation of biosafety policies is critically important to ensure that all phases of adaptive biosafety are broadly understood, built upon all relevant knowledge, and responsive to the concerns of the affected parties. Furthermore, this transparent approach maximizes the chances that people will trust the conclusions drawn from policy implementation and monitoring and thus will share in the understanding gained about biosafety. Fig. 4 represents the basic steps involved in adaptive biosafety assessment and management.

Goals

This is the stage where the overall purpose of the biosafety regime should be clearly identified and stated. Clear goals allow 'purposeful' analysis of the societal-environmental system in the next stage of the adaptive cycle. Without this clear articulation of purpose, it is impossible to determine the breadth of environmental and social factors, spatial and temporal, and the degree of detail that should be considered in subsequent phases of the adaptive cycle. Because policies to address stated goals cannot be developed and implemented in an institutional vacuum, it is also critical to identify appropriate institutional settings for addressing each goal. For instance, assessing the risks of farming transgenic fish in aquaculture operations in the Laurentian Great Lakes or the Mekong River Basin would require coordination among management agencies in state and provincial governments, federal governments of bordering nations, and intergovernmental agencies (e.g., Great Lakes Fishery Commission, Mekong River Commission). Further, a clear statement of goals and the identification of the institutional contexts for making different decision determine the necessary spatial and temporal scales of analysis.

Drawing on the ideas from many prior fora, the Scientists' Working Group on Biosafety (1998) identified four major goals of biosafety. They are to:

- determine in advance when hazards to human health and natural systems will result if any particular genetically engineered organism (GEO) is released into the environment;
- anticipate when a given GEO or any of its products(s) will be harmful if it becomes part of human foods;
- discern whether a GEO will actually yield the benefit(s) it was designed to provide; and
- make as certain as possible that hazards will not arise when GEOs are transported, intentionally or unintentionally, to different ecosystems and nations.

These exemplify the goals that should be considered in adaptive biosafety regimes at local and international scales.

Biosafety goals should address GMOs that express novel and ecologically competent traits (ABRAC 1995; Scientists' Working Group on Biosafety 1998). These organisms might be produced through a variety of methods including hybridization between species, chromosome set manipulations, gene transfer, DNA rearrangements within single organisms (synthetic genes), fusion, knockout or deletion of genes, transplantation of cellular organelles, cell fusion, nuclear transplantation, or "cloning" of multicellular organisms from cell cultures or embryos with new genes inserted in them. Presently, GMOs are produced by using genetic material already found in a living organism whereas in the future it may be possible to use genes from fossil DNA or totally new "designed" genes.

For aquatic organisms, there are compelling reasons to expand the scope of biosafety goals to include those

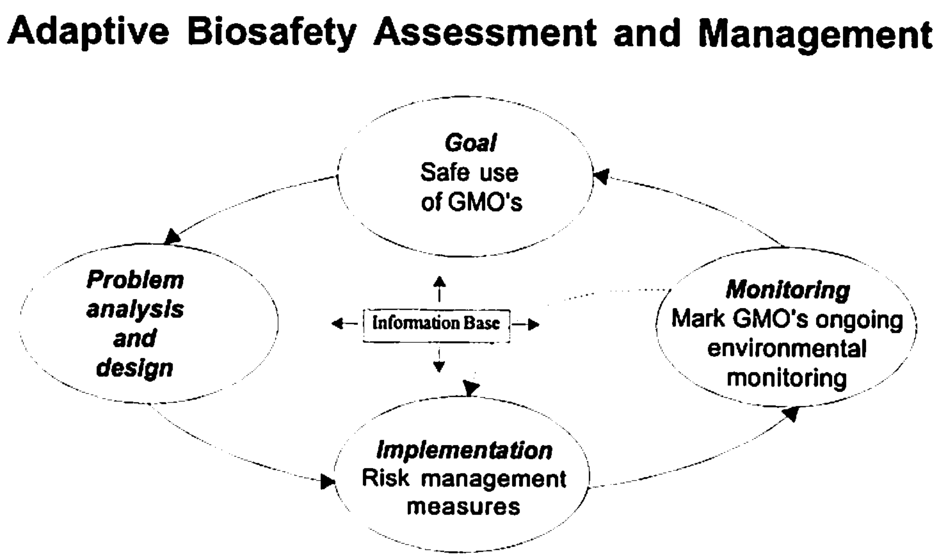

Fig. 4. The interconnected phases of adaptive biosafety assessment and mangement. These phases should be applied iteratively and across multiple spatial scales from local to global, with adequate provisions for information excahnge among people implementing biosafety policies at different scales. Reprinted with permission from: T.A. Flagg, F.W. Waknitz, D.J. Maynard, G.B. Milner and C.V.W. Mahnken. 1995. The effect of hatcheries on native coho salmon populations in the lower Columbia River, p. 366-375. *In* H.L. Schramm, Jr. and R.G. Piper (eds.) Uses and effects of cultured fishes in aquatic ecosystems. Am. Fish. Soc. Symp.15 Bethesda, Maryland.

aquatic animals and plants whose genotypes and phenotypes are altered solely by selective or captive breeding (Pullin and Bartley 1996). Most aquatic organisms thus modified are not far removed from the wildtype. When released into natural environments, they have frequently survived and proven ecologically competent, and have interbred with wild relatives of the same or closely related species. In a growing number of examined cases, selectively-bred and other captive-bred fish released into the environment have contributed to unintended genetic, behavioral or phenotypic changes in wild populations (Hindar et al. 1991; Busack and Currens 1995; Campton 1995; Committee on Protection and Management of Pacific Northwest Anadromous Salmonids 1996; Skaala et al. 1996).

Problem analysis and policy design

This stage of the adaptive biosafety cycle involves clear definition of the ecological and social problems associated with attempts to meet stated goals. It involves bringing together disciplinary specialists, policymakers, methodologists, resource users and other persons who have important experiential knowledge about the social and environmental contexts of the problems. This group considers a range of objectives, from unchecked release to a complete ban on uses of specific GMOs. Though these extremes may be unrealistic, they nonetheless provide the limits within which any realistic objective would fall; thus, they help the group to choose among policy options for testing.

This phase also involves addressing several important questions. What testing or assessment tools should be used to make predictions about potential environmental and food safety hazards of a GMO? What key indicators or driving variables of the ecosystem (e.g., suitable conditions for survival and reproduction of the GMO) and socioeconomic system (e.g., terms of global trade agreements) must be considered? How useful is current knowledge on risk assessment in formulating policies? What additional data are required?

Although there have been relatively few experiments specifically designed to test for genetic and ecological effects of GMOs under realistic ecological conditions (Regal 1994) and it is impossible to mimic the full spatial and temporal complexity and variability of ecosystems which a GMO may enter, it is feasible to conduct biosafety experiments that examine key genetic and ecological interactions between the GMO and other organisms under different environmental conditions (ABRAC 1995; Scientists' Working Group on Biosafety 1998). Initial experiments can be carried out in laboratory microcosm or mesocosm experiments (e.g., glasshouses, growth chambers, aquaria). If laboratory studies suggest that the GMO may be efficacious for the intended purpose, genetically stable, and ecologically benign, only then should confined biosafety experiments be conducted in more realistic field trials (e.g., field plots and fishponds).

The results of these confined experiments can then be used to develop quantitative or qualitative simulation models that allow testing of alternative scenarios. The work of Muir et al. (1996) provides an excellent model for the integration of well-designed risk assessment experiments with scenario exploration. Using aquarium populations of medaka (*Oryzias latipes*) as an example, they tested, separately and jointly, the four distinct mechanisms by which natural selection could increase or decrease the frequency of transgenic organisms in the wild. First, they compared the response of aquarium-reared transgenic and nontransgenic medaka in separate experiments of fecundity, sexual, viability and developmental selection. The transgenic fish had a fecundity and developmental advantage but a viability disadvantage compared to nontransgenic relatives. To explore the joint effects of these differences, data were fed into a computer model to simulate gene flow and population dynamics over hundreds of generations. Results indicate that this transgenic population would spread the transgene into wild populations and possibly be an environmental risk. Moreover, when the authors changed the starting values of fitness components and demographic variables for the transgenic and nontransgenic populations, the model generated dramatically different results. Results ranged from transgenic medaka having little effect on the wild population, to genetically swamping the wild population, and to driving the mixed population of transgenic and nontransgenic fish to extinction (Muir et al. 1996).

Such computer simulations can be used to evaluate alternative assumptions about how population dynamics, adaptive evolution, and other dynamic ecological processes might influence long-term effects of released GMOs. Computer models, however, should never be the sole basis for determining the biosafety of a GMO but they may aid in identifying important missing information.

The next step in risk assessment should be to integrate results from laboratory, field, and simulation experiments with other existing knowledge into a more comprehensive assessment framework. Good examples of tools for comprehensive assessment are the two decision-support tools that have been developed expressly to guide case-specific risk assessment and management of genetically modified or engineered organisms (ABRAC 1995; Scientists' Working Group on Biosafety 1998). Both decision-support tools guide the user through assessment of hazards posed by a specific GMO in a specific environmental context. If specific hazards are identified, they guide the user either to the decision to disallow release or to undertake risk management. Both decision-support documents have been developed through interdisciplinary and international input and through public and peer review. Another document, the International Technical Guidelines for Safety in Biotechnology (UNEP n.d.) introduces general principles of biosafety but lacks an in-depth framework for addressing the various environmental and human health factors and their interactions. Moreover, this document does not meet the need for step-by-step scientific guidance on case-specific biosafety assessment and management.

The Performance Standards for Safely Conducting Research With Genetically Modified Fish and Shellfish (ABRAC 1995) contain scientifically documented, decision-support flowcharts that aim for a common goal of biosafety while allowing flexibility in how to achieve safety. Fig. 5 summarizes the decision pathways for risk assessment and management. This tool now exists in interactive electronic versions on diskette and on the internet. It is limited to cases of smaller-scale research and development with fish, crustaceans and molluscs. Thus, it does not address the cross-scale issues involved in large-scale trade and uses of GMOs. Nor does it address aquatic organisms beyond fish and shellfish (crustaceans and molluscs) and it omits other invertebrates (e.g., tunicates, current the subjects of gene transfer research at the University of California, Santa Barbara), other aquatic vertebrates, plants and microorganisms.

The Manual for Assessing Ecological and Human Health Effects of Genetically Engineered Organisms (Scientists' Working Group on Biosafety 1998) was inspired by the Performance Standards and builds on them in some important ways. First, its decision-support paths (flowcharts) address all types of genetically engineered organisms. Secondly, it covers both environmental and human food safety. Fig. 6 summarizes the decision-support paths of this document. Regarding aquatic genetic resources, these expanded flowcharts offer two benefits. They cover additional aquatic taxa, including algae, vascular aquatic plants and aquatic microorganisms. They also cover genetically engineered organisms (e.g., genetically engineered birds, reptiles, amphibians and small mammals that feed on, transmit diseases to, or alter habitats of aquatic organisms) that would spend only part of their life in aquatic, riparian and shoreline environments but whose release might indirectly affect aquatic genetic diversity. An electronic interactive version of this document will be loaded onto the web site of the Edmonds Institute in the near future.

Environmental managers, biotechnology developers and citizens alike will need to apply the various tools discussed above in order to answer credibly questions in risk assessment. Adaptive biosafety assessment and management is predicated on an understanding that biosafety problems are situated within interconnected social and environmental systems. Thus, social and economic hazards also warrant assessment during problem analysis. To date, most risk assessments of GMOs have failed to fully address the social, economic, environmental and human health factors in an integrated manner.

Implementation

Implementation of biosafety policies should occur at the different levels at which goals are directed and problems are situated. A comprehensive set of biosafety policies would include measures for risk management (following risk assessment at the problem analysis phase), capacity building programs, national permitting of trade and uses of GMOs (see the above discussion on cross-scale issues), advanced informed agreements on transnational trade of GMOs, and an international system of liability and compensation.

Risk management

Risk management should consider a list of options for ways to reduce imposition of any identified envi-

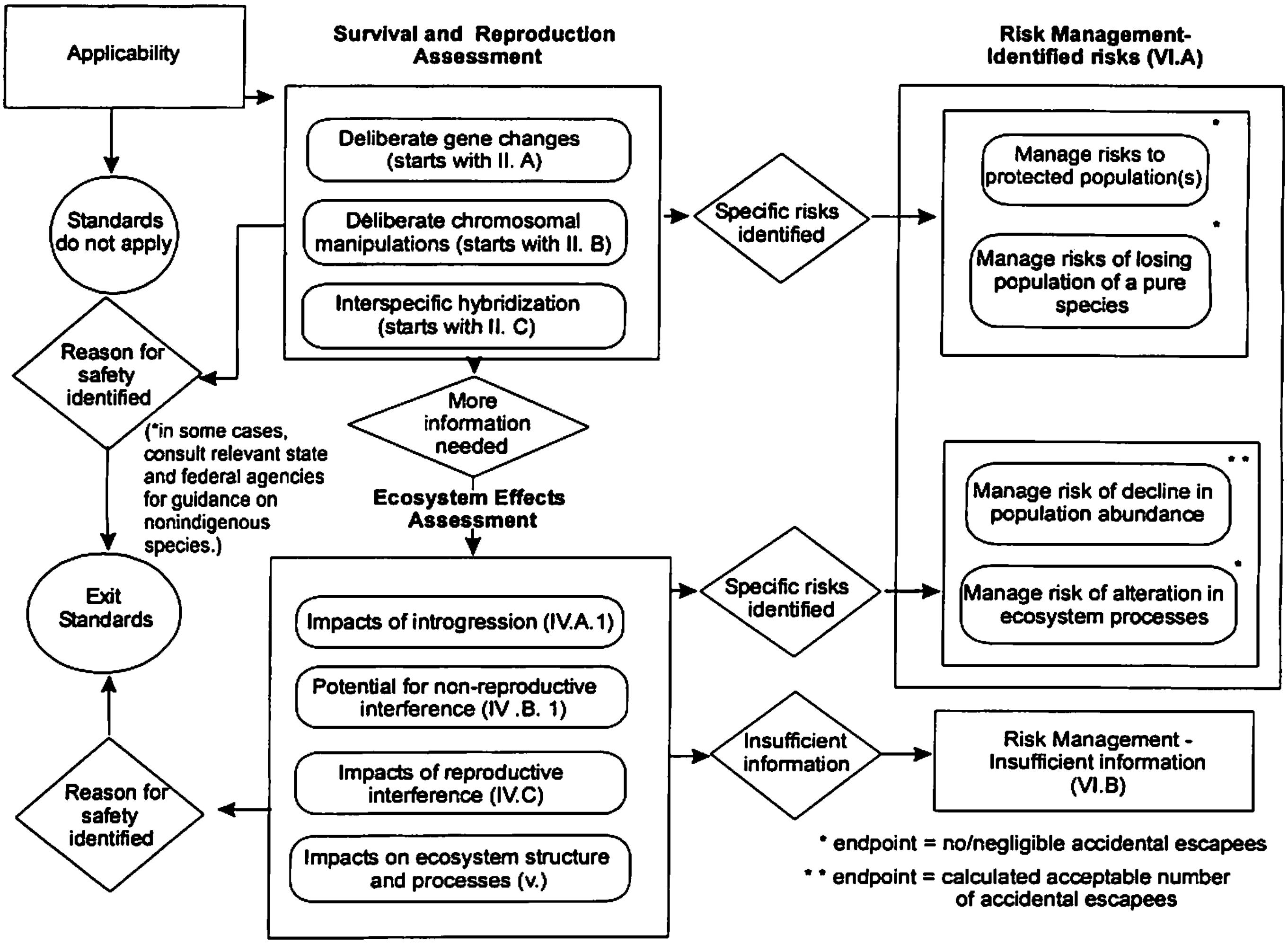

Fig. 5. Overview of the risk assessment and management pathways in the flowcharts and electronic decision-support system of the Performance Standards. These pathways exist as flowcharts on the printed version and as an interactive decision-support tool in the software version. Labels within boxes (e.g., I.A) identify the subordinate flowcharts in a given assessment pathway. The Performance Standards software or printed copies can be obtained without cost from authors Kapuscinski or Hallerman or by linking to the request section of the Performance Standards site on the Internet (www.nbiap.vt.edu/perfstands/psmain.html). This Internet address also allows running the electronic version or downloading it to local computers.

ronmental and food safety hazards. An example of risk reduction measures is the decision by AquaBounty Farms to license growout of their transgenic salmon preferably to onland recirculating aquaculture systems, or as sterile fish in cases where growers utilize net pens (Entis, this vol.). This one company operates in a limited set of societal-environmental settings. Its actions may not be a good predictor of the full range of approaches in the future when a broader variety of producers of aquatic GMOs will be operating in different societal-environmental contexts. Also, a given risk reduction measure-in this case, sterilization-will not be appropriate in all cases. Biosafety management of transgenic algae, for example, cannot rely on sterilization because most algae species have asexual modes of reproduction. Because the social and environmental systems at issue are interconnected, adaptive management should also involve development of options for reducing socioeconomic risks identified during problem analysis.

Capacity building

The aim here is to foster establishment of adaptive biosafety assessment and management at multiple jurisdictional scales, from subnational to national and

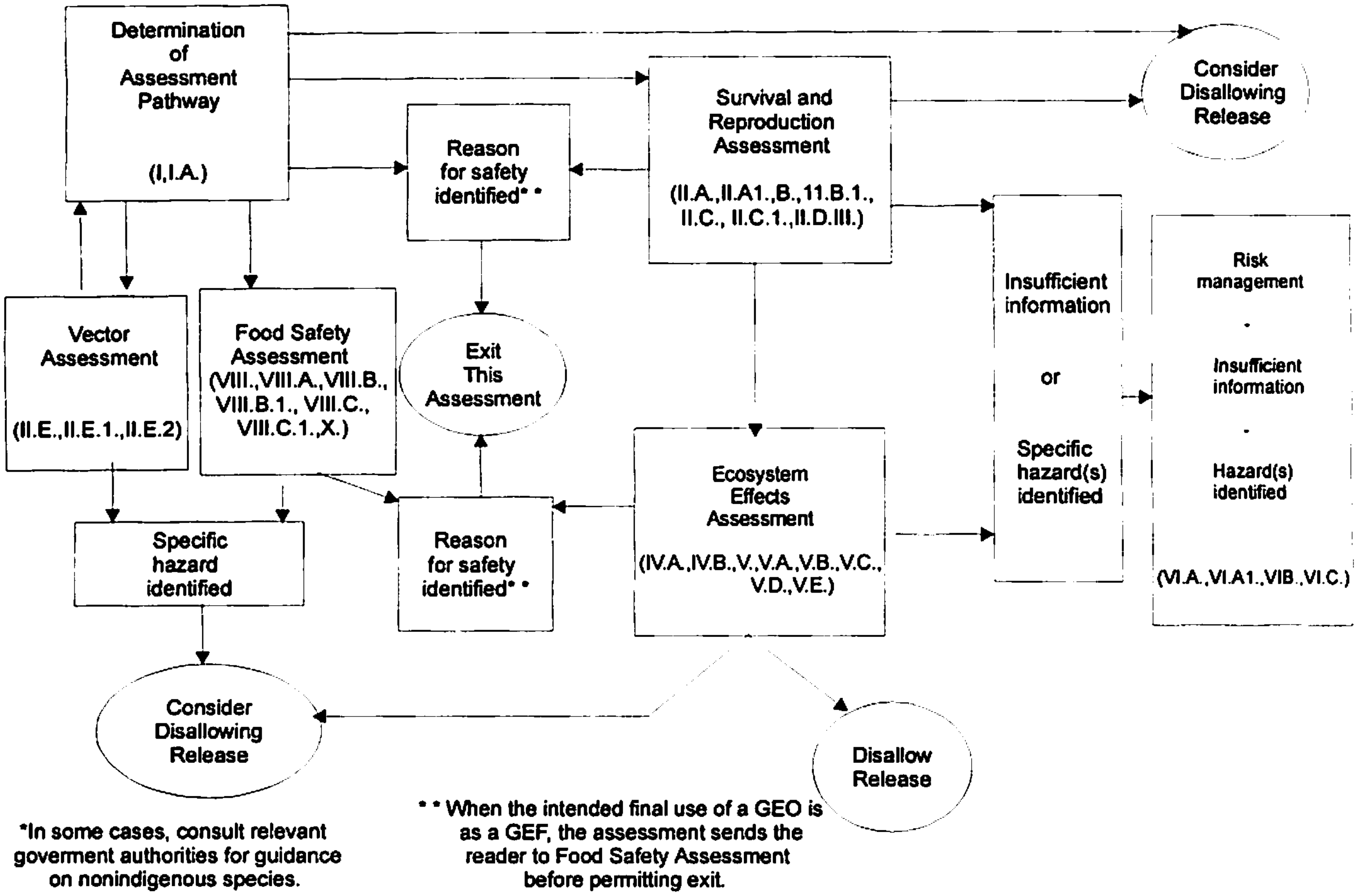

Fig. 6. Overview of the risk assessment and management pathways in *Manual for Assessing Ecological and Human Health Effects of Genetically Engineered Organisms* from Scientists' Working Group on Biosafety (Mark Wheelis, Andrew Spielman, Philip J. Regal, Deborah Letourneau, Terrie Klinger, Anne R. Kapucscinki, Conrad A. Istock, Elaine Ingham, Noman Ellstrand, Pushpa M. Bhangava and Sharon Akabas) (1998). The pathways guide case-specific assessment of possible genetic, ecological and human health hazards associated with small and large-scale uses of a particular genetically engineered organism (GEO), including genetically engineered viruses, microbes, plants, or animals, or a particular genetically engineered food (GEF). Labels within boxes (e.g., I.A) identify the subordinate flowcharts in a given assessment pathway. The Manual and an interactive version of the decision pathways will be available on the Internet in 1999 (www.Edmonds-Institute.org and linked to www.fw.umn.edu/ISEES). Reprinted with permission from the Edmonds Institute. The copyright for this flowchart remains with the Edmonds Institute.

transnational. This might involve provision of technical and financial assistance to various governments, international organizations, private companies, research and educational institutions, and other groups. As stated earlier, the understanding about safe versus dangerous applications of biotechnology and the robustness of conclusions will increase if adaptive policies are implemented at multiple levels with sufficient information exchange across levels.

Advanced informed agreements

For nation states to enter into transparent advanced informed agreements on transboundary trade of GMOs will require an international system for identification of GMOs. Modern molecular genetic techniques provide many ways to identify small DNA sequences that are diagnostic for specific groups of GMOs (see discussion on monitoring). In nearly every case, it should be possible to identify DNA sequences that do not have to reveal proprietary information about genetic sequences controlling the targeted performance traits.

Provisions for liability and compensation

At its core, an adaptive approach requires tremendous humility regarding the limits of human understanding and predictive powers. To be truly adaptive, a biosafety regime must therefore anticipate serious mistakes in decisions to release apparently benign GMOs. This implies a need for mechanisms to insure and compensate people who experience harm as a consequence of transboundary movements of a GMO. Harm should include damage to biodiversity, ecological health, human health or human welfare. The GMOs that pose a high probability of causing harm should be much easier to identify than those that pose a low probability of causing harm. At either extreme, correct identification of the dangerous cases will be greatly complicated by slow response variables that are inherent to living systems-notably the unintentional transboundary movements of GMOs and the adaptive evolution of fertile GMOs after their release into natural ecosystems.

To be efficacious over the long term, biosafety regimes therefore need to include an international legal system of liability and compensation. Sole reliance on national-level liability systems is simply inadequate to address adverse consequences of transboundary movements of living organisms. This is particularly true for aquatic organisms because of the high degree of cross-jurisdictional connectivity of aquatic ecosystems.

There are two basic types of liability systems, fault-based and strict liability. Fault-based liability requires proving negligence or fault. This implies that the accused party was aware of conditions that could cause harm prior to the actual occurrence of harm. In contrast, strict liability allows the injured party to recover compensation simply by proving harm and without having to prove negligence or fault. Fault-based liability requires a high ability to predict future conditions. While this might work fairly well for predicting the effects of inanimate objects, such as breast implants, it is wholly incompatible with a central argument of this paper, that we must expect large surprises regarding effects of living GMOs. Interestingly, strict liability does apply in the United States to products, including a vast array of inanimate objects, that might harm consumers. Further complicating these situations are the lag times between dissemination of apparently benign GMOs and the detection of adverse effects that are inherent to living organisms and complex ecosystems. In many cases where harm might arise, the suppliers of the GMOs could quite convincingly argue that they had no prior evidence of the potential for harm and therefore were not negligent. Fault-based liability would therefore rarely result in compensation of parties injured by releases and transboundary movements of GMOs.

Of the two approaches, strict liability is the most compatible with the human inability to predict fully the dynamic behavior, evolutionary potential, and great variety of potential effects of living GMOs under different environmental conditions. In other words, strict liability is the only approach that fits with principles of modern ecology and adaptive biosafety. Although developers of GMOs may not appreciate this rationale for strict liability, they need to recognize that a high degree of unpredictability goes along with choosing to produce and trade living organisms instead of inanimate widgets.

Monitoring

Once biosafety policies are put in place, key indicators and variables should be monitored carefully for system behavior. As long as monitoring data indicate 'normal' system behavior, the adaptive cycle runs between implementation and monitoring. When monitoring indicates 'abnormal' system behavior, the resulting data are used to redefine goals, to reanalyze problems, to review and to revise implementation and to revise monitoring accordingly. Monitoring the effects of GMOs released into the environment through large-scale production, trade and use will require marking or labeling of GMOs. For example, there are many ways to identify DNA sequences that are diagnostic for specific groups of GMOs. The application of polymerase chain reaction (PCR) methods permits amplification of minute quantities of DNA from unpreserved, small, and nonlethally sampled tissues. Nonlethal sampling can involve noninvasive collection of scales or slivers of fin tissue from fish (Rivers and Ardren 1998). Additionally, PCR methods allow long-term retrospective or prospective tracking of genetic changes, interbreeding and geographical movements of GMOs through comparisons of genotypes resolved from unpreserved tissues collected at different points in time and in different places (e.g., Miller and Kapuscinski 1997).

Monitoring will be nearly impossible without provision for tracking of GMOs within and across sovereign nation states. This implies a need for national permitting systems and adequate sampling and information exchange between nations. Finally, the different participants involved in other phases of adaptive assessment and management need ready access to results of monitoring. This is essential to ensure that different people who can affect the system gain an understanding of what was learned about biosafety from the adaptive process. This is the best way to reduce social conflict over goals and policies on the part of business, government, social justice groups, environmentalists and other players.

Information base

The information base serves as a 'source and sink' for each phase of the adaptive biosafety cycle. Continual updating and consultation of the information base also help to bypass or shorten the time spent at each phase by assuring that lessons learned from past experiences are incorporated into revised policies and by highlighting what remains unknown. Through this continual interaction with the information base, adaptive biosafety regimes will constantly unravel uncertainties and adaptively reformulate policies The uncertainty inherent in the interconnected natural and social systems can only be addressed by this kind of actively adaptive biosafety assessment and management.

Addressing the Limits of Adaptive Biosafety Regimes: An International Program of Aquatic Genetic Integrity Areas

On a global scale, the most adaptive approach to biosafety assessment and management, is paradoxically, not to pursue this strategy in all geographical settings. Carefully selected reference sites, where there is no activity involving GMOs, would allow comparisons to sites where GMOs have been released. Such comparisons will increase the robustness of conclusions drawn from monitoring data. Furthermore, this would provide reasonable precaution against applications of adaptive biosafety that indeed generate large surprises leading to substantial losses of unique and valued biodiversity. A possible bet-hedging approach is to design an international network of aquatic genetic integrity areas that are off-limits to production, deployment and uses of GMOs. People living in and using aquatic resources in candidate areas should share in the decision-making over site selection and continued exercise of traditional uses. Local residents should derive some community benefits from designation of an aquatic genetic integrity area. Creative approaches to local community participation in the management of these areas would be important (Pomeroy 1994). A promising option is comanagement, involving shared power between current users of the areas and local or more distant government agencies (e.g., Ruddle and Akimichi 1984; Pinkerton 1989).

Some relevant criteria for selection of genetic integrity areas include:

- They should encompass a representative sample of the global variation and distribution of aquatic and marine flora and fauna and ecosystems.
- They should be representative of known (and suspected) centers of aquatic genetic diversity. Examples include water basins in Southeast Asia and China to protect genetic diversity of cyprinid fishes (the Yangtze River Basin alone has over 400 species of cyprinids); South America for genetic diversity of caracins (the entire group of over 1 200 species occurs on this continent) and catfishes (the center of diversity for 13 families); Africa–notably the Rift Lakes–for cichlids; southeastern North America for populations of darters (Percidae, Etheostominae) and minnows (Cyprinidae, Notropinae), and North America and Europe for different salmonines.
- They should be relatively immune to invasion by distantly released GMOs, based on considerations of biophysical surroundings and sociopolitical conditions of the nearby human communities.

The above list is by no means exhaustive and each criterion warrants interdisciplinary review. Implementation of an international network of genetic integrity areas should build from rather than duplicate existing systems of protected areas that encompass freshwater, brackishwater and marine ecosystems (Agardy 1994; Rowley 1994; Mills and Carlton 1998). Illustrative examples of existing types of protected areas are: underwater coral reef parks, tide-pool reserves, springs and streams protected for historical or spiritual reasons, indigenous people's fishing grounds, rivers with wild and scenic designation, and lakes in nature parks and reserves.

Policy Recommendations at National and International Scales

We have presented the justification for and outline of an adaptive approach to biosafety assessment and management. Translating this vision into actual practice requires having in place some key policy instruments and institutions at national and international scales. The following specific recommendations are for aquatic GMOs but they are generally applicable to biosafety regimes for all taxa. Although these recommendations are directed particularly at contracting parties to the Convention on Biological Diversity (CBD), their effectiveness would be greatly enhanced by participation of all nations. The many aquatic ecosystems that cross political jurisdictions and the tremendous connectivity between different aquatic ecosystems underscore the desirability of having a global forum for coordinating risk assessment and management of aquatic GMOs. In summary, we recommend the following policy actions:

1. Under Articles 8(g), 14, and 19 of the CBD, contracting parties should encourage the development and application of science-based decision support tools that assist case-specific risk assessment and management of ecological and human health effects of GMOs and alien species. These decision-support tools need to be readily available in alternative formats such as printed documents and electronic interactive software. Case-specific decision support tools are needed because the extent to which a particular GMO poses risks versus safety is an outcome of the characteristics of the modified organism, characteristics of the accessible ecosystems, and the nonlinear interactions between the two. The Scientists' Working Group on Biosafety (1998) has developed the world's first case-specific decision-support tool that applies to small-scale, large-scale and transboundary releases of virtually all types of GMOs (except humans).
2. To assure its long-term effectiveness, the biosafety protocol (under Article 19.3 of the CBD) needs to include an international system for liability and compensation. Contracting parties should consider convening an interdisciplinary technical forum (e.g., involving biologists, ecologists and legal experts) to address the relevant issues and to propose alternative elements for an international liability and compensation system.
3. Nations should collaborate in the establishment of an international registry of genetic markers that are diagnostic for specific GMOs that are transferred, handled and used through international trade. They should also enter into an international agreement that requires parties to submit diagnostic marker data to the registry before undertaking any exportation of the specific GMO. Establishment of such an international registry is consistent with many parts of the CBD including Articles 7(c), 7(d), 8 (g), 8 (h), 10 (b), 14, 15.5, 19.3, and 19.4.
4. Nations should collaborate to establish an international network of aquatic genetic integrity areas that are off-limits to introductions of genetically modified organisms (including aquatic organisms whose genotypes are altered through captive breeding and selective breeding).

Conclusion: Whither Adaptive Biosafety?

In April, 1998, the World Trade Organization (WTO) announced a ruling against the United States that is consistent with the pathologies of natural resource management in the twentieth century. The United States requires shrimp fishers in its waters to equip nets with turtle excluder devices to protect several endangered species and prohibits shrimp imports from countries not requiring turtle excluder devices. More than three dozen countries have been certified by the United States as safe shrimp fishers, either for having installed the devices or as fishing only in waters where turtles usually are not found. The three-member WTO panel, whose meetings are closed to the public, ruled that the U.S. law prohibiting shrimp imports from countries not requiring turtle excluder devices in their fleets is an unfair trade barrier (Baker 1998; Cushman 1998). This ruling is consistent with a focus on single components of the environment (turtles) and society (free trade), a priority on fast variables (promotion of free trade) at the expense of slow variables (effects of turtle populations on the function and productivity of other marine resources), and inattention to crucial uncertainties about the complex societal-environmental systems at issue. In short, the workings of the WTO run counter to adaptive management of human actions in the environment.

In the future, the WTO is likely to receive complaints over international trade of GMOs. In light of this possibility, consider two likely outcomes of the current negotiations of an international biosafety protocol under the CBD. One possibility is that the CBD's Conference of the Parties does not reach agreement and fails to adopt an international biosafety protocol. Another possibility is that the Conference of the Parties adopts a protocol with lower standards than those set by some national biosafety policies. Under either scenario, will the WTO rule in favor of a country exporting a GMO that complains that the biosafety regulations of an importing country are an unfair trade barrier? An affirmative answer would constitute serious undermining of some existing national biosafety regulations. This is a daunting issue for parties interested in fostering conservation and sustainable use of aquatic genetic diversity.

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Discussion

Entis: The premise that you start with–that some genetically modified organisms (GMOs) will escape and get into the environment–is of course correct. So it is critically important to have a good assessment of how safe or not safe these animals will be. I support wholeheartedly the scheme presented here of Adaptive Analysis over time. There are short-term issues and long-term issues and you never get all of the answers up front. You do the best job that you can in the short-term, and then monitor and maybe change your decisions in the long-term. However, let me broaden this to consider nonenvironmental, noneconomic consequences. The issues of social impact and liability are definitely of concern to myself and, I suspect, to others who are working in this field. There are issues that tend to be used as reasons to prevent, on a nonrationale/nonscientific basis, the introduction of GMOs–whether these will benefit elements of society or not. These concerns tend to get used by specific interest groups. The kinds of evaluations presented here can get 'hijacked' for those purposes. The question is how you deal with that? How do you allow legitimate input? How do you address specific concerns and at the same time not eliminate the possibility of actually using commercially the product which you are talking about? I'll give some examples. I have been told by representatives of one country–with which we have no relationship–that when we introduce our fast-growing fish, we should pay repatriation to this country because they assume that the cost of producing their fish will increse, relative to the cost in other countries, and therefore their aquaculturists will go out of business. This is a liability issue–though maybe not in the way that you meant it. Moreover, the more extreme environmental groups base their positions more on rhetoric than on science. Ethical and religious arguments are used against the introduction of a GMO. They come out in a scientific manner, but that's pseudoscience. If you are going to have an evaluation, what weight do you give to those arguments. How do you deal with those issues? How do you prevent the process becoming centuries–long and, at the same time, still allow voices to be heard from all of these competing interests?

Kapuscinski: This is a pretty complex question. When thinking about biosafety, it might help to start by saying that we'll try to limit socioeconomic considerations to those that are essentially unintended consequences in terms of damage to some part of the environment. Your fish affecting the price of other fish is an irrelevant case–at least for biosafety. Maybe its an issue for other fora. A case that would be relevant is if transgenic fish escaped and swamped a wild population upon which somebody was dependent. That should at least be put on the table and discussed. Another way to approach this issue is to think about who needs to be sitting at the table when you are setting goals for this adaptive approach. Parties that stand to be affected, positively or negatively, are all at the table and they, at that time, decide what their goals are going to be, and then you go through all the steps. Then if someone decides to change a goal in midstream, before you have completed the loop, they probably are not going to get away with it. There will be sanctions from other people involved. This is clearly a lot easier for more local situations. I don't know how you would address this in the international arena. Again, limiting the socioeconomic considerations to unintended environmental consequences would help.

Entis: That's a very good perceptive–limiting it to biosafety–the consideration of the environment (both intended and unintended consequences) as a focus for this. I think that there would be a high degree of agreement. It's probably more difficult over time. For example, if a fish eventually mutates and becomes a locally adapted animal, which no one could possibly have predicted, then there's the question of who foots the bill and where the liability lies? I merely want to state that, from where I sit, the danger of a lot of the international approaches under the Convention on Biological Diversity (CBD) really lies in literally preventing or prohibiting any aquatic GMOs with the basis for this being, not even a low safety standard but a standard, promulgated, not on the basis of science, but on fear of a number of different consequences. I suspect that with fish, more than with plants, that might be the outcome.

Bartley: The Adaptive Approach presented here has a lot of the same elements as the Precautionary Approach. We can use this and get a common language to help spread the word. The World Trade Organization (WTO) is going to be very important here. We can look at some of the mechanisms that the WTO has in place to prevent the spread of diseases. These mechanisms can be used as a barrier to trade. This approach could be used for clearly dangerous GMOs. At the country level, a country could say that it is opposed to the use of a GMO. But the WTO also imposes some obligations on countries. So a country cannot just say, for example, "OK, this is a terrible disease and your fish have it, so they can't come in." The country has first to show that there is a monitoring system and that they are actually taking steps to prevent the spread of that disease. You could envision something like this with GMOs, where a country would have to show that, within its borders, they are taking this seriously and are not allowing their aquaculturists to manipulate things, if they are preventing entry of a foreign product. We can look at some of these analogies and see where they fit and where they don't fit in relation to GMOs.

Kapuscinski: There might be a bit of a difference between Adaptive Assessment and Management and the Precautionary Principle. In some situations, a group might decide to do something that appears to be risky, but then use the Adaptive Approach to do monitoring. I think that the Adaptive Approach can open the door more than the Precautionary Principle. I'm not sure that it has to turn out that way, but the Adaptive Approach starts more as a bottom-up approach than with top-down command and controls. The way that it actually plays out and gets used might end up leading to some more applications that, if you used the Precautionary Principle fairly strictly, you might not go forward and do. But what it then requires you to do is to treat the action seriously as an environmental experiment, and then monitor and evaluate the results seriously. This difference between the approaches might make a big difference in some cases.

Bartley: Just to say that I didn't mean to imply that the two approaches are identical, but that there are key parts of both that we really need to push for; for example, monitoring.

A. Gupta: First, on the liability issue that you raised, there were two issues raised in a case going on in the US Congress at the moment. One is, did the corporation know the risk but did not share this? If there was evidence that they knew of the risks to children but did not share this, then their liability was fixed. Second, did the corporation deliberately avoid strategies that could have reduced the risk? These are two basic principles on liability which can probably also be applied to introduction of GMOs. Also, are there marker genes that can make the task of monitoring easier?

Entis: You are accurate in this assessment and there are already codified rules of conduct in law. There is no need for another law on top of that. If my corporation, or any other corporation, were guilty of either of these breaches, then we already have a legal issue.

Kapuscinski: The question that I have for the legal experts is how will national law apply if any escaped aquatic GMO disperses by various methods to another political jurisdiction?

A. Gupta: This was tested when the Bhopal tragedy–a gas leak involving Union Carbide–took place in India. A US Court ruled that the compensation proceedings had to be handled by Indian courts because the incident took place under Indian jurisdiction. This was a landmark decision regarding compensation that arises from the actions of an international actor in a national jurisdiction. It will be cited for a long time to come and it is a good decision. An important issue here was the court's further ruling that it is not enough to say that you took enough care to avoid risks when you set up the plant. Even if people subsequently came to live near the plant, your liability remains, not because you did not disclose the hazardous nature of your activity, but because you did not take sufficient care to ensure the safety of these people, even in the unlikely event of a release, such as took place.

On another issue, when do we review the evidence? When would scientists or corporations say 'now we know enough–let's have a hearing on the subject, we are ready!' In general, corporations that have a technology ready for market would say 'well, we will never get enough evidence, so let's get started and learn, and accumulate evidence–and therefore our liability will be reduced to the extent that we know.' On the other hand, public institutions will say 'no, let's collect all the evidence possible.' They may go too far in this, but this is the position that public institutions tend to take.

Are the risks posed by GMOs higher than those posed by exotic species? In Dr. Gupta's example of yesterday, 96%of the fish of one species in a river were of hatchery origin. Is that risk any less consequential than the risk from GMOs? Are we sometimes giving too much emphasis to the GMO issues? I know that some NGOs don't like this argument, but we need to think about it.

Finally, the developing countries are putting pressure on the developed countries through the Biosafety Protocol that is being negotiated through the CBD. As long as the developed countries will not relent on Technology Transfer issues, the developing countries will use the Biosafety Protocol to bring pressure.

Neira: The question that you raised about exotic species also applies to organisms modified by simple selection. For example, salmon raised under complete captivity and selection for generations probably have reduced capacity for migration. Who knows? The problem is more general.

Kapuscinski: There is a case for including these other ways of modifying aquatic organisms. Some of the modifications are unintentional. That is why I included 'captive-bred' in my description of modified organisms. For GMOs and alien species, the question is to what extent is an organism that has invaded, playing an ecologically novel role. The different kinds of modification–selection, chromosome manipulation, gene transfer–all have different capacities to cause ecological novelty, but at the end of the day, they are all capable of causing ecological novelty.

On the question of when there is enough information assembled, the philosophy of Adaptive Assessment and Management is that this is not the right question to ask. Instead, you define goals. Then, looking at obstacles to achieving these goals, define the problems. For example, if the goals are safe transfer and handling of GMOs, you then do a systematic problem analysis (e.g., using the Performance Standards for Transgenic Fish and Shellfish). If this indicates no risks but rather gives a clear indication of safety, then you can go forward with your project, but you are still committed to monitoring. Essentially, you have to continue monitoring at levels appropriate to risk management. I don't think you can look for a time when you can say that there is definitely enough or not enough information.

Schei: I agree very much with this Adaptive Management Approach. It is much the same as the 'Integrated Ecosystem Approach.'

Kapuscinski: That's right.

Schei: This is the approach that the CBD has already taken and, if the 12 principles produced by the group invited by the CBD to Lilongwe in January 1998 are accepted for the Ecosystem Approach, then we will have taken a great step forward in developing and understanding the socioeconomic context. I also like the way you broadened the biosafety aspect. I would have broadened it even further, but I don't think there is political acceptance for this yet. The Biosafety Protocol negotiations are likely to continue just for GMOs or LMOs.

I don't see any solution to the liability and compensation question now, because this is not sought in the Convention itself. In Article 14 there is a reference to liability, and they are postponing the liability question for future discussion. Until we have some liability and compensation built into the international 'rules' that are being set up, there will be no solution to these problems. I find it a bit strange that the USA is arguing so strongly against this, when it is so common there for people to sue for compensation.

Kapuscinski: Well, not everybody in the USA feels this way about the liability provisions.

Schei: I do agree very much with your emphasis on science as the basis. There would have been little chance for the present discussions on exotic species without the controversy over GMOs. People are afraid of GMOs. I don't think that they should necessarily be afraid of GMOs. They should be afraid of exotic species. I hope that we can have a balanced discussion on this and that future management is based on science. However, I'm not too optimistic. The whaling issues have been discussed for years, but some countries will not accept the scientific evidence, and they create their own so-called 'scientific arguments' that take attention away from the real aspects.

Froese: I think that GMOs should be treated as introduced species and that we should use this opportunity to think again about how we deal with introduced species. I like very much Anne Kapuscinski's proposal for Aquatic Integrity Areas. These fit together well with other areas such as Marine Protected Areas and 'No Take Zones.' You have put the idea in my head that a 'No Take Zone' should also be a 'No Put Zone.'

Penman: With respect to markers, for a transgene the marker can be the transferred gene itself. However, especially when these things start to get moved around in countries where you have quite variable standards, you've got to know what you're looking for. It can be the same species.

Kapuscinski: With the advent of DNA methods, it should be possible to have markers to identify different strains of different species. However, this has to be thought through ahead of time – with markers noted in a registry before transfer of GMOs, perhaps as a condition of trading.

Penman: This assumes that people will obey the rules! They haven't, for exotics.

Kapuscinski: Well, I emphasize monitoring because so far there has not been enough discussion on how to go about this and what kinds of institutional regimes need to be put in place to make sure that people actually do it.

Bartley: The most recent editions of the ICES and EIFAC protocols on introduced species include Genetically Modified Organisms (GMOs). This is a nice step forward. Definitions are very important here. What is the scope of definition of a GMO for the Biosafety Protocols being negotiated under the CBD. Is the scope more than just transgenics?

Kapuscinski: At this point, it might be a little bit more. The final wording might also be applicable to, say, a new hybrid between two existing species of fish. But I don't think it will apply to movement of an existing species to a new place or to selectively-bred organisms–but I could be wrong about this.

Schei: Its scope will not be broader than the LMOBs (Living Organisms Modified by Modern Biotechnology) that we have in the Convention, but our discussion here will help future consideration of exotics.

Pullin: Well, the definition, of "biotechnology" in the CBD is exceedingly broad.

Leria: Some existing legislation for pollution and other environmental problems under national jurisdiction can help in the development of liability and compensation mechanisms for GMOs. I want to be more positive about this.

Mires: I am less optimistic on this. Let us say that a GMO escaped into the environment but, at the same time, there were other effects on the environment such as climate, etc., and then let's say there was a collapse of fish catches. Somebody would blame this GMO, others would blame other factors and this could just go on and on. Where does this stop? There could be a witch hunt guided by the media, and not much possibility to prove anything. There is also the difference between developing and using a GMO in public and doing so quietly in private. How does this affect the consequences after a catastrophe. All these things are so vague.

Kapuscinski: I'm not sure that it has to end up being so messy. This is why I emphasized the need for reference sites and for markers for GMOs–so that they can be monitored. If both these things had been done, the contribution of hatchery fish to fishery declines would have been much easier to determine, and the legal system would have been in much better shape to sort things out. The question as to whether the fish made a significant contribution to a problem could be determined. Without reference sites and reliable monitoring, there is no chance to determine this in a systematic matter. Also, we cannot control what people do in secret. I believe that we need to put marking and monitoring in place and these will help to catch some of the really big errors that might take place and also be able to assign blame in those situations.

Mires: But how long can you legally stop a commercial operator from releasing a GMO, not to the environment but rather for farming, while waiting for those references?

Kapuscinski: Well, you have to truly integrate all of the steps in the cycle that I was talking about. In some cases, when you go through the risk assessment, you'll conclude that the organisms in question should always be raised. In other cases, you might decide otherwise and recommend a different level of risk management. You go through these steps and then you put the monitoring in place.

Entis: Our company is moving from the 'more restricted' to the 'less restricted' over time, which fits with this Adaptive Monitoring Approach. Right now, we don't have the answers but we obviously want to commercialize a product as safely and quickly as possible. So what do we do? We go along with existing rules and regulations in our country. There, the Food and Drug Administration holds sway, not only over the food safety issues associated with our product, but also over the environmental issues associated with transgenic fish. However, the FDA does not have a clear set of policies on this, so since we do not truly know what these animals could do in the wild (we are optimistic about the risk levels, but we don't know), we say that, for the time being, we will propagate fertile fish only in inland recirculation systems and sterile fish in less safe environments. In the meantime, we go along with adaptive monitoring. We are as interested as the next person to find out what can happen with these animals in the environment. On long-term consequences and how to deal with liability, I agree with Dan Mires: its a problem. We would no more like to be sued 40 years from now for an unintended consequence than, say, the automobile manufacturers would like to be sued for global warning. That's a safe analogy in some respects. All human activities have unintended consequences and we cannot predict what they all will be. So there is a limit to liability for everybody in the world, and for all companies in the world. One last and very important point, and I'm glad to see that this group seems to accept this, is that the biosafety of GMOs is a consequence of the product, not of the process used to produce it. Molecular redistributions are not the issue, it is how the organism acts and what it does to the environment. There seems to be a consensus on this here and I'm very pleased to see this for the first time in an international group.

Kapuscinski: The question of liability is complicated enough to deserve its own conference: to bring together environmental and legal experts and biologists who deal with ecosystems, together with interested people who care about how this is going to turn out. However, one way to consider liability in the meantime is to ask whether a liability regime should address the fast variables differently from the slow variables. If even within a country, a company is permitted to go forward with a project involving a GMO, with some conditions specified under which they have to operate; and then if there is failure in compliance with some of those conditions (say an escape from containment facilities into the environment), that's a fast variable. Perhaps liability should really concentrate on fast variables. The difficulty might be that the escape did not cause any immediately observable effects, but you would have to have monitoring in place to see whether, say, two to five years later there was a problem. Then you would have to sort out the claims for liability and the compensation, focused on that fast variable. I know that we don't have this all sorted out yet, but this might be a path to follow.

A. Gupta: There is indeed a case for a further working group to consider these issues. There was mention of how to isolate the effects of a GMO from confounding effects of other factors. Well, in jurisprudence, there are two questions that can be asked: (1) what caused?; and (2) what facilitated? The environment could not have caused the consequence if there was no GMO around that place. So the environment can only amplify, or perhaps diminish, the consequences – it cannot cause them. So whatever the changes in climate, etc., that could not be predicted, the consequences of the passage of genes from a GMO or an exotic species to a native species is clearly caused by the GMO or the exotic species.

On the question of how long liability lasts, it could be 15 to 20 years or longer. So while you are right that the automobile industry could not be sued for global warming, there have been instances where liability has been held to be valid after 20 years by US courts. We need to study this more before concluding that there is a time limit on liability.

Entis: It's not time that's the issue, it's direct vs. indirect liability. Anything that involves direct liability is not necessarily time-limited. So I think that the issue for us is not necessarily the slow vs. fast components. The issue is direct vs. degree of 'indirection.' In other words, if you have to go through several permutations and various evolutionary phases, none of which can be accurately predicted, the question is 'at what point does liability get diminished?' If there's a direct liability, then there's no argument.

Pullin: I'm not sure, Dr. Gupta, that your analysis for separating different causes and effects can work as simply as that. I can think of several examples in the Philippines where some of the freshwater lakes, all of which are in trouble, have suffered from, for example, deforestation of the catchment with consequent soil erosion and siltation of the waterbody. There can also be a 5% per year increase in the human population on the catchment from natural increase in the residents plus in-migration. There is also overfishing, etc. There is also tilapia, introduced as an alien species. The native fish and those lakes are not necessarily having a hard time because of the tilapia. Even without the tilapia, most would be in bad shape anyway.

A. Gupta: Well, the only way then for scientists and policymakers is *ceteris paribus*: are there other instances where tilapia have been introduced and these consequences have been observed? If consequences occur 9 times out of 10 where tilapia has been introduced, the influence would be obvious.

Pullin: There is still an element of uniqueness.

Kapuscinski: Another underlying premise of Adaptive Biosafety Assessment and Management is that we will never have fully accurate information. That's reality. So, if a new technology is to be tried, somebody has to take the responsibility in case our predictions are not good enough and something goes wrong. Unlike automobiles, living organisms can evolve and change. We have to do the best that we can to predict their evolution, but somebody has to take the responsibility for wrong choices.

Kooiman: Different criteria have to be weighed – and scientific criteria are just one set of these. I disagree with Elliot Entis' treatment of ethical and philosophical issues. These are important. This is what politics is for. We elect politicians (good or bad) and we live with the result. When we take a 'step in the dark', very often they have to take the responsibility.

Pullin: Can we revisit briefly the comparison between GMOs and unmodified alien species? There could be some lessons here. The legal, advisory and other instruments that were supposed to guarantee biosafety with respect to introductions of alien species basically have not worked. Last year I was phoned up in the Philippines from a government agency and asked whether I thought it would be a good idea for the Philippines to introduce African catfish. I advised application of the ICES-EIFAC Codes of Practice to ensure a thorough prior appraisal of the possible consequences–and was then told 'well, it's already here!' (Laughter). That is the general state of the world with respect to alien species. I'm encouraged by Peter Schei's opinion that the biosafety debate in the CBD might eventually be broadened beyond GMOs (narrow sense) to include alien species and other alien genotypes. ICLARM's current policy on this (Pullin 1994) treats alien species and GMOs (broad sense) alike and includes a schema for decisionmaking that came from a previous ICLARM-GTZ Bellagio conference (Pullin et al. 1993). I have no evidence at all that this schema has ever been used – in fact, it probably hasn't been used. My point is that a schema like this and the flowcharts presented by Anne Kapuscinski have got to consider who will apply them? Are they simple enough and robust enough to be applied everywhere? Is there the will to apply them? A look back at what has not worked for controlling introductions and transfers of alien species can give us some clues here as well. The ICES Codes have hardly been used in developing countries relative to the huge numbers of introductions that have taken place. I know of their extensive use in only one project–a UNDP-FAO Sepik-Ramu restocking project in Papua New Guinea led by Dr. David Coates–and their occasional use by other FAO projects and one use by ICLARM. Why have the Codes not been used as intended by those who framed them. I think because their requirement to gather opinions about the biology, ecology and behavior of the species relevant to the recipient environment is just too demanding and cumbersome for those appraising the proposed introduction. It should of course be a demanding process, because an introduction of an alien species changes the planet. But in some political and commercial circles, there is neither the capacity nor the will to apply something like this. Another reason why the Codes might not be used much in the developing world, and this is a sensitive point, is that the Panels of Experts convened to consider a introduction under the Codes, are usually composed predominantly of 'Northern'/ 'Western' scientists. Consequently the advice might be considered as having a 'Northern' bias and this creates a tension. So, whatever schema is drawn up for GMOs and whatever comes out as the Biosafety Protocol under the CBD, somehow these have to be developed and accepted globally, and they have to be non-cumbersome and globally applicable. We should strive to help this process. The schemas presented by Anne Kapuscinski are quite simple. They do, however, appear to be kind-of 'endless.' Can there be a simple route to arriving at actual decisions?

Kapuscinski: First, on the issue of the cumbersome process of gathering all available information about an organism, one way to cope with this but to still have a rigorous assessment system is exemplified by the "Performance Standards." The starting point is to identify a critical question, the answer to which would give clear separation between indications of safety and risk. Based on the answer to that question, the questioner is led, if using the interactive version, to another question. So, no one person has to answer all the questions and you don't need to provide all the information that is known about the organism. Instead, a lot of critical thinking by a very multidisciplinary group, including scientists, government people and industry people has gone into figuring out the critical questions to ask and in what order. This is a kind of expert system. So although, when you look at the Performance Standards book, you see pages and pages of flowcharts, when you actually use it, a given user does not have to answer all the questions. The interactive version on disc or online is easy to use. So there are some ways to make these processes less cumbersome. On the point about this process seeming 'endless', one way to get around this might be to show some more dynamism in the pictures so that one is not always led back to the same goal. For example, if your evaluation and monitoring have achieved a goal, then these ends have been accomplished and you can approach other goals.

Pullin: Who is 'you' at this point?

Kapuscinski: It has to be this mixed group of stakeholders and affected parties as well as the scientists and policymakers. That's why I made the point that this inclusive group has to be involved in the various phases. This would also address the concern that you raised about having just a 'rarified' group sitting at a table and doing the analyses. I agree with you that that would be an impediment because the people likely to be affected would not feel that they had a say, either in the design of the project or its implementation–so they would have reason to distrust and disbelieve the decisions. For example, when the Performance Standards were developed, Elliot Entis was at the table–one of 150 people, mostly from the USA, but some from other countries. I suggest that these standards also have not been used as much as they should have been, because they are voluntary standards. But I can tell you that Elliot and others around the country have called me up and asked questions about them. So there are some thoughtful people out there who have applied these standards: probably because they were involved in their development and felt that they had some merit.

Welcomme: The ICES-EIFAC Codes have been used; for example, on a couple of occasions by COPESCA, such as an application to introduce sturgeons into the Uruguay River. This was stopped. The appraisal was done by a varied group of Latin American fisheries administrators. The reason that these Codes failed is that they were developed ahead of their time and in a different socioeconomic climate. When the Codes were being written, there were national representatives present who at that very time were introducing alien species into their marine and inland waters. So there was an atmosphere of complete administrative cynicism. The other point about these Codes is that they assume that once an organism has crossed the borders and entered a country, then it is assumed to be present in the natural waters of that country. Appraisal of an introduction using these Codes is a 'one-off' act, and I don't see how you can make such a 'one-off' act subject to an iterative process. You have to take a decision on the best information available for assessing risk, relative to your value system. In Europe, ostensibly we would be more rigorous than would be the case in Africa, because Africa generally lacks the capacity, quarantine facilities, etc. to do this. But the effects of an introduction there can be just as damaging, if not more so. So while I appreciate the processes of going round flowcharts and loops, monitoring, etc., when you are doing something, that is irreversible, you have got to subject that to the appropriate rigorous procedures before you do it.

Kapuscinski: Well, I would argue that if the decision ends up being to allow broadscale use of a GMO, and then that does lead to an escape that causes problems; if you had used the adaptive process, you would have at least detected those problems, done the monitoring, and then the next time this situation arose, you could approach it differently. Or have I misunderstood your point?

A. Gupta: What he is saying is that, even if the risks are not completely known, when the potential effects are irreversible you must avail of all the relevant knowledge and make a conscious decision.

Pullin: To Robin Welcomme, I stand corrected on the use of the Codes in Latin America. I did not know of these examples. But I still would think that they have been used for less than 1% of all introductions of alien aquatic species.

Welcomme: Yes, for virtually none. In the Latin America example, the government concerned wanted to stop something without appearing to be doing this itself.

Pullin: So, is there not a danger then, if gene transfer and GMOs become very commonplace (which they probably will), that, in a way similar to that in which the Codes on alien species have been disregarded, codes and protocols for GMOs will also be disregarded?

Welcomme: I think that this is a real risk. And I think that there is an equal risk that some governments will use this cynically, to exclude products.

Kooiman: You cannot look at these things only in 'process' terms. The processes are taking place between institutions and organizations. Some institutions have to take formal steps, otherwise this does become an 'endless game.' So although I like the charts presented, we have experience of about 40 years with policy analysis–which was all flowcharts and very nice process developments–but the institutional elements (i. e., who is applying these policy models) were lacking. I've been advising a committee in the Netherlands on applying policy analysis and it has taken about 20 years for some of the basic principles to be accepted by say 25% of the civil servants and others who were meant to be using these tools. It is also important to have these things embedded in democratic procedures. You can have nice flowcharts but somewhere there has to be a democratically elected body that says 'OK, this is the goal for the next so many years, these are the procedures to monitor, and these are the adaptations taking place, etc.' Without this, the system can become a closed system of experts and such closed systems usually have inputs but no outputs! Or, and this possibility is even worse, the issue becomes so diluted in terms of public awareness that politically responsible people just get fed up with it and say 'Well, if you can't make up your minds, should we bother?' Then I come back to the philosophical and the ethical point, and maybe then someone says 'OK, God says that we shouldn't do it.'

Bartley: If we look at the database started by Robin Welcomme on alien species introductions, most of the introductions were done by or through national governments. So you have a government body making a decision on their own request to introduce something. As Jan Kooiman said, probably a democratically elected body would be better than a group of foreigners. The ICES-EIFAC Codes have been accepted in principle by other FAO Regional Bodies. In addition to the fact that the Codes are quite difficult to apply, another reason why they have not been applied is that people did not know about them. We need to do a much better job to promote them – in a simple form. Finally, if you can get governments to accept such instruments, this can help to protect scientists and others in country who might otherwise be forced to go along with an introduction to which they are opposed. This is one of David Coates' big points: that the Codes can protect resource managers, who can say 'Well, lets apply these Codes first.'

Entis: Well, I don't know anything about this – I imported fish across borders in 1996. They were selectively-bred tilapia. How many fish farmers know about these Codes, etc.?

Pullin: But they are not aimed specifically at fish farmers. Everyone who farms fish does so within a national jurisdiction, and sometimes within a local jurisdiction within that. We hope we could move from what has been, to all interests and purposes, a *laissez faire* situation which, under the CBD, might be more cautious and therefore less potentially dangerous.

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Consensus Statement

The participants of the ICLARM-FAO Bellagio Conference 'Towards Policies for Conservation and Sustainable Use of Aquatic Resources' agreed upon the following consensus statement.

Bellagio Consensus Statement

An International Conference, 'Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources,' organized by the International Center for Living Aquatic Resources Management (ICLARM) in association with the Food and Agriculture Organization of the United Nations (FAO), was held at the Bellagio Conference and Study Center of the Rockefeller Foundation, Italy, from 14 to 18 April 1998. The participants, from 14 countries, contributed a series of papers from their expertise in a wide range of disciplines (aquatic biology, aquaculture, genetics, governance of natural resources, fisheries, public awareness, intellectual property rights, law, etc.). The participants also discussed, at length, the present status of and likely requirements for policies for the conservation and sustainable use of aquatic genetic resources. The participants agreed upon the following suggestions, of particular relevance to aquatic genetic resources, for action and areas of concern.

Suggestions for action

The provisions of the Convention on Biological Diversity with respect to aquatic genetic resources remain relatively undefined. The following actions are suggested to sharpen the focus of the Convention for this sector.

- Develop national curricula which integrate conservation and sustainable use of aquatic genetic resources into all levels of education.
- Clearly assign national responsibilities for conservation and sustainable use of aquatic genetic resources among institutions and agencies.
- Ensure international sharing of knowledge and methods through the Clearing House Mechanism and other appropriate mechanisms, including among local communities.
- Operationalize the ecosystem approach including the incorporation of transboundary and cross-sectoral elements for the conservation and sustainable use of aquatic genetic resources,
- Develop policies and practices for access to and benefit-sharing (monetary and non-monetary) from aquatic genetic resources.

Areas of concern

These are areas where there is need to clarify the conceptual, social, scientific and political bases for taking action and for new initiatives with respect to aquatic genetic resources. It is recognized that these areas will involve collaboration of the Convention on Biological Diversity with other Conventions and mechanisms.

- How to establish international liability provisions for damage to or loss of aquatic genetic resources resulting from human interventions including *inter alia* habitat change, overharvesting, and the impacts of alien species and genotypes including living.
- How to provide for the protection and reward of knowledge, innovations and practices of indigenous and local communities and individuals, and how to relate these provisions to intellectual property right regimes.
- How to apportion some of the benefits from the exploitation of aquatic genetic resources that are found outside national jurisdiction, such as straddling stocks, highly migratory fishes and high seas fish stocks, towards their conservation and sustainable use.
- Recognize that in the formulation of biosafety policy and regulations for living modified organisms, the characteristics of the organisms and of potentially accessible environments are more important considerations than the processes used to produce those organisms.

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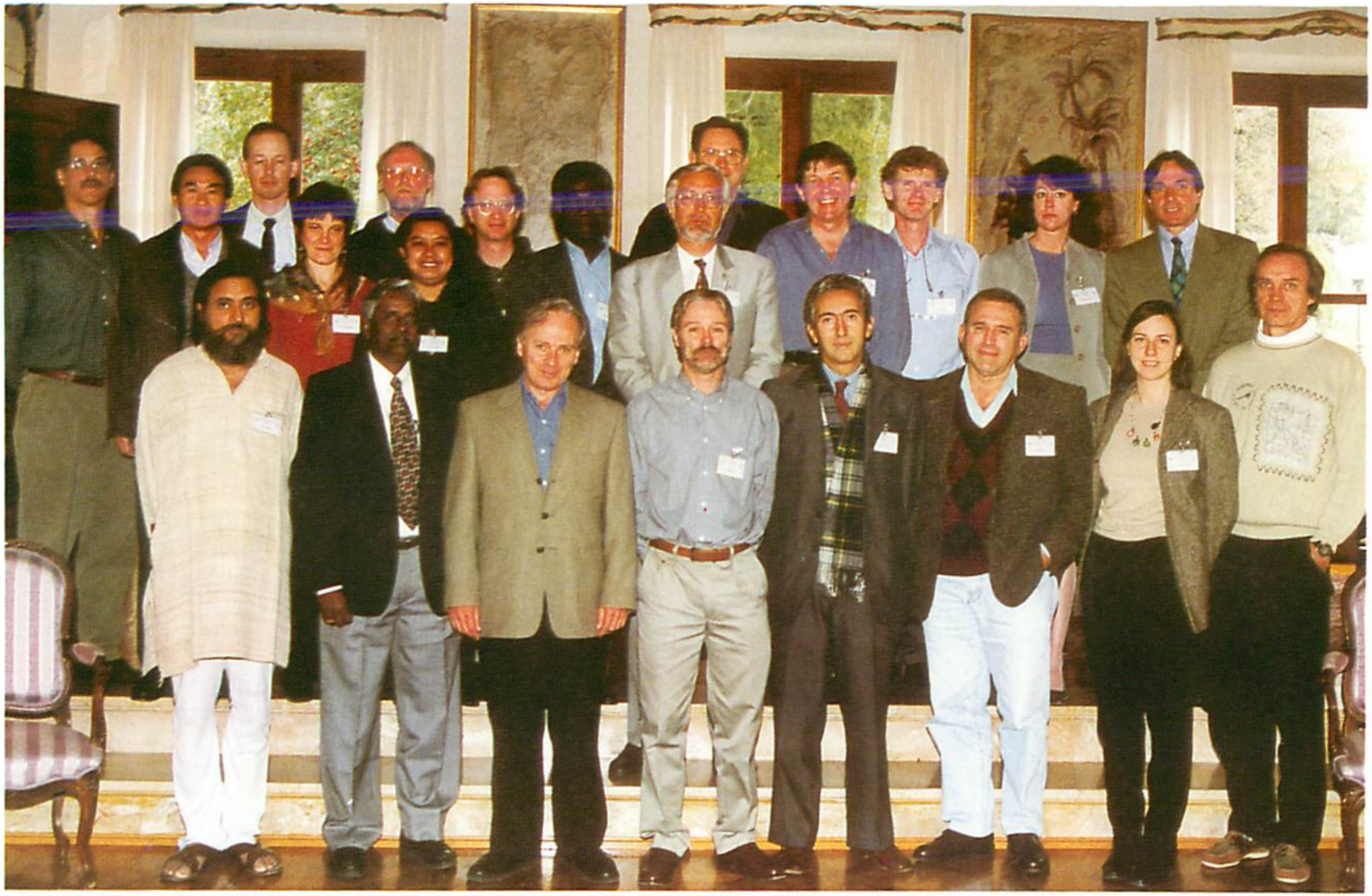

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