

# Fisheries Production Systems, Climate Change and Climate Variability in West Africa



# An Annotated Bibliography

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**Fisheries Production Systems, Climate Change  
and Climate Variability in West Africa:  
An Annotated Bibliography**

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## Preface

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According to the United Nations' definition, the West African region constitutes of 15 ECOWAS\* member states plus Mauritania. It covers a total coastline of 6,500 km with a continental shelf of 310,050 km<sup>2</sup> and extends over a surface area of 7,500,000 km<sup>2</sup> with a population of nearly 250 million inhabitants. The countries of this region can be divided into coastal and landlocked states. The marine waters of almost all coastal countries are located in the Gulf of Guinea Large Marine Ecosystem, with periods of upwelling effects ensuring a high fisheries production. Peculiar differences for instance in fishing capacities, history of fishing, resource abundance and many others prevail within West African countries. The coastal countries belonging to the sub-regional fisheries commission (CSRP) are Cape Verde, The Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone. These countries have exceptional climatic and ecological conditions and possess rich and abundant fisheries resources. A second group formed by Benin, Ghana, Nigeria, Togo, Côte d'Ivoire and Liberia is often referred to as 'other coastal countries'. Finally, the landlocked countries comprise of Mali, Burkina Faso and Niger. They are practicing inland fisheries and, compared to the coastal countries, have a low level of fish catch and also lower per capita fish consumption.

The West African fisheries sector is of high importance in terms of trade, food security and livelihoods; however, its magnitude varies greatly across countries. On average, fish exports make up for more than a quarter of total 'agricultural' exports and account for nearly a third of the average daily animal protein consumption in the region. Recently it has been reported that for some countries, fisheries make up to 17 percent of the GDP, and generate up to a third of national export revenue. West Africa as a whole accounted for nearly three percent of the world's total annual fish production in 2008, estimated at 143 million metric tons. The artisanal sector is the main supply for fish production and is estimated to contribute nearly two thirds of the total marine catch. The industrial sector is often operated by foreign fleets. Inland fisheries comprising lagoons, lakes, rivers and aquaculture, are entirely artisanal based and make up for roughly 20 percent of the region's total fish production.

Countries like Senegal, The Gambia, Sierra Leone and Ghana largely depend on the fisheries sector for their national economies and as major source of foreign revenue. The region had relatively stable catches in the 1970s, but they have dropped in the last two decades like in other regions of the world, presumably driven by unsustainable utilization of resources, overexploitation and illegal fishing activities. Stock levels

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\*The Economic Community of West African States (ECOWAS) is a regional group of 15 West African countries to promote economic integration.

especially for demersal species in countries such as Senegal, Ghana and The Gambia have reached a critical condition; and it has been predicted that an unabated exploitation will lead to their collapse.

Aquaculture in West Africa is still at its infancy stage. However, it has been advocated as an option to fulfill the increasing demand for fish products following the decline of wild capture fisheries – both marine and freshwater. Until now, the region contributes less than one percent to the total global aquaculture production. Despite a high potential, aquaculture in West Africa is still hampered by ineffective institutional arrangements and its dependence on donor funds. However, there are promising examples where aquaculture has demonstrated its competitiveness from Senegal, Ghana, The Gambia and Nigeria, producing fish that feeds low on the food chain in a range of well adapted environments, and providing profitable farming systems that meet the needs of user groups.

A number of climate-related threats to both capture fisheries and aquaculture have been identified which are expected to bring marked changes in distribution, abundance and productivity of fish species thereby exacerbating local species loss. In 2007, IPCC clearly articulated that Africa will likely be the continent most affected by climate change. Among the expected impacts are changes of sea surface temperatures that may lead to the disruption of ecosystems and threaten entire food chains. This could also have an impact on the migration of species and therefore on catches in the zone. Considering the social and economic relevance of fisheries, climate change constitutes a tremendous threat for the livelihood of millions of people in West Africa. There is an urgent need to understand the implications of climate change and variability on the fisheries production systems in these countries. As parts of the impact will be most likely unavoidable, a broad understanding of current and future trends is required. This will be the basis for developing policies that can make the fisheries sector more resilient and adaptable as a whole and, in particular, strengthen the adaptive capacities of small-scale fishers in the region.

To date, specific studies on climate change impacts on the fisheries sector are still rare. Most of them have focused on direct effects caused by key parametric changes such as sea surface temperatures, ocean acidification, sea level rises etc. The majority of these studies have been carried out in temperate areas instead of tropical areas where the majority of developing countries are located. Having this in mind, this bibliography has been prepared. It includes literature from the late 1960s to 2010 on the fisheries and aquaculture sector in West Africa, and on climate change and climate variability impacts. It was compiled with the aim to understand the major drivers of change in fisheries production systems, especially in relation to climate change. There are few studies in the West African region (and Africa in general) specifically focusing and analyzing the impacts of climate change on fisheries sector at country, sub-regional or regional levels, necessitating the need for researchers in this region to acquire information from studies carried out in temperate and developed areas. The intention was to focus on fisheries and aquaculture research, but

it also includes information on biophysics, oceanography, geology, climatology and meteorology since this provides the background for many fisheries and aquaculture studies. The literature in this bibliography includes peer-reviewed journals, books and book chapters, grey reports and institutional technical papers, but is restricted to literature in English. They were gathered through an extensive web search using fisheries, fish, coastal, inland, aquaculture and/or in combination with climate change and impacts, climate variability, specific country names, West Africa and Gulf of Guinea as the main keywords.

This bibliography is intended for people who are involved in fisheries, aquaculture, climate change, disaster management and policy development in West Africa or interested in one or more of these issues. It was prepared by Robert Katikiro from the Leibniz Center for Tropical Marine Ecology (ZMT Bremen) in collaboration with Dr. Kathleen Schwerdtner Máñez (ZMT Bremen) and Prof. Dr. Michael Flitner (Artec Sustainability Research Center, University of Bremen); and Dr. Marie-Caroline Badjeck (Worldfish Center, Penang). We are gratefully acknowledging authors who have contributed to this collection.

## SECTION I: Fisheries and aquaculture sectors (production, trends, management, development)

**Abban, E.K., Casal, C.M.V., Falk, T.M. & Pullin, R.S.V. (eds.), 2000. Biodiversity and sustainable use of fish in the coastal zone. ICLARM Conf. Proc. 63, 71p.**

These proceedings comprise the presentations made and the results of working group discussions held at a combined international and national (Ghana) workshop entitled "Biodiversity and Sustainable Use of Fish in the Coastal Zone." They reflect the complex issues involved in the sustainable use and conservation of different fish species and different ecosystems. The contributions to the meeting covered a wide range of natural resources within the coastal zone which is a wide concept and includes inland waters.

*Keywords: biodiversity; fish; coastal zone*

**Adite, A. & Vanthielen, R., 2005. Ecology and fish catches in natural lakes in Benin, West Africa. Environmental Biology of Fishes, 43(4), 381-391.**

A preliminary study of the ecology and commercial fish catches was carried out in the Toho-Todougba, Ahouangan and Dati lakes (1500 ha) in southern Benin (West Africa) over a period of 18 consecutive months. Water quality, species richness, and the reproductive biology of the dominant species, *Sarotherodon galilaeus*, were examined. Unlike Lagoon Toho-Todougba, lakes Ahouangan and Dati are less favourable for fish production because of their high total iron content and their relative low pH. The study revealed the existence of 19 species belonging to eleven (11) families: 16 species in Lagoon Toho-Todougba, 12 in Lake Ahouangan, and 7 in Lake Dati. Lakes Ahouangan and Dati had a relatively high faunal similarity whereas Lagoon Toho-Todougba exhibited a relatively low faunal similarity with the former systems. In Lagoon Toho-Todougba, six cichlid species were the most important component of the fishery: *Sarotherodon galilaeus*, *Tilapia guineensis*, *T. zillii*, *T. mariae*, *Chromidotilapia guntheri*, *Hemichromis fasciatus*. Three catfish species *Chrysichthys auratus*, *Clarias agboyiensis*, and *Clarias lazera* were harvested in low abundances. Some other fish, such as *Polypterus senegalus*, *Protopterus annectens* and *Heterotis niloticus* were captured sporadically, with *H. niloticus* appearing more consistently in catches than the others. Although not abundant, *Gymnarchus niloticus* and the African pike, *Hepsetus odoe*, were almost always present in the catches. *Ctenopoma kingsleyae* appeared only in Ahouangan. Some predatory species, such as *Notopterus afer* and *Xenomystus nigri*, are encountered only in lakes Ahouangan and Dati. In Lagoon Toho-Todougba, *Sarotherodon galilaeus* had a sex ratio (male:female) of 0.49:1, and size at maturation was estimated as 12.3 cm TL. The spawning period extended from May to September with the peak occurring in July. Fecundity was correlated to log-body length ( $r = 0.74$ ) and log-body weight ( $r = 0.76$ ). Fish catches were estimated at 389 kg ha<sup>-1</sup> year<sup>-1</sup>; about 73% of which was *Sarotherodon galilaeus*. The overexploitation of juvenile fish and the use of this lagoon for the irrigation of palm tree plantations have reduced fish recruitment and mean size.

*Keywords: fisheries, irrigation reproductive seasonality, Sarotherodon galilaeus, species richness, water quality*

**Ajana, A., 1980. Fishery of the mangrove oyster, *Crassostrea gasar*, Adanson (1757), in the Lagos area, Nigeria. Aquaculture, 21(2), 129-137.**

The mangrove oyster, *Crassostrea gasar*, constitutes an important source of animal protein among some communities in the Lagos area. This paper summarises present knowledge of the fishery of the mangrove oyster in the Lagos area, highlights its prospects, and suggests how oyster production for consumption can be improved.

*Keywords: mangrove oyster, fishery, Lagos*

**Albaret, J. & Laë, R., 2003. Impact of fishing on fish assemblages in tropical lagoons: the example of the Ebrie lagoon, West Africa. Aquatic Living Resources, 16(1), 1-9.**

Lagoon fish communities often consist of complex assemblages of numerous species, difficult to manage with conventional stock assessment models. Useful data are still lacking for evaluating the importance of man-made disturbance and reference situations are missing, especially in developing countries. As a consequence, by analyzing data collected 20 years ago in two of the six sectors of the Ebrie lagoon (Ivory Coast), this study aims to evaluate the impact of fishing effort on fish assemblages. These two sectors (V and VI), located far from the inlet, have similar physical, chemical, biological and fish fauna characteristics. The major difference lies in the fishing intensity: sector VI has a low fishing intensity (fishing for personal consumption using only individual gear), whereas sector V is heavily fished (professional fishing with both individual and collective gear, particularly beach seines which result in a considerably higher fishing effort). Comparisons between the two sectors were based on two complementary scientific approaches: a 3-year commercial fisheries survey (1978-1980) and a 1-year experimental survey (1981). The impact of fishing on fish assemblages is analysed through the main characteristics of fish populations and communities. The results show that there were major changes including an increased catch yield (37.5-189 kg ha<sup>-1</sup> y<sup>-1</sup>), a lowering of fish diversity in catches, of fish biomass (100-20 kg ha<sup>-1</sup>), of average catch length (22.6-14.6 cm) and of trophic level of catches (26-58.5% of herbivore/detritivore species in total catches). Such results are quite unusual because they occurred even in non-overfished ecosystems: the fish assemblage was deeply modified in sector V compared to the lightly fished adjacent sector VI, even though fishing effort in sector V was only high but at a reasonable level. These data must be completed by similar studies in tropical lagoons with variable levels of fishing intensity in order to understand fish assemblage re-organization when submitted to stresses of different intensity.

*Keywords: fishing, fish assemblage, tropical lagoon, Ebrie*

**Alder, J. & Sumaila, U.R., 2004. Western Africa: A Fish Basket of Europe Past and Present. *Environment and Development*, 13(2), 156-178.**

This article shows that despite increasing catches by foreign fishing fleets, the economic growth and social benefits from marine resources have not been met for many western African countries that host these fleets. A meta-analysis of changes in catches, market values, exports, imports, employment, access, and domestic supplies in western Africa since 1960 illustrates the impact of the expansion of distant-water fleets on not only the status of the marine resources and their ecosystems but also on the economic and social conditions of the people of western Africa. Finally, recommendations are made on appropriate management options for foreign fishing fleets and the key initiatives that could be considered by regional fish bodies and governments in western Africa.

*Keywords: fish, West Africa, foreign fishing fleets, economic, social, marine*

**Anetekhai, M.A., Akin-Oriola, G.A., Aderinola, O.J. & Akintola, S.L., 2004. Steps ahead for aquaculture development in Sub-Saharan Africa – the case of Nigeria. *Aquaculture*, 239, 237-248.**

Conventional aquaculture began in Nigeria about 1951 with the establishment of the Panyan Fish Farm in Jos. The farm served as the first training and extension center for fish farming in the country. At present, most fish farms in Nigeria are fresh water based and cultured species include cichlids of the genera (*Oreochromis* and *Sarotherodon*) and catfishes (*Clarias*, *Heterobranchus* and their hybrids). Current production from aquaculture is about 26,000 metric tonnes which is less than 0.01% of the national capacity. The major constraints identified as being responsible for the low production from aquaculture are: shortage of inputs (fingerlings and feed), lack of knowledge resulting in poor management, inadequate funding, theft and direct involvement of the government in production. This paper recommends some measures to be taken for the development of aquaculture in Nigeria particularly the creation of a Ministry of Fisheries to co-ordinate all activities in the sector and provides an enabling environment for aquaculture.

*Keywords: Aquaculture, challenges, steps ahead, Nigeria*

**Anguis, V. & Cañavate, J.P., 2005. Spawning of captive Senegal sole (*Solea senegalensis*) under a naturally fluctuating temperature regime. *Aquaculture*, 243, 133-145.**

Senegal sole aquaculture is at present limited due to poor reproduction of captive breeders in many facilities. Temperature seems to play an important role in controlling reproduction of *Solea senegalensis*, and differences in temperature regimes followed by various hatcheries are likely to be responsible for lack of success in some of them. This work describes the reproduction of captive soles, held in facilities that used water at ambient temperature, from a marshy environment where this species naturally breeds. Acclimated sole breeders were kept for two consecutive years. The

main spawning period occurred from February to May, with a secondary spawning in autumn. Total yearly fecundity ranged from  $1.15 \times 10^6$  to  $1.65 \times 10^6$  eggs  $\text{kg}^{-1}$  body weight. Of the total egg batches produced, only 5.4% corresponded to autumn spawns. The male population was found to produce sperm all year round, with a maximum proportion of 100% occurring in spring, and a minimum proportion of around 50% in summer. Females showed the more developed ovary stages from October to May, with partial regression in the summer months. During the main spawning period, eggs were produced between 46% and 69% of days. Spawning took place at temperatures from 13 to 23 °C, although higher fecundities ( $P < 0.05$ ) occurred between 15 and 21 °C. Within the range between 17 and 20 °C, the mean number of spawned eggs was  $29,600 \pm 21,600$  eggs  $\text{day}^{-1}$   $\text{kg}^{-1}$ . Most of the eggs (65–73%) were produced after temperature increased up to 2.5 °C within 3 days prior to spawning. Mean egg fertilization was  $63.1 \pm 17\%$  (year 2002) and  $44.9 \pm 18\%$  (year 2003), and hatching rates varied from  $69.7 \pm 24\%$  (2002) to  $56.5 \pm 25\%$  (2003). Weak correlations were found between either fertilization or hatching and fecundity, whereas a positive regression ( $P < 0.05$ ) indicated that higher hatching rates were achieved when fertilization increased. A weak, but significantly ( $P < 0.05$ ) positive correlation was found between egg fertilization and the spawning temperature. Present results indicate temperature is an important control factor for reproduction of *S. senegalensis*, and suggest it can be used to properly manage controlled captive reproduction of this species.

*Keywords: Spawning, Solea senegalensis, temperature, fecundity, egg viability, hatching*

**Annala, J., 1997. Fisheries and aquaculture research planning needs for Africa and West Asia. *ICLARM Conference Proceedings* 50, 80p.**

The report describes the process in identifying the research agenda for conducting research on living aquatic resource management in the Africa and West Asia region.

*Keywords: fisheries, aquaculture, research programme*

**Aryeetey, B., 2002. Socio-Economic Aspects of Artisanal Marine Fisheries Management in West Africa. In J. McGlade, K. Koranteng, & N. Hardman-Mountford (eds.). *The Gulf of Guinea Large Marine Ecosystem- Environmental Forcing & Sustainable Development of Marine Resources*. Amsterdam: Elsevier Science, pp. 323-344.**

Artisanal fisheries in West Africa including the Gulf of Guinea are facing serious challenges due to the virtually open access nature of the industry and the fact that the natural resources supporting this industry are beginning to show serious signs of stress, linked to overexploitation and natural environmental variability. This has been traced to an overdependence on fishing and allied activities as a means of livelihood in fishing communities and also expansionary policy measures in the past that encouraged more people to enter the fishing sector. The nature of artisanal fisheries

in West Africa are described. National and sub-regional structures for traditional and formal management of the sector are reviewed.

*Keywords: artisanal fisheries, Gulf of Guinea, socioeconomic, management*

**Atta-Mills, J., Alder, J. & Sumaila, U.R., 2004. The decline of a regional fishing nation: The case of Ghana and West Africa. *Natural Resources Forum*, 28, 13-21.**

Inadequate trade policies, globalization of the fishing industry, dominance of Europe's distant water fleets, declarations of exclusive economic zones (EEZs) by neighbouring West African nations, overfishing and a lack of good governance contributed to the decline of Ghana as a regional fishing nation, a position it had held since the 18<sup>th</sup> century. The prohibitive cost of access arrangements limited Ghana's access to distant waters. The country's marine environments have been impacted by overexploitation of stocks and the use of destructive methods. Subsistence fishing has become the sole means of survival for many fishers. The decline of the fishing sector has limited the country's ability to meet domestic demand and threatened the economic and food security of many Ghanaians. The article traces the early history of Ghana's fisheries, their gradual decline during the last four decades, and outlines recommendations for policy changes to address the situation and steer the nation on a course towards sustainable fisheries.

*Keywords: Ghana, fisheries, artisanal fisheries, trade, international fishing agreements*

**Baio, A., 2010. Show me the way: Inclination towards governance attributes in the artisanal fisheries of Sierra Leone. *Fisheries Research*, 102, 311-322.**

A decentralised artisanal fisheries resource stewardship framework brings the decision-making process closer to users, obliging the downward transfer of stewardship power sharing and incorporating local stakeholder input in assessing outstanding needs. Local councils were instrumental in implementing this strategy in Sierra Leone and their dissolution in 1972 impacted negatively on local participation. Their reintroduction in 2004 was rushed, and desired outcomes are yet to be realized. The relative importance of stakeholders in the artisanal fisheries of Sierra Leone and that of governance attributes have been evaluated using the Analytical Hierarchy Process methodology under two scenarios (the current stewardship arrangement and a theoretical reformed system). The objective of the study is to elicit stakeholder's opinions on stewardship arrangement in order to evaluate attributes which may aid (or deter) governance thereby creating a baseline against which changes from governance reform can be measured. Results indicate that the Ministry of Fisheries and Marine Resources currently wields disproportionate power over the stewardship of fisheries resources scoring the highest normalised geometric mean of 43% compared to about 20% reported for the University of Sierra Leone. The Ministry of Local Government scored 13.5% but all other stakeholders scored less

than 10%. The Ministry of Fisheries saw a drop in its rating to about 24% under a reformed system whilst the Ministry of Local Government increased in stature to 17% as the University of Sierra Leone remained unchanged. Endowment attribute was the most dominant at 72% under the current system, but political and institutional attributes were more important with about 40 and 31% respectively under the reformed scenario (compared to 17% for endowment attribute). A receptive Ministry of Fisheries and Marine Resources sharing power and responsibility in a reformed system is sought. The communities perceive equity in the political and institutional governance attributes as the means of achieving equity in the endowment and economic attributes as the end. Reforms could only succeed in the spirit of the ministry's quest to effectively implement the fisheries policy by empowering and facilitating institutions best suited to carry out stewardship functions at the local level.

*Keywords: stakeholder preferences, government attributes, artisanal fisheries*

**Baran, E., 2000. Biodiversity of estuarine fish faunas in West Africa. *NAGA, WorldFish Center Quarterly* 23 (4), 4-9.**

In West Africa (between Ivory Coast and Sénégal), estuarine environments vary from lagoons to high discharge rivers to inverse hypersaline estuaries. This results in a high diversity of estuarine fish species, with an important turnover and a core of ubiquitous species. The species richness of a given estuary depends on the combination of hydrological factors (marine or freshwater dominance) and biogeography (continental biogeographic regions). The catch rate is higher in lagoons and inverse estuaries than in normal estuaries, which can be explained by the predominance of small juveniles in the latter. Clupeids are the most abundant fishes all over the region, but different systems have different dominant species. Assessing the functioning of West-African estuaries provides useful comparisons to Asian estuarine systems.

*Keywords: estuarine fisheries, resources management, fauna, species diversity, West Africa*

**Béné, C., 2007. Diagnostic study of the Volta Basin fisheries Part I – overview of the Volta Basin fisheries resources. Report commissioned by the Focal Basin Project - Volta. Cairo Egypt: WorldFish Center Regional Offices for Africa and West Asia, 31 p.**

The Basin Focal Project for the Volta (BFP-Volta) is a research project funded by the Challenge Programme on Water and Food (CPWF). Its aim is to provide an in-depth analysis of the basin through three main thematic issues: water-poverty, water availability/use and water productivity. The overall objective of the BFP-Volta is to contribute to the main goal of the CPWF, that is, to alleviate poverty through better management of water in order to enhance agricultural productivity and environment conservation.

*Keywords: fisheries, Volta Basin, water availability, poverty*

**Béné, C., 2008. Global Change in African Fish Trade: Engine of Development or Threat to Local Food Security? Paris: OECD. 20p.**

Today fish is the most traded food commodity in the World. This situation is not without generating potential issues. On the one hand, fish trade is said to support economic growth processes in developing countries by providing an important source of cash revenue. On the other hand, fish trade is also said to lead to a decline in food security and a decrease in the availability of fish for the local population. In this paper we explore more thoroughly those two opposite views in the specific case of sub-Saharan Africa. For this we consider a range of eight national development indicators that encapsulate both economic and wellbeing of sub-Saharan countries over the last decade and correlate them against four indicators reflecting the country-specific importance of fish trade, industrial and small-scale fisheries in the economy of Sub-Saharan Africa. Our statistical analysis shows that when sub-Saharan countries' data are considered at the macro-economic level the fear that fish trade may affect negatively fish food security is not substantiated by any statistical evidences. At the same time the analysis also shows no evidence to support the claim that international fish trade contributes effectively to national economic development and/or wellbeing. The last section of the paper discusses the various possible reasons for this apparent lack of correlation and highlights the respective flaws underlying the two opposite discourse about the role of fish trade in national development and food security.

*Keywords: fish, trade, sub-Saharan Africa, national economy, well-being*

**Béné, C. & Friend, R., 2009. Water, poverty and inland fisheries: lessons from Africa and Asia. *Water International*, 34(1), 47-61.**

Relying on experience from West Africa and the Mekong Basin, we contend that small-scale inland fisheries are a critical element in the livelihoods of many farming households who live near water bodies in developing countries. Empirical evidence suggests that the relation between poverty and small-scale fisheries cannot be reduced to a simple correlation with income. A more thorough analysis is required. Using vulnerability and exclusions as two dimensions of poverty, we show that poverty in fishing communities includes a wide range of variables: income but also land ownership, debt, access to health, education and financial capital, and political and geographical marginalization.

*Keywords: small scale fisheries, poverty, West Africa, Mekong, livelihoods, vulnerability*

**Béné, C. & Heck, S., 2005. Fish and Food Security in Africa. *NAGA, The WorldFish Center Quarterly*, 28 (3&4), 8-13.**

Today, in sub-Saharan Africa, one out of every two people (49%) lives on less than \$1 a day. While in other regions chronic hunger is receding, in sub-Saharan Africa malnutrition is still rising in both absolute and relative terms. More than one third (34%) of the sub-Saharan African population is undernourished – an increase

of 9 million since the 1996 World Food Summit – with dramatic and sometimes irreversible consequences on the physical, social and economic development of the communities concerned. Between 15 000 and 20 000 African women die each year (41–55 every day) due to severe iron-deficiency anemia. Vitamin A deficiency in children is common across the whole continent, contributing to the deaths of more than half a million African children annually. Fish, as a source of “rich food for poor people”, can play an important role in improving Africa's food security and nutritional status; more than 200 million Africans eat fish regularly. Fresh, but more often smoked, dried, or even as powder, fish is a critical source of dietary protein and micronutrients for many isolated communities in rural areas. Fish may also be the sole accessible and/or affordable source of animal protein for poor households in urban or peri-urban areas. Nutritionally, fish is therefore one extremely important direct source of protein and micronutrients for millions of people in Africa. But fish also contribute indirectly to national food self-sufficiency through trade and exports. In equivalent terms, 50% of the low-income food deficit countries' import bill for food was paid in the year 2000 by receipts from fish exports.

*Keywords: fish, food security, protein, Africa, smoked, dried, fresh*

**Béné, C., Hersoug, B. & Allison, E., 2010. Not by Rent Alone: Analyzing the Pro-Poor Functions of Small-Scale Fisheries in Developing Countries. *Development Policy Review*, 28(3), 325-358.**

The dominant view in academic and policy arenas is increasingly one in which the major contribution of capture fisheries to development should be derived from the capacity of society to maximise the economic rent of fishery resources. Drawing upon empirical experience from the South, this article highlights the potentially disastrous consequences that a universal implementation of the rent-maximisation model would have in developing countries, and argues that a more gradual approach would be preferable. The welfare function of small-scale fisheries, namely, their capacities to provide labour and cash income to resource-poor households, should be preserved until the appropriate macroeconomic conditions for rent-maximisation and redistribution are fulfilled.

*Keywords: Washington consensus, livelihoods approach, fishing communities, chronic poverty, West Africa, vulnerability, policy, management, market, world*

**Béné, C., Lawton, R. & Allison, E.H., 2010. “Trade Matters in the Fight Against Poverty”: Narratives, Perceptions, and (Lack of) Evidence in the Case of Fish Trade in Africa. *World Development*, 38(7), 933-954.**

Two opposing views exist in the literature on the potential role that international fish trade plays in economic development. While some claim that fish trade has a pro-poor effect, others denounce the negative effect of fish export on local populations' food security and doubt its contributions to the macro-economy. In this paper, we explore this debate in sub-Saharan Africa. Our analysis did not find any evidence of

direct negative impact of fish trade on food security; neither did it find evidence that international fish trade generates positive, pro-poor outcomes. This paper discusses the possible reasons for this apparent lack of development impact and highlights the unsupported assumptions underlying the current discourse about international fish trade. We suggest that, given lack of evidence for the development benefits of fish trade between Africa and developed countries, fisheries policy could consider support for regional (Africa-to-Africa) trade that meets the growing African demand for lower-value fish. Means of overcoming barriers to intra-African trade in fish are discussed.

*Keywords: food security, international fish trade, poverty reduction, small-scale fisheries, Africa*

**Béné, C. & Merten, S., 2008. Women and Fish-for-Sex: Transactional Sex, HIV/AIDS and Gender in African Fisheries. *World Development*, 36(5), 875-899.**

This paper analyzes the phenomenon of fish-for-sex in small-scale fisheries and discusses its apparent links to HIV/AIDS and transactional sex practices. The research reveals that fish-for-sex is not an anecdotal phenomenon but a practice increasingly reported in many different developing countries, with the largest number of cases observed in Sub-Saharan African inland fisheries. An overview of the main narratives that attempt to explain the occurrence of FFS practices is presented, along with other discourses and preconceptions, and their limits discussed. The analysis outlines the many different and complex dimensions of fish-for-sex transactions. The paper concludes with a set of recommendations.

*Keywords: artisanal fisheries, vulnerability, poverty, public health, Africa*

**Béné, C. & Neiland, A.E., 2003. Fisheries development issues and their impacts on the livelihoods of fishing communities in West-Africa: An overview. *Food, Agriculture & Environment*, 1(1), 128-134.**

Fisheries (in particular small-scale fisheries) provide a vital source of food, employment, and economic well-being for rural people throughout the world. In West Africa several million households along the coast and also inland are critically dependent on fishing for their livelihoods. However, fishing communities are often characterized as being amongst “the poorest of the poor”. The main objective of this paper is to review the major issues relating to the development and management of small-scale fisheries in West Africa and to examine their impacts on the livelihoods of the fisheries-dependent communities of the region. Several major issues are identified, discussed and briefly illustrated using numerical examples or extracts of official documents. Globally, it appears that the fisheries sector, despite its potential role as a powerful lever for poverty reduction, is often neglected by national or supra-national decision-makers. Since 1999, however, a number of international initiatives (sponsored by Donor Agencies) have attempted to overturn this negative perception.

*Keywords: Small-scale fisheries, West Africa, development policies, livelihoods, poverty*

**Béné, C. & Obirih-Opareh, N., 2009. Social and economic impacts of agricultural productivity intensification: The case of brush park fisheries in Lake Volta. *Agricultural Systems*, 102, 1-10.**

The intensification of agricultural productivity through technological innovation has often been reported to induce considerable social and economic transformation in the rural communities where those innovations are introduced. This paper investigates those changes in the case of acadja, a particular technique for intensifying fishing, which has been adopted in various parts of the developing world. Using the case of Lake Volta in Ghana, the paper investigates the social and economic impacts of this technique, looking in particular into issues of income, assets and (re)distribution of the wealth created by those acadjas. Our analysis shows that the impact of acadjas on fishing communities is mixed. While acadja certainly helps to enhance the supply of protein-rich food and may have trickle down effects at the community level, those positive contributions are greatly reduced by other more negative effects. The data show in particular that acadjas are not a poor-neutral technology in the sense that their contribution to household income seems to benefit disproportionately the wealthiest owners. As such, acadja fisheries often create negative sentiments amongst the households who cannot afford investing in this technology, creating a situation which may lead to social tension and intra-community conflicts.

*Keywords: Poverty, rural development, inland fisheries, enclosure of the commons, sub-Saharan Africa*

**Béné, C. & Russell, A., 2007. Diagnostic study of the Volta Basin fisheries Part 2 – Livelihoods and poverty analysis, current trends and projections. Report commissioned by the Focal Basin Project - Volta. Cairo Egypt: WorldFish Center Regional Offices for Africa and West Asia, 66 p**

The present document is the second part of this report. Its main objective is to conduct a socioeconomic and poverty analysis of the fishing communities living in the Volta Basin, based on an assessment of the current situation and potential future changes. More specifically the report will be articulated around the following two questions:

- Amongst the poor (and poorest) living in the Volta Basin, are there households that are engaged in the fishery sector, and if so what is, or are, the reason(s) of their ‘poverty’?
- Which solutions in relation to the water management and watery resources can be proposed to improve the livelihoods and living conditions of these poor fishing households in a durable way (horizon 2050)?

To provide element of answer to these questions, the report will address the following specific objectives:

- Characterize the current activity of fishing in the basin, its socio-economic importance and the degree of poverty of the actors,



- Identify among the fisheries stakeholders, the poor or vulnerable social categories, and to analyze the reasons of this poverty,
- Analyze the trends and risks at the time horizon 2025-2050, notably with respect to climate change,
- Propose solutions to improve the living conditions of the categories of disadvantaged fisher-folk, under the current situation as well as under the climatic change scenarios or changes related of water management at the basin scale.
- Identify knowledge gaps and research questions.

Commensurate with the relatively high densities of fisherfolk around Volta Lake itself, much of the published data on fishing livelihoods comes from this area. However, where possible, the analysis will include the situations of the other water bodies of the basin, i.e. hydropower reservoirs, rivers, floodplains, and the numerous small-scale seasonal ponds that are scattered throughout the basin. Through its analysis, the report will essentially concentrate on two countries within the basin: Ghana and Burkina Faso, but it is thought that the main conclusions can also apply to a large degree to the other inland fishing communities living in the other part of the basin in Togo, Benin, Cote d'Ivoire and Mali.

*Keywords: Volta Basin, fisheries, trends, poverty, households*

**Bennett, E., 2005. Gender, fisheries and development. *Marine Policy*, 29(5), 451-459.**

Although West African fisheries have been the subject of considerable study, little attention has paid to the role of gender in the development process and, more specifically, the work done by women in the overall management of fisheries. Lack of attention to the gender dimension of fisheries management can result in policy interventions missing their target of creating sustainable livelihoods at the community level. There is little doubt that fishing-dependent communities have a vital role to play in the overall development process of many coastal West African States, but without a complete understanding of the complexity of gender roles, the goal of sustainable livelihoods is unlikely to be achieved. In a bid to improve knowledge about gender roles in fishing communities, and to provide policy makers with some guidance as to where interventions might be most useful, a workshop was held in Cotonou, Benin (West Africa) in December 2003. This paper provides a brief introduction to the theory on gender and fisheries development and then goes on to report the findings of the workshop. The most significant conclusion is that policy interventions which help strengthen institutional capacity in coastal artisanal communities would have the greatest overall impact. A move toward collecting gender and fisheries disaggregated data would also help expand existing knowledge about what are often marginal and isolated economic sectors.

*Keywords: Gender, West Africa, sustainable livelihoods, fisheries policy*

**Brinsona, A.A., Diea, D.J., Bannerman, P. & Diattac, Y., 2009. Socioeconomic performance of West African fleets that target Atlantic billfish. *Fisheries Research*, 99(1), 55-62.**

Managing marine resources is a contentious and complicated process. There are various users with competing objectives, especially in the case of artisanal and recreational fisheries management. Managers must consider not only the biological sustainability of the resources, but also account for the socioeconomic objectives of the fishery users, particularly in developing countries. In-person surveys were implemented with artisanal fishers that target billfish in Ghana and with recreational charter boat anglers that target billfish in Senegal. Data from the survey were used to compile financial performance indicators that describe the sustainability of the operations. In addition social and resource management perception data were collected in each location. The results of the study indicate that both fleets exhibit positive profit levels. Although fishers in both study locations perceived a declining billfish resource, they were largely unwilling to accept management measures to improve the resource. If management measures were to be considered for the artisanal fleet, managers should simultaneously introduce mechanisms to improve the technological storage capacity of harvested fish and training on saving schemes for artisanal fishers. Managers should also monitor the number of recreational vessels and their effort in Senegal. Performance indicators such as these are applicable and appropriate for quantitatively assessing the profitability of fishing fleets.

*Keywords: Socioeconomic, billfish, West Africa, fisheries management, performance indicators, artisanal, recreational*

**Brulhest, J., 1975. Observations on the biology of Mugil *Cephalus ashentensis* and the possibility of its aquaculture on the Mauritanian coast. *Aquaculture*, 5, 271-281.**

After the family Mugilidae has been described in Mauritanian waters, the first observations on the biology of *Mugil cephalus ashentensis* are mentioned: growth, feeding, reproduction and spawning period, migrations. All the biological aspects of this *Mugil* indicate that it is suitable for aquaculture. Description of the Mauritanian coast is given with special emphasis to indicate the area where culture of *Mugil* is possible. The best place for this project is in the south of the country, near the Senegal River.

*Keywords: Mugilidae, biology, aquaculture, Mauritania*

**Brummett, R.E., Lazard, J. & Moehl, J., 2008. African aquaculture: Realizing the potential. *Food Policy*, 33(5), 371-385.**

Despite 40 years of research and development, and hundreds of millions of dollars spent, aquaculture is struggling to realize its high biophysical potential in Africa. Hampered by ineffective institutional arrangements and donor-driven projects, the substantial gains in desperately needed food security and economic growth predicted

by development agencies have generally not been achieved. Nevertheless, African aquaculture has demonstrated its competitiveness, producing fishes that feed low on the food chain in a range of well-adapted, environmentally friendly and profitable farming systems that meet the needs of a broad spectrum of user-groups. Key constraints to broader growth include lack of good quality seed, feed and technical advice; poor market infrastructure and access; and weak policies that, rather than accelerate, impede expansion, largely by emphasizing central planning over private sector initiative. If African aquaculture is to make substantial and much needed contributions to the continent's development, government policy should attempt to facilitate the alleviation of key constraints and rely more heavily on commercial investments to lead future growth. Evidence to date indicates that a pragmatic business approach focusing on small and medium-scale private enterprises would produce more benefits for more people than centrally planned and government led development projects.

*Keywords: Fish farming, development*

**Brummett, R.E. & Meryl J.W., 2000. The evolution of aquaculture in African rural and economic development. *Ecological Economics*, 33(2), 193-203.**

In Africa, aquaculture has developed only recently and so far has made only a small contribution to economic development and food security. We review developments and identify constraints to the expansion of aquaculture in economic and rural development at the continental, national and farm levels. Past development initiatives failed to achieve sustainable increases in production. In contrast, a growing number of smallholder farmers in many countries have been adopting and adapting pond aquaculture to their existing farming systems and slowly increasing their production efficiency. An evolutionary approach that builds on a fusion of local and outside participation in technology development and transfer appears more likely to produce fish production systems that are more productive and more environmentally and socially sustainable in the long term.

*Keywords: Aquaculture, Africa, rural development, food security, integration, evolution of aquaculture*

**Coll, C., Morais, L., Læe, R., Lebourges-Dhaussy, A., Simier, M., Jean, G., Josse, E., Ecoutin, J., Albaret, J.-J., Raffray, J. & Kantoussan, J., 2007. Use and limits of three methods for assessing fish size spectra and fish abundance in two tropical man-made lakes. *Fisheries Research*, 83, 306-318.**

A comparative study, combining three different assessment methods (fish gillnet sampling, artisanal fisheries surveys and hydroacoustics) was conducted in Mali where two man-made reservoirs (Sélingué and Manantali) are particularly suited for investigating the impact of fishing effort on the fish assemblage. These two ecosystems have relatively similar areas, edaphic and environmental properties but are subjected to different levels of fishing exploitation (low at Manantali, high at

Sélingué). The comparison is based on two indicator parameters: the abundance indices and the size spectra distributions, obtained by the three methods at two contrasting hydrological seasons (April and October). The results were compared first between the two seasons, and then between the two lakes. The present work is based on two main hypotheses: (1) that there is a higher fish abundance in October associated with smaller overall sizes, after spawning; (2) a lower abundance and smaller sizes in the Sélingué reservoir than in Manantali, because of the much higher fishing pressure in Sélingué. The relevance of each method to the selected indicators is discussed. On the one hand, the three methodologies on the whole gave similar conclusions and they also complement each other. On the other hand, some results do not match the hypotheses because of biases due to difficulties and technical limitations of each method in such ecosystems (shallow water with vegetation and stumps of former forests).

*Keywords: Fish sampling, artisanal fisheries, hydroacoustic, abundance estimate, size distribution, shallow waters, West Africa*

**Chukwuone, N.A., Ukwe, C.A., Onugu, A. & Ibe, C.A., 2009. Valuing the Guinea current large marine ecosystem: Estimates of direct output impact of relevant marine activities. *Ocean & Coastal Management*, 52(3-4), 189-196.**

This study is a first step towards valuing the Guinea Current Large Marine Ecosystem (GCLME), one of the five world's most productive marine areas that are rich in fishery resources, petroleum production, and an important global region of marine biological diversity. The area is highly degraded and thus demands urgent attention to recover and sustain depleted fisheries; restore degraded habitats; and reduce land and ship-based pollutions. Achieving this goal would be a mirage if the actual value of the ecosystem's contribution to the society is not known. Valuation can help identify the main beneficiaries of conservation and the magnitude of benefits they receive, and help design measures to capture some of these benefits and contribute to financing of conservation. Hence this study used the direct output approach to estimate the value of relevant marine activities in the area. The result shows that the total value of output in GCLME when some outputs namely, marine fishery, offshore oil production, NTFP (periwinkle) and mining, are considered as \$49,941.4 million. Among these uses, offshore oil production has the highest value accounting for 59.79% of the total estimate. These estimates provide sufficient evidence to show that GCLME provide enormous value and should be managed appropriately to sustain the gains if the economic development would be guaranteed especially considering that most countries in the GCLM depend on natural resources for their survival. Evolving a well defined property rights regime and an efficient governance system for management is recommended.

*Keywords: Guinea Current, large marine ecosystem, fisheries, habitats, degradation*

**Dankwa, H.R., Shenker, J.M., Lin, J., Ofori-Danson, P.K. & Ntiamo-Baidu, Y., 2004. Fisheries of two tropical lagoons in Ghana, West Africa. *Fisheries Management and Ecology*, 11(6), 379-386.**

The fisheries of two coastal lagoons, Keta and Songor, were studied as part of Ghana Coastal Wetlands Management Project (GCWMP) aimed at sustainable exploitation of wetland resources. Fish samples were obtained with seine nets and cast net as well as from local fishermen. Water quality parameters (pH, dissolved oxygen, temperature and turbidity) were similar in the two lagoons, except for salinity, which was significantly different ( $P < 0.001$ ). Despite their close geographical proximity, the two lagoons supported different fish assemblages with the blackchin tilapia, *Sarotherodon melanotheron* Ruppell, and the redchin tilapia, *Tilapia guineensis* (Bleeker), being the most important commercial fishes in both lagoons. The number of individuals for each species in Songor Lagoon were far more abundant, with densities several orders of magnitude higher than in Keta Lagoon. However, both species were significantly larger ( $P < 0.01$ ) in the latter [15-121 and 25-157 mm standard length (SL)] than in the former lagoon (30-102 and 15-95 mm SL) for *S. melanotheron* and *T. guineensis* respectively. Over-fishing, use of small-size mesh nets, limited mixing of marine and fresh water were some of the factors limiting fish production in both lagoons.

*Keywords: economic, fish communities, fisheries, tropical lagoons*

**Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S. & Ahmed, M., 2003. Outlook for fish to 2020 Meeting Global Demand, Penang, Malaysia: A 2020 Vision for Food, Agriculture, and the Environment Initiative International Food Policy Research Institute WorldFish Center, Fish for All, International Food Policy Research Institute (IFPRI).**

The world's fish sector may become a victim of its own success. In the past 30 years the global appetite for fish has doubled. From 45 million metric tons in 1973, total fish consumption jumped to more than 91 million tons in 1997. This enormous growth signals changes in who is consuming fish and where. Consumption of fish in the developed countries stagnated between 1985 and 1997, mainly because populations remained stable and people there were already eating large quantities of fish. But at the same time, rapid population growth in the developing world, along with increases in the average amount of fish consumed per person in those countries, led to soaring increases in global fish consumption.

*Keywords: fish, food, consumption, developing countries*

**Dugan, P., 2003. Investing in Africa: the WorldFish Center's African strategy in summary. *NAGA, The WorldFish Center Quarterly*, 26(3), 4-8.**

Across much of Africa, freshwater and coastal fisheries provide an important source of food and livelihood for many millions of people. In addition, the aquaculture potential of the continent has only recently begun to be developed. To help sustain

these capture fisheries, support the emergence of aquaculture and foster the contribution of both to sustainable livelihoods and improved food security, the WorldFish Center is increasing its investment in Africa. The framework for this investment is provided by a new Strategy for Africa and West Asia 2002-2006 that identifies priorities for the Center's work in rivers and floodplains, lakes and reservoirs, coastal fisheries, aquaculture, policy research and capacity building. The present article summarizes the issues being addressed by the Center and describes initial research priorities.

*Keywords: Worldfish Center, fisheries, aquaculture, research program, training*

**Ecoutin, J.M., Simier, M., Albaret, J.-J., L e, R. & de Morais, L.T., 2010. Changes over a decade in fish assemblages exposed to both environmental and fishing constraints in the Sine Saloum estuary (Senegal). *Estuarine, Coastal and Shelf Science*, 87(2), 284-292.**

To investigate the changes in the fish assemblage of the Sine Saloum estuary (Senegal) over a 10-year period, it was surveyed during a complete hydrological cycle (three principal hydro-climatic seasons) first in 1992 and then in 2002-2003. The sampling protocol for the two surveys was identical, using the same sampling technique, the same collection periods, and the same sampling stations. The Sine Saloum is an inverse estuary in terms of its salinity gradient. It is affected by the intense drought that has occurred in this biogeographic region for more than 50 years. The estuary is also subjected to high fishing pressure. The second data-collection period followed a few years of higher recorded rainfall (approximately 35% higher than in 1992) and was characterized by increased fishing pressure (over 50% higher than in 1992). For the two study periods, the same set of indicators were calculated, including fishing indicators (catches, density, yields), size-based indicators (size structures, mean length, maximum observed length, size spectra), ecological indicators (richness, species diversity, K-dominance models, ABC curves, ecological categories) and trophic indicators (mean trophic level, trophic composition of catches). Overall, the main changes in the estuary's fish assemblage between 1992 and 2002 were (1) a loss in total biomass (40% less) for an equivalent species richness (approximately 55 species); (2) a decrease in the maximum observed lengths for many species (mean decrease of 17%); and (3) a decrease in the mean trophic level (more than 0.11 units). Analysis by bio-ecological and trophic category showed that the main species concerned were benthophagous species and, to a lesser degree, generalist predator species from marine origin that inhabit the estuary more or less permanently.

*Keywords: indicators, environmental factors, overfishing, long-term changes, fish assemblages, Sine Saloum/Senegal/West Africa*

**Essuman, K., 1990. The role of inland fish in food consumption in West Africa: A review and annex: Artisanal fish containers in Ghana: A case study. In: *Symposium on Post-harvest fish technology*. CIFA Technical Paper. Cairo, Egypt: FAO.**

Inland water bodies provide man with fishery and agricultural resources. Man-made lakes have become an important source of livelihood for many fishermen in West Africa because commercial fishing has replaced subsistence fishing. About 20% of the total annual catch of 1.2 million t come from inland water bodies. Inland fishing, from catch to distribution, is entirely an artisanal activity, and the total catch is consumed within the subregion. Fish is the most important animal product in diet of the coastal people of West Africa, providing 30–80% of total animal protein intake. Fish consumption has however been declining lately due to stagnating supplies and expanding population. Marine fish trade involves the export of large quantities of high value species from West Africa to Europe, and importation of cheap low value frozen fish to the subregion. Inland fish constitutes a significant proportion of the total intra-regional fish trade. About 80 000 t of cured fish from centres located on Lake Volta, Lake Chad Basin, and along the banks of Rivers Niger and Benue are distributed throughout the region. Fish is preserved mainly by smoke-drying to low moisture content. Some is salted, fermented and dried. These products provide food fish and condiment in the traditional diets. Blowfly attack on wet fish and beetle infestation of dry fish, coupled with fragmentation, are major causes of fish loss. Some traders apply unapproved insecticides to destroy insects in stored fish. Toxic chemicals and explosives are also used for fishing in lakes and rivers. Due to the shortage of wood fuel, the quality of cured fish from the Sahelian zone is sometimes poor. In Ghana, freshwater fish are well cured and of a high quality, although they often appear scorched. Smoked freshwater fish products are valued in Ghana and are relatively more expensive than marine fish, especially at distant markets. Salted, fermented and dried fish are cheaper and are widely used by a large section of the Ghanaian population.

*Keywords: inland, fish, artisanal, fish containers, Ghana*

**Fur, J.L. & Simon, P., 2009. A new hypothesis concerning the nature of small pelagic fish clusters. An individual-based modelling study of *Sardinella aurita* dynamics off West Africa. *Ecological Modelling*, 220, 1291-1304.**

Coastal populations of small pelagic fish display nested aggregation levels. Above the level of the school structure, clusters are observed the nature of which has not been definitively determined. We hypothesized that these clusters corresponded to a materialisation of the microcohorts originating from successive spawnings of fish populations in their vital domain. A candidate individual-based model was developed to investigate this hypothesis. This model is based on pattern-oriented modelling of a concrete documented case: the dynamics of the round sardinella (*Sardinella aurita*) population living off the West African coasts and subject to environmental

fluctuations caused by seasonal upwelling. The simulated agents were round sardinella microcohorts situated and moving in a discretised physical environment. The combined effects of environmental forcing (temperature, wind, retention) and inner biological dynamics (reproduction, growth and mortality, competition) condition the dynamics of this population. The modelled behaviour generated realistic dynamic patterns (population distribution, spawning zones, periods and plasticity, biomass fluctuations), which were obtained simultaneously and successfully compared with observations. The steady-state number of microcohorts obtained after simulation convergence was similar to the number of clusters observed *in situ* in this area for this population. The realism and diversity of the patterns simultaneously simulated suggested the cluster-microcohort equivalence hypothesis as a candidate framework accounting for the origin of the clusters observed *in situ*. Within this preliminary exploration, we discuss the consistency of the hypothesis and the accuracy of the model. If the correspondence between clusters and microcohorts proves to be real, it may be transient and progressively modified by other environmental factors. If stable over time, as simulated in the model, the number of observed clusters should be related to the number of spawning events in the species' lifetime.

*Keywords: Individual-based model, observed patterns, upwelling, small pelagic fishes, Sardinella aurita, microcohort, cluster, aggregation, West Africa*

**Gascuel, D., Zeller, D., Taleb Sidi, M.O. & Pauly, D., 2007. Reconstructed catches in the Mauritanian EEZ. p. 105-119. In: Zeller, D. and Pauly, D. (eds.), *Reconstruction of marine fisheries catches for key countries and regions (1950-2005)*. Fisheries Centre Research Reports 15(2). Fisheries Centre, University of British Columbia.**

The present catch reconstruction for 1950-2005 refers to the three main fisheries operating in the waters of the Mauritanian Exclusive Economic Zone (EEZ): the artisanal fishery, the demersal industrial fishery and the pelagic industrial fishery. This reconstruction is based on all information available, including data coming from the national surveys system of the Institut Mauritanien de Recherches Océanographiques et des Pêches (IMROP) and from assessment working groups regularly held in the country since 1985. Additionally, approximate estimates of the unreported catch and by-catch of the two industrial fisheries are proposed, and the catches of the national Mauritanian fisheries were estimated. Here, we provide the first picture of long term catch trends by the various fisheries. The demersal fisheries, overwhelmingly dominated by the industrial sector, developed in the 1960s, while artisanal fisheries remained underdeveloped until the 1990s, followed by a very rapid increase. In the context of rapidly increasing fishing effort, landings were estimated around 160,000 t·year<sup>-1</sup> over the last 40 years (including 40,000 to 70,000 t of unreported by-catch). While total landings remained rather stable, the composition in term of taxa significantly changed since the 1970s, suggesting severe overexploitation and the harvest of an increasingly wider range of ecosystem compartments. For the

more recent years, artisanal demersal catches are estimated around 60,000 t-year<sup>-1</sup> (80,000 t-year<sup>-1</sup> including pelagic fishes). Thus, demersal fisheries, in particularly the artisanal fishery, appears much more important than usually considered. Regarding the pelagic industrial fishery, landings exhibit a high year to year variability, but with a clear and still increasing trend. Estimates suggest unreported catches larger than several hundred thousand tonnes per years, mean total landings reaching 900,000 t-year<sup>-1</sup> during the last years. We also show that several hundred thousand tons officially caught by foreign vessels operating as 'Mauritanian chartered vessels' (and recorded in the IMROP database) have not been reported to the global community via FAO statistics. More generally, we underline the substantial importance of foreign countries in the exploitation of Mauritanian waters. Finally, the present case study of Mauritania is the first independent test of the results obtained by the spatial allocation approach of FAO data as undertaken by the *Sea Around Us* project. This test appears successful, i.e., catches from the *Sea Around Us* for Mauritania's EEZ waters being very close to our estimates of the official landings of the industrial fisheries.

*Keywords: fisheries, catch, reconstructing, EEZ, Mauritania*

**Gascuel, D., Labrosse, P., Meissa, B., Sidi, M. & Guenette, S., 2007. Decline of demersal resources in North-West Africa: an analysis of Mauritanian trawl-survey data over the past 25 years. *African Journal of Marine Science*, 29(3), 331-345.**

Mauritania is characterised by fast-growing fisheries that have developed over the past decades. Since 1982, scientific trawl surveys have been conducted regularly, allowing assessment of the impact of this increasing fishing pressure on exploited species as well as on demersal communities. Based on 55 bottom trawl surveys and using linear model techniques, the annual abundances were estimated for a selection of 24 fish stocks and for the whole demersal biomass. Changes in the demersal community structure were also investigated, using Biomass Trophic Spectra representations. It is shown that the demersal biomass has been reduced by 75% on the Mauritanian continental shelf over the past 25 years, corresponding to a biomass loss of around 20 000t per year. Top predators abundance has been reduced by 8-10-fold and in some case up to 20-fold. The trophic structure has been significantly modified and the mean trophic level of the catchable biomass decreased from >3.7 to <3.5. The results are discussed at the regional scale, taking into account recent studies in Senegal and Guinea in which a similar decline in demersal biomass was observed. This decline was due to severe overexploitation that affected the various groups in succession.

*Keywords: biomass decrease, demersal resources, Mauritania, North-West Africa, trawl survey, trophic structure*

**Goffinet, T., 1992. Development and Fisheries Management: The Case of Northwest Africa. *Ocean & Coastal Management*, 17 (2), 105-136.**

The paper examines the state of fisheries and fisheries management in northwest Africa. Typical problems and constraints faced when attempting to manage a fishery resource are discussed. The particular fishery management problems faced by developing nations in general and with reference to countries in northwest Africa are addressed such as the inability, because of political constraints, to avoid short-term solutions which then place the resource-base at risk. Ironically, the relative effectiveness of other countries' management plans may place the resources of these less-developed countries at greater risk as fishermen weigh the costs of entering various fisheries and choose those with ineffective management. Internationalization of fisheries management presents the only tool that can effectively address these structural problems.

*Keywords: fisheries, management, West Africa*

**Heck, S., Béné, C. & Reyes-Gaskin, R., 2007. Investing in African fisheries: building links to the Millennium Development Goals. *Fish and Fisheries*, 8(3), 211-226.**

Despite the large economic and social benefits fisheries can offer to address Africa's development needs, investment in African fisheries and aquaculture has been remarkably low. However, if fisheries and aquaculture are to meet the challenges of technological change, institutional reforms and resource mobilization needed in support of the sector's development potential, fisheries stakeholders must make the case for investment much more clearly within the context of wider socioeconomic development. In this paper, we argue that the global consensus around the Millennium Development Goals (MDGs) offers an important opportunity to pursue this agenda in Africa. In particular the MDGs' human development focus provides a compelling framework for articulating the comprehensive value of fisheries for poverty reduction and long-term socioeconomic development. The paper has two objectives. The first is to examine the direct and indirect links between fisheries and the individual MDGs, drawing together findings and lessons learnt from recent African case studies with relevant examples from elsewhere. The second is to translate these findings into recommendations for action in support of improved investments in fisheries aimed at increasing the overall development value of the sector.

*Keywords: African fisheries, development value, investments, Millennium Development Goals*

**Hem, S. & Avit, J., 1994. First results on Acadja-enclos as extensive aquaculture system (West Africa). *Bulletin of Marine Science*, 55(2-3), 1038-1049.**

Acadja is a fishing method widely practiced in the coastal lagoons of Benin. The principle of this traditional fishery is to set a dense mass of branches in shallow water, which attract the fishes from the wild. The West African "Acadja" is a kind of fish aggregator.

The harvest was found variable from 7 to 20 tons of fishes, per hectare and per year. The acadja may also act as a culture system. The study presented here attempts to give evidence of the role of acadja as a potential culture system. Two types of experimental design have been compared: enclosure with acadja (named "acadja-enclos") and enclosure without acadja used as a control. After 12 months, a biomass equivalent of 8 tons per hectare has been harvested from the acadja-enclos, equivalent to eight times that of the control system. Among the 18 species of fish harvested, *Sarotherodon melanotheron* (Cichlidae) represented 79% of the biomass. Analysis of the fish population showed that young fry had entered through the net at the beginning of the experiment and grown in the acadja-enclos. There were no differences in the condition factor between the *S. melanotheron* from the acadja-enclos and from the wild. The acadja-enclos system appears to be a promising way to exploit the lagoon areas. This principle could be applied in extensive aquaculture or in some aquatic management programs. Further research to understand the trophic structure of the system and the basis of the exchange mechanism of the food chain in the system is necessary. It could lead to improve it further. This is proposed in the discussion presented here.

*Keywords: aquaculture, acadja fishing, coastal lagoon, Benin*

**Jouffre, D. & Inejih, C.A., 2005. Assessing the impact of fisheries on demersal fish assemblages of the Mauritanian continental shelf, 1987-1999, using dominance curves. *ICES Journal of Marine Science*, 62, 380-383.**

The assemblages of demersal fish and associated species of the Mauritanian continental shelf are characterized on the basis of annual trawl surveys conducted during the period 1987–1999. Species composition is dominated by exploited species (*Dentex* spp., *Pagellus bellottii*, and *Octopus vulgaris*). Dominance curves (Abundance Biomass Comparison plots) were used to evaluate the impact of fisheries, which have increased in magnitude over several decades. The diagnosis of a "stressed" assemblage seems to converge with the results of a similar study conducted off Senegal, but here there was no trend in impact during the period of study. The sensitivity of the present results to the various ways of considering the available taxonomic information is also analysed.

*Keywords: community structure, dominance curves, fisheries impact, marine fish, West Africa*

**Kaczynski, V.M., 1989. Foreign fishing fleets in the sub-Saharan West African EEZ: The coastal state perspective. *Marine Policy*, 3(1), 2-15.**

This article analyses fishery resource use trends in waters adjacent to the West Africa and coastal states' capabilities to control distant water fishing fleets. Serious difficulties in resource management are compounded by unsatisfactory performance of local administrations in regulating license fishing and joint venture activities. Although not the only remedy, the civilian, scientific resource monitoring and surveillance systems can greatly reduce these problems and increase coastal countries' share in rents generated by their fishery resources. The author concludes

that the whole concept of existing controls of the 200-mile EEZ should be re-designed and new measures undertaken by the local governments with increased support of international donor community. Specific improvements and changes are recommended in the final part of the study.

*Keywords: fishing fleets, foreign, EEZ, West Africa*

**Kaczynski, V.M. & Fluharty, D.L., 2002. European policies in West Africa: who benefits from fisheries agreements? *Marine Policy*, 26(2), 75–93.**

Fishery cooperation agreements with the Sub-Saharan West African coastal states are considered by the European Union as purely commercial deals that are designed to maximize access to coastal state fishery resources, secure employment for European harvesting and processing industries and supply European seafood consumption markets at the lowest possible cost. Financial compensation paid by Brussels to the West African countries for fishing rights covers two-thirds or more of the license fees and is a subsidy for European vessel owners. This subsidy puts EU in position of a preferred user of the coastal resources. That displaces foreign investors and local entrepreneurs in the coastal states, distorts economics of the European fishing enterprises and promotes excessive pressure on the resources that greatly harms the marine environment in the West African region. Analysis of EU's relations with Guinea-Bissau shows that together with manipulation of the size of fishing fleet used by EU in this country's waters, there were significant irregularities resulting from excessive by-catch, underpayment of tuna license fees and denial of timely statistical information for the coastal state. Continuation of this type of relations with Sub-Saharan West Africa is against the long-term interests of the coastal states and sustainability of the coastal resources. Unless significant changes in fishing policies of the EU are made, West African coastal countries will face severe overexploitation of their resources and subsequent drop in license revenues. The EU's departure from purely business approach in fisheries relations with the West African coastal countries and termination of subsidization of the European fleets should be considered as important steps toward new fisheries relations with the region. On other hand, coastal states should undertake more coordinated approach in dealing with foreign pressures on their resources and harmonize negotiation of the fisheries agreements with the EU. They also must improve the investment climate so foreign fleet operators would be encouraged to integrate their offshore activity with the coastal states' economies.

*Keywords: European policies, fisheries, European fishing fleets, West Africa*

**Kaczynski, V.M. & Looney, S.W., 2000. Coastal Resources as an Engine of Economic Growth and Reduction of Poverty in West Africa: Policy Considerations. *Coastal Management*, 28, 235-248.**

Coastal resources of the Sub-Saharan West Africa have great potential to become an engine of growth and poverty reduction in this region, provided their use patterns

are radically changed. Today, a lion's share of these resources is taken away by foreign fleets, mainly by the European Union member-states and Asian operators. There is no integration of their activity with the coastal states' economies. With the exception of meager license fees and domestic artisanal harvest, mostly for local consumption, coastal countries receive no other benefits from these resources. To reverse this trend it is necessary to create a favorable investment climate in coastal states' economies and to take decisive legislative measures to encourage foreign operators to invest in coastal infrastructures, and to start unloading and processing their catches in local plants using the comparative advantage of inexpensive local manpower and other local inputs. This will create jobs and hard currency revenues from exports of seafood and will stimulate the development of other subsectors of the national economy. This study shows that by moving processing of the coastal resources to the land infrastructures, the benefits for the national economy will be 10 times greater than West African countries receive from the license fees paid by international fleet operators. The real issue, however, is that by establishing onshore processing, new jobs are created and hard currency revenues are substantially increased through exports of value-added seafood products. Higher fiscal revenues, more jobs, and increased supplies of fish for the local consumption markets are important benefit that currently are taken away by foreign users. These benefits can accelerate West African economic development and contribute to the reduction of poverty in the coastal states of this region. These opportunities are fully realistic provided structural changes are introduced by the governments, including legislative measures giving resource use priority to those who process them in the coastal country's onshore facilities.

*Keywords: coastal resources, policy, economic growth, poverty reduction, West Africa*

**Koranteng, K.A. & Pauly, D., 2004. Long-term Trends in Demersal Fishery Resources of Ghana in Response to Fishing Pressure. In M. L. D. Palomares & D. Pauly (eds.), *International Symposium on Marine fisheries, ecosystems, and societies in West Africa: half a century of change. Key findings of the International Symposium on Marine Fisheries, Ecosystems and Societies in West Africa – Half a century of change. Dakar, pp. 75-80.***

A brief review is presented of the structure of the Ghanaian fishing fleet, and of the changes they induced on their resource base since the 1960s. These changes consist of a reduction of the biomass of longer lived fishes, particularly in shallower waters, and in conjunction with environmental fluctuation, the creation of opportunities for invasive species of fish (triggerfish *Balistes carolinensis*) and invertebrates (e.g., scallops) to experience short-lived population outburst. The relative impacts of fishing and environmental changes in generating these outbursts are difficult to disentangle. It is evident, however, that the effort jointly exerted by several Ghanaian fleets onto their supporting fisheries resources is excessive and that the country would benefit from a reduction of that effort.

*Keywords: fishing fleets, demersal fishery, fishing pressure, Ghana*

**Laë, R., Williams, S., Massou, M., Morand, P., Mikolasek, O., Welcomme, R.L. & Petr, T., 2004. Review of the present state of the environment, fish stocks and fisheries of the river Niger (West Africa). In R. Welcomme & T. Petr (eds.), *The second International Symposium on the Management of Large Rivers for Fisheries. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining livelihoods and biodiversity in the new millennium. Sustaining livelihoods and biodiversity in the new millennium. Rome: FAO.***

The Niger River is the fourth most important river in Africa. It is 4 200 km long with an estimated watershed area of 1 125 000 km<sup>2</sup>. It traverses a variety of ecological areas shared by a number of countries in the West African Region: Guinea, Mali, Niger and Nigeria for its main course; Cote d'Ivoire, Burkina Faso, Benin, Chad and the Cameroon for its tributaries. The mean annual flow is 6 100 m<sup>3</sup> s<sup>-1</sup>. Since the beginning of the century, the Niger River has been subjected to several natural and anthropogenic perturbations: first, a very long drought period started in the 1970s when the discharges decreased strongly and the areas flooded were considerably reduced. Second, the building of dams and numerous irrigated perimeters fed by water pumping modify the hydrologic conditions of the Niger, increasing the effects of drought. These hydrological variations led to changes in the flora of the river-floodplain system and also to fragmentation or disappearance of habitats usually occupied by numerous fish species. The biological cycle of the fish that were adapted to the former hydrological cycle was modified to varying degrees, although the species richness of the river evaluated at 260 fish species did not change. Nevertheless, fish abundance changed from 1968 to 1989, fish landings declined from 90 000 metric tonnes to 45 000 metric tonnes in the central delta and large-sized species were gradually eliminated to be replaced by a sequence of small-sized and more productive species. The river is fished by dynamic and labour intensive small-scale fisheries, conducted by full and part time fishers, using diverse fishing gears adapted to various biotopes and seasonal variations in the ecosystem and the fish communities. Women play an important role in fish processing (drying or smoking fish) and marketing. In several countries around the Niger River watershed, the fish stocks have been reduced by dramatic increases in fishing activities. Aquaculture has been introduced as an accepted strategy to meet the very high demand for fish products. Aquaculture was introduced in Nigeria and Cote d'Ivoire in the 1950s based on indigenous species of tilapias and catfishes but is still in an embryonic state. The River Niger Commission was created in 1964 and evolved in 1980 into the Niger Basin Authority (NBA) to promote cooperation among the member countries and to develop its resources, notably in the field of energy, water resources, industry, agriculture, forestry exploitation, transport and communications.

*Keywords: fish stocks, environmental status, Niger River*

**Lawson, R. & Robinson, M., 1983. Artisanal fisheries in West Africa: Problems of management implementation. *Marine Policy*, 7(4), 279-290.**

This article discusses the relevance and effectiveness of management measures for West African artisanal fisheries. The structure of the fisheries is described and the sociological background outlined. The authors then analyze direct control over effort, control of imported inputs, closed seasons, taxes and subsidies, and the relevance of such management measures to the West African context. Measures such as changes in the supply of competing protein imports, indirect control through the fish market and management through traditional institutions are discussed and the authors conclude by arguing that, while overfishing does not yet present a serious problem to West African fisheries, the area will present special problems to the fisheries manager in future.

*Keywords: fisheries, management, West Africa*

**Longhurst, A.R., 1965. A Survey of the Fish Resources of the Eastern Gulf of Guinea. *Journal du Conseil, Conseil Permanent International pour l'Exploration de la Mer* 29 (3), 302-334.**

This resource survey was undertaken by the Federal Fisheries Service, Nigeria, in 1962 in order to estimate in a quantitative fashion the stocks potentially available to the developing Nigerian fishing industry. It was known that the small fleet of mechanized fishing vessels based in Lagos restricted themselves to the shallow water trawl fishery in the western section of the Bight of Benin and rarely ventured deeper than 36-5 m (20 fathoms), or further south than the Benin River, and it was important to determine the further extent of the resources they were exploiting in order to rationalize the planned development of the industry. In addition to the direct exploration of the stocks of demersal fish along the Nigerian continental shelf by the two research vessels "Kiara" and "Kingfisher" of this Service, use was made of a previously unpublished survey from the Bight of Biafra to the Togolese coast by the "Cape St. Mary" of the late West African Fisheries Research Institute, Freetown, performed during 1952. Information on the pelagic fish stocks was obtained at the observational level during the cruises of these vessels, both during the demersal fish survey and also during the oceanographic cruises of "Kiara" south from Lagos to the equator some 400 nautical miles from the coast. Local fishermen were questioned wherever convenient to obtain as complete a picture as possible of the likely distribution of pelagic stocks along the continental shelf.

*Keywords: fish resources, eastern Gulf of Guinea, fishing industry, Nigeria*

**Marquette, C.M., Koranteng, K.A., Overå, R., & Aryeetey, R.B., 2002. Small-scale Fisheries, Population Dynamics, and Resource Use in Africa: The Case of Moree, Ghana. *Ambio*, 31(4), 324-336.**

We consider population dynamics and sustainable use and development of fishery resources in Moree, a small-scale fishing and coastal community of 20,000 people in the Central Region of Ghana near Cape Coast. Moree suggests that relationships

between population dynamics and fishery resources are more complex than the concept of Malthusian overfishing implies. Reasons include changing biophysical characteristics of the upwelling system along the coast of West Africa; qualitative as well as quantitative changes in fishing activity throughout the year; the market nature of fishing activity and nonlocal demands for fish; regular fishery migration; and institutions regulating fishery resource access at home and at migration destinations. Population and resource relationships in Moree may be the effects of fishery resource and economic changes on migration rather than population pressure on fishery resources. Fisheries management policies must take into account processes that lie beyond the influence of local fishermen.

*Keywords: population dynamics, fishery resources, economic changes, Moree, Ghana*

**Mensah, M. & Quatey, S., 2002. An Overview of the Fishery Resources and Fishery Research in the Gulf of Guinea. In J. McGlade, P. Cury, K.A. Koranteng & N.J. Hardman-Mountford (eds.), *The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources*. Amsterdam: Elsevier Science. pp. 227-239.**

The countries of the region have been collaborating in fishery research activities mainly through the activities and support of international organizations such as the Fishery Committee for the Eastern Central Atlantic (CECAF), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and Institut de Recherche pour le Développement (IRD, ex-ORSTOM) and regional projects such as the Gulf of Guinea Large Marine Ecosystem Project. As a result of these activities, a number of resource surveys have been conducted in the Gulf of Guinea over the past four decades, the results of which are examined in this paper. The fishery resources are classified broadly as small pelagics, large pelagics, demersal, crustaceans and molluscs and are currently under various degrees of exploitation. While the small pelagic and coastal demersal resources are over-exploited, deep water demersal and large pelagic resources are either under-exploited or are being exploited close to their maximum sustainable yield. Changes have occurred in the fishery resources over the last two and half decades. The *Sardinella aurita* stock of the western Gulf of Guinea nearly collapsed in early 1970s and an increase in the abundance of *Balistes capriscus* was observed during the same period. *B. carolinensis* which became the most abundant demersal/semi-pelagic species in the 1980s has virtually disappeared from the entire region. Increases in the abundances of small pelagics and cephalopods was observed in the 1990s.

*Keywords: fishery resources, fishery research, Gulf of Guinea*

**Moses, B.S., 2000. A review of artisanal marine and brackishwater fisheries of south-eastern Nigeria. *Fisheries Research*, 47, 81-92.**

Analysis of 23 year (1969–1991) catch–effort statistics of the artisanal fisheries of south-eastern Nigeria, using both the linear and the exponential surplus production



models showed that the pelagic, demersal and crayfish resources available to the artisanal fisheries have been overfished; the stocks were most seriously depleted between 1984 and 1987. There was a slight improvement between 1988 and 1991, but currently the stocks are still in a depressed state. The problems of sustainability of the artisanal fisheries resources are discussed.

*Keywords: Artisanal fisheries, Nigeria, overfishing, sustainability, environmental impact, integrated management, coastal zone*

**Moses, B.S., Udoidiong, O.M. & Okon, A.O., 2002. A statistical survey of the artisanal fisheries of south-eastern Nigeria and the influence of hydroclimatic factors on catch and resource productivity. *Fisheries Research*, 57, 267-278.**

A statistical survey of the artisanal fisheries of south-eastern Nigeria conducted from September 1992 to August 1993 showed that the mean catch per canoe fishing unit per year was 6204 kg and well within the 95% confidence interval of existing earlier estimates. Bonga, *Ethmalosa fimbriata*, dominated the catch of the coastal/estuarine fisheries; in the freshwater sector, the catfish *Chrysichthys nigrodigitatus* was the dominant (albeit relatively seasonal) species in the landings. Regression/correlation analysis indicated positive linear relationships between the mean monthly catch ( $Y$  (MA)) as well as the catch-per-unit effort (CPUE) ( $Yf^{-1}$  (MA)) of the marine inshore fisheries and air and water temperatures ( $T_a$  and  $T_w$  respectively) and estuarine salinity (SAL). No such linear relationships were observed in the case of freshwater fish catch ( $Y$  (FW)); however, the regression of CPUE (i.e.,  $Yf^{-1}$  (FW)) on the river/floodplain water level gave a highly significant negative correlation reflecting the difficulty of catching fish in the very much expanded volume of water during floods. *Keywords: Nigeria's artisanal inshore fisheries, proportional probability sampling, catch rates, fishing effort, hydroclimatic factors*

**Nunoo, F., Eggleston, D. & Vanderpuye, C., 2006. Abundance, biomass and species composition of nearshore fish assemblages in Ghana, West Africa. *African Journal of Marine Science*, 28(3-4), 689-696.**

Many of the world's fish populations are overexploited, including Ghana's fish resources. This study examines spatio-temporal trends in fish species composition in relation to biotic, abiotic and anthropogenic factors, towards achieving better-informed management of the beach-seine fisheries. Fishery-dependent data were collected between November 1999 and October 2001 from 94 beach-seine hauls fished at two stations along the Ghanaian coast. The catch consisted of fish, crustaceans, other invertebrates, and macroalgae. Generally, juveniles of species that are exploited by offshore fisheries were found in the catches. Species abundance and their occurrence generally peaked between November and January. Duration of solar radiation and tide level appeared to be important predictors of fish biomass. It is important to exploit the nearshore fish assemblage sustainably because of its

nursery role. A co-managed (fishers and government) three-month ban on beach-seining (between May and July) is recommended as the most appropriate control measure towards the sustainability of Ghanaian fish stocks.

*Keywords: artisanal, beach-seine, fisheries, Ghana, nearshore, surf zone, West Africa*

**Nunoo, F.K.E., Boateng, J., Ahulu, A.M., Agyekum, K. & Sumaila, U.R., 2009. When trash fish is treasure: The case of Ghana in West Africa. *Fisheries Research*, 96(2-3), 167-172.**

The term 'trash' fish has been used to denote fish, usually non-targeted, that are caught as by-catch, and normally command no price in the market. Ecologists have long objected to this notion because in the natural system no creature is trash, they argued. In this paper, we demonstrate that even from the economic perspective, the term 'trash' fish is problematic, as what is considered trash in a given place and/or time may actually be treasure in another place and/or time. We demonstrate this in the case of Ghana. The current paper describes the organization of the trash fish business in Ghana, and the composition of marketed trash fish. It also determines the effects of the trash fish business on fish stocks and fishers' life, as well as suggests possible management interventions to ensure sustainable fish exploitation.

*Keywords: By-catch, discards, trash fish, fisheries management, juveniles, Ghana*

**OECD, 2008. The development dimension: Fishing for coherence in West Africa. Policy coherence in fisheries sector in seven West African countries, Organization for Economic Cooperation and Development (OECD), 124p.**

This report presents outcomes of a study, conducted by the OECD Fisheries Policies Division, in partnership with the SWAC and ENDA Diapol/REPAO, which takes a developing country perspective on the issue of policy coherence in fisheries. The aim of the study is to apply the OECD policy coherence for development analytical framework to the fisheries situation within a regional African context. Seven West African countries (Cape Verde, the Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone, - all members of the Sub-Regional Fisheries Commission) are analysed within this framework. Key areas for action by international, regional and local partners are suggested in the report, including the need for a multi-stakeholder dialogue on policy coherence as a priority-setting exercise.

*Keywords: fisheries, West Africa, policy, OECD*

**Ofori, J.K., Dankwa, H.R., Brummett, R. & Abban, E.K., 2009. Producing Tilapia in Small Cages in West Africa. Worldfish Center Technical Manual No. 1952. The Worldfish Center, Penang, Malaysia. 16p.**

This document is part of a series of 5 technical manuals produced by the Challenge Program Project CP34 "Improved fisheries productivity and management in tropical reservoirs". The Water Research Institute (WRI) in Akosombo, Ghana, is working to

bring cage aquaculture technology to smallholder farmers. The stocking, feeding and cage-construction technology piloted by WRI is now being widely adopted in the Lower Volta basin in Ghana. The results of WRI research over the period 2005-2009 are presented here as a guide to potential investors.

*Keywords: cage culture, gear construction, stocking, feeding, harvesting, marketing*

**Robinson, M.A. & Lawson, R., 1986. Some reflections on aid to fisheries in West Africa. *Marine Policy*, 10(2), 101-110.**

This article considers the reasons for the rather disappointing impact of projects to aid the growth and development of fisheries in West Africa. Possible reasons for this, at the stages of both identification and implementation, are examined and some suggestions are made for improved performance in the future.

*Keywords: aid to fisheries, West Africa*

**Simier, M., Blanc, L., Aliaume, C., Diouf, P.S., Albaret, J.J., 2004. Spatial and temporal structure of fish assemblages in an “inverse estuary”, the Sine Saloum system (Senegal). *Estuarine, Coastal and Shelf Science*, 59(1), 69-86.**

As a consequence of the Sahelian drought, the Sine Saloum, a large estuarine system located in Senegal (West Africa), has become an “inverse estuary” since the late sixties, i.e. salinity increases upstream and reaches 100 in some places. To study the fish assemblages of such a modified system, a survey was conducted in 1992, collecting fish every two months with a purse seine at eight sites spread over the three main branches of the estuary. A total of 73 species belonging to 35 families were identified. Eight species comprised 97% of the total numbers of fish. The predominant species was a small clupeid, *Sardinella maderensis*, representing more than half of the total biomass and nearly 70% of the total number of fish. The spatio-temporal structure of the fish assemblages was studied using the STATIS-CoA method, which combines the multitable approach with the correspondence analysis method. Whatever the season, a strong spatial organization of fish assemblages was observed, mainly related to depth and salinity. Three types of assemblages were identified. In shallow water areas, fish assemblages were dominated by Mugilidae, Gerreidae and Cichlidae and were stable with time. In open water areas, large fluctuations in the species composition were observed, due to the occasional presence of large schools of pelagic species: in the southern area, where salinity and water transparency were the lowest, the main species were *Ilisha africana*, *Brachydeuterus auritus* and *Chloroscombrus chrysurus*, associated with a few Sciaenidae and Tetraodontidae, while the poorest areas were characterized by only two dominant species, *S. maderensis* and *Scomberomorus tritor*.

*Keywords: inverse estuary, high salinity, fish assemblages, spatio-temporal pattern, multivariate analysis, West Africa*

**Simier, M., Laurent, C., Ecoutin, J.M. & Albaret, J.-J., 2006. The Gambia River Estuary: A reference point for estuarine fish assemblages studies in West Africa. *Estuarine, Coastal and Shelf Science*, 69, 615-628.**

The Gambia River is one of the last aquatic ecosystems in West Africa that has not yet been affected by strong environmental changes and human disturbances. In contrast to the neighbouring Casamance and Sine Saloum estuaries, the Gambia estuary is free of major climatic perturbation and remains a “normal” estuary, with a salinity range from freshwater to 39. The present paper aims to study the spatial and seasonal variability of fish assemblages in this estuary in terms of bio-ecological categories and of their relation with some environmental variables. Four surveys were conducted, from June 2001 to April 2002, in order to cover the major hydroclimatic events, at 44 sampling sites along the lower, intermediate and upper zones of the Gambia estuary (up to 220 km). Fish assemblages were sampled using a purse seine net, fish were identified to species level and environmental variables such as water depth, transparency, salinity, temperature and percentage oxygen saturation were measured. The main spatial structure of the fish assemblages and its seasonal changes were first studied using the STATIS-CoA multitable method. The combination of fish assemblages and environmental variables was then analysed using the STATICO method, designed for the simultaneous analysis of paired ecological tables. A total of 67 species were observed, belonging to all bio-ecological categories characterizing West African estuaries. The marine component of the community was largely dominant throughout the estuary, while the freshwater component was permanently observed only in the upstream zone. The main spatial structure was a longitudinal gradient contrasting marine and freshwater affinity assemblages, with strong seasonal variations. The most complete gradient was observed in December, at the beginning of the dry and cool season, while in June, at the end of the dry and warm season, there was the least structured gradient. The role of salinity, always correlated with temperature, was emphasized, while turbidity appeared to be another important factor. Oxygen and depth did not play a major role at the estuary scale. The relative importance of the bio-ecological categories varied according to the season and the distance to sea. Stable fish assemblages were observed in the lower zone at the end of the dry season, in the upper zone during the flood and in the middle zone throughout the year. In some situations, a relative inadequacy between fish assemblages and their environment was noticed. The present study contributes to the definition of the functioning of a “normal” West African estuary, the Gambia estuary, with balanced effects of marine and freshwater influences and the presence of all bio-ecological categories. The Gambia estuary can therefore be considered to be a reference ecosystem for further comparisons with other tropical estuarine ecosystems, subjected to natural or artificial perturbations.

*Keywords: brackishwater fish, community composition, seasonal variations, salinity gradients, environmental factors, multivariate analysis, West Africa, The Gambia*

**Thomas, D.H.L., 1994. Socio-economic and cultural factors in aquaculture development: a case study from Nigeria. *Aquaculture*, 119(4), 329-343.**

Intensification of fish production from ponds in an African floodplain, through water management, fertilization and stocking with fingerlings, was technically a success. Fish production per hectare was 171% greater in managed ponds compared with unmanaged ponds, and in terms of income derived from labour inputs for pond management (the main “cost” of production) returns per man hour compared favourably to alternative activities. However, due to a poor understanding of socio-economic and cultural factors the technology as originally introduced was not adopted by the community.

*Keywords: aquaculture, development, socio-economic, cultural, factors*

**Thorpe, A., Andrew, N.L. & Allison, E.H., 2007. Fisheries and poverty reduction. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 2(85), 12p.**

There is a somewhat pervasive belief in much of the fisheries literature (especially that relating to small-scale fisheries in the developing world) that fishers are among the ‘poorest of the poor’. The purpose of this review therefore is to review historic and contemporary research into fisher poverty. Our review commences by acknowledging the paucity of studies on the levels of (income) poverty within the sector and highlights the fact that, somewhat paradoxically, a growing number of studies are suggesting that average incomes for fishing households outstrip those recorded by non-fishing households in the same areas. Nevertheless, these findings must be qualified as poverty cannot be captured exclusively in income terms – and social manifestations of poverty (low literacy levels, reduced access to health care, education, water and sanitation facilities) may be more acute within the fisheries sector. Equally, while fisher households may be more vulnerable (given their lifestyles/location) to exogenous shocks (such as tsunamis), the sector is not a homogenous one and factors such as technological change may also induce the impoverishment of certain subgroups of fishers over time. As a consequence, fisher households have derived a variety of coping mechanisms, mechanisms which (we argue) militate against considering ‘fishing’ as an activity in isolation from other facets of the household livelihood strategy. One response, as we note, to this has been the application of livelihoods analysis as a technique for assessing (and redressing) fisher poverty. Championed initially by the Sustainable Livelihoods Fisheries Programme (SFLP) operating in West Africa from 1999 to 2006, the technique has subsequently been deployed in a number of other regions/fisheries. Our review then moves on to assess how interventions within the fisheries sector can contribute to fisher poverty reduction. At the macroeconomic level, while, the emphasis historically has been on the sector’s contribution to domestic nutritional requirements and the goal of food security, more recent research has examined the prioritization of the sector within national development plans and poverty reduction strategies. At the microeconomic

level, we provide two contrasting examples to show that, while poverty-reducing policy interventions are to be welcomed at the local level, the heterogeneity of the local environment militates against the prescription of a ‘one size fits all’ approach to poverty reduction. This theme is picked up in the concluding comments of the review, where directions for further research are also highlighted.

*Keywords: Fisheries, aquaculture, poverty, vulnerability, livelihoods, poverty reduction strategy papers (PRSPs)*

**Thorpe, A., Whitmarsh, D., Ndomahina, E., Baio, A., Kemokai, M. & Lebbie, T., 2009. Fisheries and failing states: The case of Sierra Leone. *Marine Policy*, 33(2), 393-400.**

Marine fisheries play an important role in the economy of Sierra Leone, supporting livelihoods and contributing significantly to food security. This paper looks in detail at how the performance of fisheries was impacted by the ten year civil war, an event which contributed to the country’s reputation for being a “failed state”. The paper focuses mainly on the artisanal fisheries sector, which employs the majority of the country’s coastal population, and demonstrates how the conflict caused major social dislocation to fishing communities as well as reducing the productive capacity of the fleet. The paper concludes with a discussion of the policy challenges now facing Sierra Leone, particularly the prevention of resource looting through illegal fishing of the offshore stocks and the development of strategies to enable the potential wealth of these fisheries to be captured.

*Keywords: Sierra Leone, marine fisheries, failed state, economic development, food security, natural resources*

**Ukwe, C.N., Ibe, C.A. & Sherman, K., 2006. A sixteen-country mobilization for sustainable fisheries in the Guinea Current Large Marine Ecosystem. *Ocean & Coastal Management*, 49(7-8), 385-412.**

The Guinea Current Large Marine Ecosystem (GCLME) extending from Bissagos Island (Guinea Bissau) in the north to Cabinda (Angola) in the south defines the shared transboundary waters off the coast of western Africa, which embodies some of the major coastal upwelling sub-ecosystems of the world and is an important centre of marine biodiversity and marine food production. The GCLME is characterized by distinctive bathymetry, hydrography, chemistry, and trophodynamics and represents the number 28 Large Marine Ecosystem (LME) ranked among the most productive coastal and offshore waters in the world with rich fishery resources. However, over-exploitation of fisheries, pollution from domestic and industry sources, habitat destruction and poorly planned and managed coastal developments and near-shore activities are resulting in a rapid depletion of the rich fisheries resources and degradation of vulnerable coastal and offshore habitats putting the economies, productivity and health of the populace at risk. Recognizing the urgency of the fisheries decline and the environmental and socio-economic consequences for the region, the

16 countries bordering the ecosystem have mobilized complementary resources to the funding from the Global Environment Facility and United Nations Industrial Development Organization to implement priority management actions agreed in the preliminary Strategic Action Programme for the recovery of depleted fish stocks and restoration of degraded habitats for the advancement of the achievement of the World Summit on Sustainable Development (WSSD) Johannesburg Plan of Implementation targets for recovery of fish stocks.

*Keywords: fisheries, sustainable, Gulf of Guinea, Large Marine Ecosystem*

**Warren, J.P., Griffin, W.L. & Grant, W.E., 1982. Regional fish stock management: A model for north-west Africa. *Marine Policy*, 6(2), 121-130.**

Development of a bioeconomic model for applications in managing an important North African fishery is reported in this article. The model is applied through identification of baseline conditions and analysis of two alternative fishery management plans; limiting the number of vessels and instituting a dosed season. Several key assumptions relative to biological and fleet variables are necessarily made, since in some areas historical data are limited. However, results strongly suggest that rents to resources owners (African coastal countries) can be substantially increased by either method of limiting access to the fishery and by licensing vessels and fishermen.

*Keywords: fisheries, management, Atlantic*

**Westlund, L., Holvoet, K. & Kébé, M. (eds.), 2008. *Achieving poverty reduction through responsible fisheries. Lessons from West and Central Africa. FAO Fisheries and Aquaculture Technical Paper. No. 513. Rome. 2008. 168p***

Despite massive development efforts, chronic poverty still remains a harsh reality for millions of Africans. The Sustainable Fisheries Livelihoods Programme (SFLP) examined ways to reduce poverty, and improve livelihoods, in the fisheries sector. In Africa, an estimated ten million men and women are involved in fishing and related activities such as processing and trading. Seven million fishing people live in West Africa and the fisheries sector is a major source of livelihoods in many coastal communities, both inland on lake shores and on the Atlantic coast. In addition to providing employment and income, fisheries play an important role in local and national economies. The SFLP, a partnership between the Food and Agriculture Organization of the United Nations (FAO), the Department for International Development (DFID) of the United Kingdom of Great Britain and Northern Ireland and 25 participating countries in West Africa, ran from November 1999 to October 2006. The Programme aimed at enhancing the livelihoods of artisanal fishery communities in coastal and inland lake areas by supporting the development and adoption of appropriate and replicable strategies for responsible and equitable fisheries, and by strengthening human and social capital. New ways of working were explored, vulnerability and social exclusion were addressed as two central

concepts of poverty, and emphasis was given to policy changes and institutional capacity building. The SFLP adopted the sustainable livelihoods approach to poverty alleviation and worked to implement the FAO Code of Conduct for Responsible Fisheries to sustain fishery resources. The Programme promoted strategies for poverty alleviation that reinforce peoples' existing capabilities, are participatory and empowering and take into account the limitations of resource renewability. This technical paper reports on the important lessons generated by the SFLP with regard not only to reconciling poverty reduction and responsible fishing but also showing how the two are mutually dependent and essential for sustainable outcomes. The paper provides a consolidated account of main lessons learned to serve as a source of information and inspiration for further work with small-scale fishing communities, in West and Central Africa, as well as elsewhere.

*Keywords: poverty reduction, fisheries, SFLP, West Africa*

## SECTION II: Climate change, climate variability, biophysics, climatology, and oceanographic changes

**Akegbejo-Samsons, Y., 2009. Climate change impacts on fisheries production in land-water interface. In IOP Conference Series: Earth and Environmental Science 6. Climate Change: Global Risks, Challenges and Decisions. IOP Publishing Ltd.**

It has been considered that the impacts of climate change are likely to be considerable in tropical regions. Developing countries are generally considered more vulnerable to the effects of climate change than more developed countries. This has been attributed to a low capacity to adapt in the developing countries. Fisheries and aquaculture are threatened by changes in the earth atmosphere and ocean, such as increasing global surface temperature, rising sea levels, increases in incident UV radiation, irregular changes in average annual precipitation, and increases in the variability and intensity of extreme weather events. Greater climate variability will surely complicate the task of identifying impact pathways and areas of vulnerability requiring research to devise and promote coping strategies and improve the adaptability of fishers and aquaculturists especially in the developing countries. Many coastal and island communities where poverty is widespread and livelihood alternatives are limited depend heavily on fish resources for their well-being. Fish also provides an important source of cash income for many poor households especially in Africa. This paper examines the ways in which climate change and extreme events may directly affect fisheries and aquacultural production in Africa. Specifically the paper looks at the effects on African river fisheries, coastal fisheries, coral reefs and mariculture. It presents the implications for this important sector on the people, resources and the environment. The paper recommends (a) the strengthening of capacity including that of African scientists, governments and civil society; (b) supporting adaptation by rural /urban people particularly the most vulnerable and (c) adding value to existing adaptation initiatives to enable African scientists to apply expertise and carry out research in support of adaptation projects in land-water interface ecosystem.

*Keywords: climate change, fisheries production, Nigeria*

**Allison, E.H., Andrew, N.L. & Oliver, J., 2007. Enhancing the resilience of inland fisheries and aquaculture systems to climate change. The Journal of Semi-Arid Tropical Agricultural Research ICRISAT, 4(1), 1-35.**

Some of the most important inland fisheries in the World are found in semi-arid regions. Production systems and livelihoods in arid and semi-arid areas are at risk from future climate variability and change; their fisheries are no exception. This paper reviews the importance of fisheries to livelihoods in 'wetlands in drylands', with a focus on case-studies in Africa. We examine the threats posed by climate change to the traditional 'tri-economy' of fishing, farming and

livestock herding. Although both livelihood strategies and local institutions are highly adapted to cope with, and benefit from, climate-induced variability, weaknesses in the wider governance and macro-economic environment mean that the overall adaptive capacity of these regions is low and the farmer-herder-fishers are vulnerable to projected climate change. In order to maintain the important nutritional, economic, cultural and social benefits of fisheries in the face of climate change, planned adaptation at scales from the local to the regional (trans-national) is required. We use the concept of resilience in linked social-ecological systems to examine how such responses may be developed and promoted. Key strategies include facilitating people's geographical and occupational mobility, improving intersectoral water and land-use planning, and promoting forms of aquaculture that help build resilience of farming systems to seasonal and episodic water deficits.

*Keywords: vulnerability, adaptation, fisherfolk, livelihoods, Lake Chilwa, Malawi*

**Allison, E.H., Perry, A.L., Badjeck, M.-C., Adger, W.N., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L. & Dulvy, N.K., 2009. Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries, 10(2), 173-196.**

Anthropogenic global warming has significantly influenced physical and biological processes at global and regional scales. The observed and anticipated changes in global climate present significant opportunities and challenges for societies and economies. We compare the vulnerability of 132 national economies to potential climate change impacts on their capture fisheries using an indicator-based approach. Countries in Central and Western Africa (e.g. Malawi, Guinea, Senegal, and Uganda), Peru and Colombia in north-western South America, and four tropical Asian countries (Bangladesh, Cambodia, Pakistan, and Yemen) were identified as most vulnerable. This vulnerability was due to the combined effect of predicted warming, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities. Many vulnerable countries were also among the world's least developed countries whose inhabitants are among the world's poorest and twice as reliant on fish, which provides 27% of dietary protein compared to 13% in less vulnerable countries. These countries also produce 20% of the world's fish exports and are in greatest need of adaptation planning to maintain or enhance the contribution that fisheries can make to poverty reduction. Although the precise impacts and direction of climate-driven change for particular fish stocks and fisheries are uncertain, our analysis suggests they are likely to lead to either increased economic hardship or missed opportunities for development in countries that depend upon fisheries but lack the capacity to adapt.

*Keywords: adaptation, climate change, fisheries, poverty, vulnerability*

**Arfi, R., Bouvy, M., Ménard, F., McGlade, J.M., Cury, P., Hardman-Mountford, N.J. & Koranteng, K.A., 2002. Environmental variability at a coastal station near Abidjan: Oceanic and continental influences. In J.M.McGlade, P. Cury, K.A. Koranteng & N.J. Hardman-Mountford (eds.), *The Gulf of Guinea Large Marine Ecosystem – Environmental Forcing & Sustainable Development of Marine Resources*. Amsterdam: Elsevier Science, pp. 103-118.**

Hydrobiological conditions (light penetration, temperature, salinity, chlorophyll biomass at six depths and bacterioplankton abundance at the surface) were measured weekly for six years (1992–1997) at a station located in a coastal area of the Gulf of Guinea (Abidjan, Côte d'Ivoire). Nutrient concentrations completed the data set from December 1994. This coastal area is strongly influenced by a major upwelling (July–September) and by a minor upwelling (short cold events during January–February). Continental inputs induced by local rainfalls (May–June and October) and river floods (September–November) have also pronounced hydrological effects. SST varied from 20.6°C (August) to 30.7°C (May), while surface salinity showed an obvious annual cycle with a minimum of 30.12 psu in June and a maximum of 35.87 psu in September. Bacterial abundance and phytoplankton biomass show seasonal cycles, with simultaneous peaks noted during the main upwelling (maximum:  $1.9 \cdot 10^6$  cell ml<sup>-1</sup> and 5.6 µg l<sup>-1</sup> respectively). Interannual fluctuations of upwelling intensity and of continental inputs explain the hydrological variability. Freshwater inputs are associated with oligotrophy, while upwellings contribute to the enrichment of the euphotic layer. As a consequence of the drought in the Sahel and of the decreasing rainfall on the coastal area, freshwater inputs are now considerably reduced, and the related impoverishment is less pronounced. At the opposite, the increasing duration of upwellings (and the importance of the short cold events) allows a higher primary productivity (and therefore a more active bacterial compartment). Combined, these two factors would explain the marked outburst of small pelagic fishes in this part of the Gulf of Guinea.

*Keywords: environmental variability, coast, upwellings, Abidjan*

**Badjeck, M.-C., Allison, E.H., Halls, A.S. & Dulvy, N.K., 2010. Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy* 34(3), 375-383.**

There is increasing concern over the consequences of global warming for the food security and livelihoods of the world's 36 million fisherfolk and the nearly 1.5 billion consumers who rely on fish for more than 20% of their dietary animal protein. With mounting evidence of the impacts of climate variability and change on aquatic ecosystems, the resulting impacts on fisheries livelihoods are likely to be significant, but remain a neglected area in climate adaptation policy. Drawing up on our research and the available literature, and using a livelihoods framework, this paper synthesizes the pathways through which climate variability and change impact fisherfolk livelihoods at the household and community level. We identify current and potential

adaptation strategies and explore the wider implications for local livelihoods, fisheries management and climate policies. Responses to climate change can be anticipatory or reactive and should include: (1) management approaches and policies that build the livelihood asset base, reducing vulnerability to multiple stressors, including climate change; (2) an understanding of current response mechanisms to climate variability and other shocks in order to inform planned adaptation; (3) a recognition of the opportunities that climate change could bring to the sector; (4) adaptive strategies designed with a multi-sector perspective; and (5) recognition of fisheries potential contribution to mitigation efforts.

*Keywords: fisheries, livelihoods, climate change, climate variability, adaptation*

**Bah, A., 1981. Upwelling in the Gulf of Guinea: Results of a Mathematical Model. *Oceanography Series*, 32, 99-140.**

A numerical simulation of the oceanic response of an x-y-t two-layer model on the β-plane to an increase of the wind stress is discussed in the case of the tropical Atlantic Ocean. It is shown first that the method of mass transport is more suitable for the present study than the method of mean velocity, especially in the case of non-linearity. The results indicate that upwelling in the oceanic equatorial region is due to the eastward propagating equatorially trapped Kelvin wave, and that in the coastal region upwelling is due to the westward propagating reflected Rossby waves and to the poleward propagating Kelvin wave. The amplification due to non-linearity can be about 25 % in a month. The role of the non-rectilinear coast is clearly shown by the coastal upwelling which is more intense east than west of the three main capes of the Gulf of Guinea; furthermore, by day 90 after the wind's onset, the maximum of upwelling is located east of Cape Three Points, in good agreement with observations.

*Keywords: wind stress, coastal upwelling, Gulf of Guinea, Kelvin waves, Rossby waves*

**Bakun, A., 1978. Guinea current upwelling. *Nature*, 271, 147-150.**

The historical record of maritime observations are summarized here to indicate the dominant seasonal variations in upwelling, and in certain associated processes, within the Guinea Current region. The region is similar to other eastern ocean boundary upwelling areas in the appearance of cool sea temperatures near the coast, productive coastal fisheries, and a zone of low rainfall on the adjacent coast. It differs from some of the more studied regions in several important respects. These include the zonal rather than meridional trend of the coast, the influence of a rather narrow intense coastwise current, and an unusual lack of correspondence on the seasonal time scale between sea-temperature features attributable to upwelling, and features in the overlying wind stress field. There seems to be a link between interyear variations in upwelling intensity and corresponding variations in both coastal rainfall and local fishery success.

*Keywords: upwelling, Gulf of Guinea*

**Binet, D., 1997. Climate and pelagic fisheries in the Canary and Guinea currents 1964-1993: The role of trade winds and the southern oscillation. *Oceanologica Acta*, 20(1), 177-190.**

Upwellings off the coasts of western Africa provide abundant but fluctuating marine resources. Sea surface temperature and wind stress, monitored by the ship-of-opportunity observation network, are compared to fishery statistics from 1964 onwards. In the Canary Current, off Sahara and Mauritania, upwellings are mostly wind driven. In the Guinea Current, off Cote d'Ivoire and Ghana, the link with local wind is very weak. In the southern Canary Current, two wind-intensification periods occurred in the early 1970s and from 1986 onwards. On each occasion, *Sardina pilchardus* landings were multiplied approximately threefold. During the first event, catches of species living at the periphery of the upwelling, *Sardinella*, *Trachurus*, *Decapterus* and *Scomber*, decreased slightly. During the second event, interrupted by some warming, catches of sardinelle increased, those of horse-mackerel decreased; mackerel landings increased only during the warm years. Sardine catches are correlated to the alongshore wind stress of the year (n-2), except during the very early months of larval life. Each wind stress increase induces an enrichment which favours larval survival, except just after hatching, when the adverse effects of turbulence and offshore advection prevail. In the part of the Guinea Current submitted to seasonal shoaling of the thermocline, a dramatic increase of the *Sardinella aurita* catch began at the beginning of the 1980s. Nevertheless, the SST warming trend does not indicate an intensification of deep-water uplift. Another hypothesis, based on the change of sign of the Southern Oscillation Index since 1976, is proposed. The tropical Atlantic would be in a long-term, warm, El Niño-like phase, with strengthened eastward circulations in the vicinity of the equator. Coastal surface and subsurface currents, linked to this eastward flux, would be intensified. Therefore, the number and/or the surface of eddies formed in these currents by Cape Palmas and Cape Three Points would be increased. Since sardinelle spawning occurs in these regions, which play the role of retention cells, enlargements of the turbulent structures would enable a larger number of larvae to thrive and sustain a larger population, according to the Sinclair hypothesis.

*Keywords: Pelagic fisheries, West Africa, trade winds, oceanic currents, Southern Oscillation*

**Binet, D., Goberta, B. & Malouekib, L., 2001. El Niño-like warm events in the Eastern Atlantic (6°N, 20°S) and fish availability from Congo to Angola (1964-1999). *Aquatic Living Resources*, 14, 99-113.**

Long term changes in catches of two sardinella species off equatorial West Africa seem inconsistent with their thermal preferences. *Sardinella niaderensis* is usually fished during the warm season in low salinity waters, while *S. aurita* is associated with cold upwelled waters. However, in the Congo fisheries, *S. maderensis* dominated the catches from 1964 to 1983, when temperatures were moderate or cool; subsequently *S. aurita* became the most important from 1984 onward, as there was

pronounced warming. The movement of water masses related to Atlantic Niño-like episodes explains this paradox. These warm events are associated with enhancement of the equatorial counter currents. When the eastward transport strengthens south of the equator (Benguela Niño), it drives an influx of warm water towards Angola, which repels *Sardinella aurita* northwards. Then, trapped near the coast by the subsurface warm water intrusion and the deviation of the Congo River plume, *S. aurita* becomes more concentrated and vulnerable to fishing. This is the most frequent situation during warm events. However, when the anomaly involves the north equatorial counter current (Guinea Niño), we assume that this surge of water in the Bight of Biafra leads to a water leakage toward the south, along the Gabon coast. This warm and low salinity water tongue, homologous to the Peruvian El Niño current, would drive *Sardinella inaderensis* towards the Congo fisheries, but would force *Sardinella aiwita* offshore making it less accessible to the fisheries. This situation is likely to have occurred in 1987-1988 when there were large catches of several species linked to brackish waters (bongas, *Pseudotolithius*, soles, catfish, sharks and spiny lobsters). On the contrary, decadal variations of catches of the two species are consistent with regime shifts of the Congo River: *Sardinella niaderensis* is dominant when the outflow is above average (1960s and 1970s) and is replaced by *Sardinella aurita* when the runoff is weak (1980s and 1990s). In Angola, the catches of horse mackerel shift southwards during the warm years preceding 1976, then northwards during a cool period ending in 1983. From 1984, the abundance of horse mackerels over the shelf increases after warm events.

*Keywords: warm events, Atlantic El Niño, coastal pelagic fisheries, clupeids, sardinella, tropical Atlantic Ocean, Western Africa*

**Binet, D. & Servain, J., 1993. Have the recent hydrological changes in the Northern Gulf of Guinea induced the *Sardinella-aurita* outburst? *Oceanologica Acta*, 16(3), 247-260.**

Sea surface temperature along the northern coast of the Gulf of Guinea drops abruptly twice a year, with a moderate decrease in boreal winter and a greater one in summer. Several mechanisms have been proposed to explain these coolings: Ekman upwelling due to local wind, remote wind forcing in the western Atlantic, geostrophic adjustment to the Guinea current variations or eddies created by headlands in the current. The resulting seasonally-induced plankton production has led to the development of pelagic fisheries, with dramatic increases in *Sardinella aurita* catches in Cote d'Ivoire and Ghana during the last decade and new spatial and seasonal distributions. A study to account for these changes was undertaken on the basis of wind and temperature data recorded by merchant ships from 1964 to 1990 and coastal temperature measurements from 1978 to 1990. During the study period, pseudo-wind stress increased by 0.23 (m<sup>2</sup>/s<sup>2</sup>)/year and sea surface warming by about 0.03-degrees-C/year. The main changes occurred during the 1980s; in coastal waters, warming was very marked in the western area (0.069-degrees-C/

year), even during the cold seasons, and the eastern side experienced a slight cooling (-0.034-degrees-C/year). The latter change is compared to westerly wind intensification (increased speed and slight rotation) which should have enhanced Ekman pumping. These developments are viewed in the context of recent data concerning warming in tropical regions, controversial increased speed of trade winds and changes in oceanic circulation. More frequent Ekman upwelling events in the east of the Ivorian gulf might have favoured an expansion of the *S. aurita* stock of Ghana towards the Cote d'Ivoire. This possibility does not exclude the hypothesis of a circulation change which has been proposed to explain the settlement of sardinelles up to the western side of the gulf.

*Keywords: climate change, pelagic fisheries, upwelling, West Africa*

**Clark, B.M., 2006. Climate change: A looming challenge for fisheries management in southern Africa. *Marine Policy*, 30(1), 84-95.**

It is now widely accepted that the earth's climate is changing under the influence of anthropogenic activities. A number of key changes in the earth's atmosphere and ocean have already been detected (including increasing global surface temperature, rising sea levels, increases in incident UV radiation, changes in average annual precipitation, and increases in the variability and intensity of extreme weather events, among others), while speculation regarding future changes is rife. The implications of global climate change for fish stocks and fisheries is of concern to many scientists, but little effort has been made to incorporate observed changes or even such thinking into management models and paradigms. This paper summarises available evidence linking the production of key greenhouse gases with observed and future projected changes in the earth's climate, specifically in respect of a number of key atmospheric and oceanographic parameters likely to affect fish stocks in South Africa (temperature, pressure/wind fields, CO<sub>2</sub> concentration, rainfall, mean sea level and UV radiation). It also explores likely effects of these changes on fish stocks and key fishery sectors. In addition, it highlights a number of positive steps that be taken by management authorities to ensure that they and the fishing communities for which they are responsible are in the best possible position to deal with the effects of changing global climate as they become manifest.

*Keywords: South Africa, fish stocks, global climate change, fisheries management*

**Cury, P. & Roy, C., 2002. Environmental forcing and fisheries resources in Côte d'Ivoire and Ghana: Did something happen? In J. McGlade, P. Cury, K.A. Koranteng & N.J. Hardman-Mountford (eds.), *The Gulf of Guinea Large Marine Ecosystem*. Elsevier Science, pp. 241-260.**

The main environmental characteristics off the coasts of Cote d'Ivoire and Ghana are reviewed. Seasonal variability as well as long-term environmental changes observed during the last three decades are presented using a seasonal-trend decomposition procedure. Striking similarities are observed between changes in the

Gulf of Guinea and the Pacific. This suggests that the observed changes are not the result of local processes but rather are induced by inter-oceanic teleconnection via the atmosphere. Fisheries productivity in the Gulf of Guinea appears to be quite important but is limited by the duration of the upwelling process. Thus, using comparative methods between several upwelling systems, relationships are identified between pelagic productivity and several environmental factors (wind, turbulence, and upwelling index) and only a weak relationship is observed when considering the demersal fish productivity and the upwelling intensity. Fisheries as a whole off Ghana and Cote d'Ivoire have been expanding during the last four decades: the total marine fish catch off Cote d'Ivoire and Ghana has been increasing from less than 50 thousand tonnes in the 1950s to around 400 thousand tonnes in the mid-1990s. For the pelagic species, there has been a noticeable increasing trend is observed since the 1950s and the total catch reached about 250 thousand tonnes in the 1990s. By contrast, the demersal fisheries in Cote d'Ivoire and Ghana have fluctuated between 30 and 50 thousands tonnes since the mid-1960s without any trend. Fishing effort by purse-seiners and trawlers has decreased significantly since the 1970s in Cote d'Ivoire. The abundance, estimated from cpue of both pelagic and demersal, does not appear to be related to fishing activity. Trends in several environmental time series are in phase with the observed trends in the cpue data of the demersal fisheries in Côte d'Ivoire. This suggests that in Cote d'Ivoire the abundance of the demersal fish stock is strongly related to large scale environmental changes.

*Keywords: environmental, coastal, fisheries productivity, CPUE, Cote d'Ivoire, Ghana*

**Daw, T., Adger, W.N. & Badjeck, M., 2009. Climate change and capture fisheries-impacts, adaptation, mitigation, and the way forward. In K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). *Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp. 107-150.***

Climate change is predicted to have a range of direct and indirect impacts on marine and freshwater capture fisheries, with implications for fisheries-dependent economies, coastal communities and fisherfolk. This technical paper reviews these predicted impacts, and introduces and applies the concepts of vulnerability, adaptation and adaptive capacity. Capture fisheries are largely driven by fossil fuels and so contribute to greenhouse gas emissions through fishing operations, estimated at 40-130 Tg CO<sub>2</sub>. Transportation of catches is another source of emissions, which are uncertain due to modes and distances of transportation but may exceed those from fishing operations. Mitigation measures may impact on fisheries by increasing the cost of fossil fuel use. Fisheries and fisherfolk may be impacted in a wide range of ways due to climate change. These include biophysical impacts on the distribution or productivity of marine and freshwater fish stocks through processes such as ocean acidification, habitat damage, changes in oceanography, disruption to precipitation and freshwater availability. Fisheries will also be exposed to a diverse range of direct and indirect



climate impacts, including displacement and migration of human populations; impacts on coastal communities and infrastructure due to sea level rise; and changes in the frequency, distribution or intensity of tropical storms. Fisheries are dynamic social-ecological systems and are already experiencing rapid change in markets, exploitation and governance, ensuring a constantly developing context for future climate-related impacts. These existing socioeconomic trends and the indirect effects of climate change may interact with, amplify or even overwhelm biophysical impacts on fish ecology. The variety of different impact mechanisms, complex interactions between social, ecological and economic systems, and the possibility of sudden and surprising changes make future effects of climate change on fisheries difficult to predict.

The vulnerability of fisheries and fishing communities depends on their exposure and sensitivity to change, but also on the ability of individuals or systems to anticipate and adapt. This adaptive capacity relies on various assets and can be constrained by culture or marginalization. Vulnerability varies between countries and communities, and between demographic groups within society. Generally, poorer and less empowered countries and individuals are more vulnerable to climate impacts, and the vulnerability of fisheries is likely to be higher where they already suffer from overexploitation or overcapacity. Adaptation to climate impacts includes reactive or anticipatory actions by individuals or public institutions. These range from abandoning fisheries altogether for alternative occupations, to developing insurance and warning systems and changing fishing operations. Governance of fisheries affects the range of adaptation options available and will need to be flexible enough to account for changes in stock distribution and abundance. Governance aimed towards equitable and sustainable fisheries, accepting inherent uncertainty, and based on an ecosystem approach, as currently advocated, is thought to generally improve the adaptive capacity of fisheries. However, adaptation may be costly and limited in scope, so that mitigation of emissions to minimise climate change remain a key responsibility of governments.

*Keywords: climate change and variability, fisheries, vulnerability, adaptation, mitigation*

**Coetlogon, G. de., Janicot, S. & Lazar, A., 2010. Intraseasonal variability of the ocean - atmosphere coupling in the Gulf of Guinea during boreal spring and summer. *Quarterly Journal of the Royal Meteorological Society*, 136 (Special Issue: Sp.Iss.SI Suppl. 1), 426-441.**

Statistical analyses of the satellite TMI sea-surface temperature (SST) and QuikSCAT surface winds in boreal spring and summer are performed to investigate the intraseasonal variability of air sea interactions in the Gulf of Guinea. There, empirical orthogonal function decomposition shows the existence of peaks around 15 days and their lagged cross-correlation the signature of an expected 5-day lag wind forcing and 3-day lag strong negative SST feedback. Lagged linear regressions are performed onto a reference SST index of the cold tongue northern front in the Gulf of Guinea. A cold SST anomaly covering the equatorial and coastal upwelling is forced after about

one week by stronger-than-usual south-easterlies linked to the Si Helena anticyclone suggesting that intraseasonal variability in the Gulf of Guinea is connected to large-scale fluctuations in the South Atlantic. Within about 5 degrees S and 5 degrees N, two retroactions between SST and surface wind appear to dominate near-surface atmosphere conditions. When the wind leads the SST, stronger monsoonal winds north of 2 degrees N are partly sustained by the developing SST anomaly and bring more humidity and rainfall toward the continent. When the SST leads the wind, a reversal of anomalous winds is observed mainly south of 2 degrees N closing a negative feedback loop with a biweekly periodicity. Eventually further in with an ocean model emphasizes the contribution of the horizontal advection in shaping these intraseasonal SST signals. The contribution of vertical processes may also be important but was more difficult to estimate.

*Keywords: sea-surface temperature, eastern equatorial pacific, West-African monsoon, Saharan weather anomalies, layer heat-budget, tropical Atlantic, seasonal cycle, interannual variability, rainfall variability, circulation patterns*

**Diou, K., Guilhaumon, F., Aliaume, C., Ndiaye, P., Do Chi, T. & Panfili, J., 2009. Effects of the environment on fish juvenile growth in West African stressful estuaries. *Estuarine, Coastal and Shelf Science*, 83(2), 115-125.**

The knowledge of juvenile fish growth in extreme environmental conditions is a key to the understanding of adaptive responses and to the relevant management of natural populations. The juvenile growth of an extreme euryhaline tilapia species, *Sarotherodon melanotheron* (Cichlidae), was examined across a salinity gradient (20–118) in several West African estuarine ecosystems. Juveniles were collected during the reproduction period of two consecutive years (2003 and 2004) in six locations in the Saloum (Senegal) and Gambia estuaries. Age and growth were estimated using daily otolith micro increments. For each individual, otolith growth rates showed three different stages (slow, fast, decreasing): around  $4 \pm 0.5 \mu\text{m d}^{-1}$  during the first five days,  $9 \pm 0.5 \mu\text{m d}^{-1}$  during the next 15 days and  $4 \pm 0.50 \mu\text{m d}^{-1}$  at 60 days. Growth modelling and model comparisons were objectively made within an information theory framework using the multi-model inference from five growth models (linear, power, Gompertz, von Bertalanffy, and logistic). The combination of both the model adjustment inspection and the information theory model selection procedure allowed identification of the final set of models, including the less parameterised ones. The estimated growth rates were variable across spatial scales but not across temporal scales (except for one location), following exactly the salinity gradient with growth decrease towards the hypersaline conditions. The salinity gradient was closely related to all measured variables (condition factor, mean age, multi-model absolute growth rate) demonstrating the strong effect of hypersaline environmental conditions—induced by climate changes—on fish populations at an early stage.

*Keywords: growth models, age estimation, hypersalinity, black-chinned tilapia, Saloum estuary, Gambian estuary*

**Dixon, R.K., Smith, J. & Guill, S., 2003. Life on the Edge: Vulnerability and Adaptation of African Ecosystems to Global Climate Change. *Mitigation and Adaptation Strategies for Global Change*, 8(2), 93-113.**

Donor countries are providing financial and technical support for global climate change country studies to help African nations meet their reporting needs under the United Nations Framework Convention on Climate Change (UNFCCC). Technical assistance to complete vulnerability and adaptation assessments includes training of analysts, sharing of contemporary tools (e.g. simulation models), data and assessment techniques, information-sharing workshops and an international exchange programme for analysts. This chapter summarizes 14 African country studies (Botswana, Côte d'Ivoire, Egypt, Ethiopia, the Gambia, Kenya, Malawi, Mauritius, Nigeria, South Africa, Tanzania, Uganda, Zambia and Zimbabwe) assessing vulnerabilities to global climate change and identifying adaptation options. The analysis revealed that the participating African countries are vulnerable to global climate change in more than one of the following socio-economic sectors: coastal resources, agriculture, grasslands and livestock, water resources, forests, wildlife, and human health. This vulnerability is exacerbated by widespread poverty, recurrent droughts, inequitable land distribution, environmental degradation, natural resource mismanagement and dependence on rain-fed agriculture. A range of practical adaptation options were identified in key socio-economic sectors of the African nations analysed. However, underdeveloped human and institutional capacity, as well as the absence of adequate infrastructure, renders many traditional coping strategies (rooted in political and economic stability) ineffective or insufficient. Future African country studies should be more closely coordinated with development of national climate change action plans.

*Keywords: adaptation, Africa, global climate change, vulnerability, agriculture, forests, wildlife, water, health*

**Elasha, B.O., Medany, M.M., Niang-Diop, I., Nyong, T., Tabo, R. & Vogel, C., 2006. Background paper on Impacts, vulnerability and adaptation to climate change in Africa for the African Workshop on Adaptation, Accra, Ghana: UNFCCC. 54p.**

This paper presents background information as input to the African Regional Workshop on Adaptation (Accra, Ghana, 21- 23 September, 2006). The paper is wide in scope as it broadly covers the main issues relating to impacts, vulnerability and adaptation to climate change in relation to Africa. It starts with a general outline of African circumstances and an overview of existing capacities as well as gaps related to the availability and use of climate information, including status of existing observational networks and contribution of Africa to the Global Climate Observing System (GCOS), access to information, availability of communication infrastructure and other important issues relating to the dissemination and effective utilization of climatic information in adaptation to climate change. The paper then describes

the availability and use of analytical tools, such as climate and impact models and the existing capacity for vulnerability and adaptation studies, including training opportunities. The paper focuses further on current and projected climate change and variability and their impact on key sectors: water, food security, health, energy and biodiversity and ecosystems. It also describes different factors contributing to vulnerability and their interaction with different climatic and non-climatic elements. The paper further explores opportunities for combating future climate change impacts and provides information on previous and current adaptation initiatives and programmes, including National Adaptation Programmes of Action (NAPAs), projects and networks and their role in reducing the overall vulnerability of Africa. Finally, the paper summarises the issues described, underlining major conclusions and bringing to light those important adaptation needs and concerns as well as Africa's potentials and opportunities for future adaptation. The paper draws upon recent studies on vulnerability and adaptation, national communications and other reports, and extracts lessons from the studies which employed both a top-down scenario-driven approach, as well as those that adopted bottom-up approaches.

*Keywords: climate change, impacts, vulnerability, IPCC, Africa, NAPA*

**Gabche, C., Youmbi, T. & Angwe, C., 2000. The impacts of sea-level rise on the coastal fisheries resources and aquatic ecosystems of Cameroon (Central Africa). In B. Flemming, M. Delafontaine, & G. Liebezeit (eds.), *Muddy Coast Dynamics and Resources Management. South-West Province, Cameroon: Amsterdam: Elsevier Science.***

Sea-level rise (SLR), in association with the topography of low-lying coastal areas, their hydrology, sedimentology, natural dynamics, and anthropogenic interactions, will profoundly affect the coastal zone of Cameroon in the new century. Anticipated impacts of SLR on species abundance, distribution, and diversity in the wetlands and aquatic ecosystems are highlighted, focusing on fish and plant species. Such impact assessments are based on time series (1970-1990) of fisheries resource production, projected demands (1990-2010), and economic value as well as the aquatic ecosystems at risks in case of SLR. As an example, the artisanal fisheries resources within three fishing camps highly vulnerable to SLR are evaluated with respect to several SLR scenarios. Adaptive measures and policies are suggested to combat these effects, thereby reducing possible socio-economic and cultural losses in the region.

*Keywords: sea level rise, coastal, fisheries, aquatic, Cameroon*

**Hardman-Mountford, N.J. & McGlade, J.M., 2003. Seasonal and interannual variability of oceanographic processes in the Gulf of Guinea: an investigation using AVHRR sea surface temperature data. *International Journal of Remote Sensing*, 24(16), 3247-3268.**

The Gulf of Guinea is situated in a critical position for understanding Atlantic equatorial dynamics. This study investigates seasonal and interannual variability in

sea surface temperature (SST) throughout this region, focusing on dynamical ocean processes. A 10.5-year time series of remotely sensed SST data with 4 km spatial resolution from the Advanced Very High Resolution Radiometer (AVHRR) were used for this investigation, as they are sufficient to resolve shelf processes. Firstly, patterns of cloud cover were assessed, then spatio-temporal variability in SST patterns was investigated. Features identified in climatological SST images were the Senegalese upwelling influence, coastal upwelling, tropical surface water, river run-off and fronts. Of particular interest is a shelf-edge cooling along the coast of Liberia and Sierra Leone in February. Interannual variability, assessed using annual mean images, time series decomposition and spectral analysis, showed a quasi-cyclic pattern of warm and cool years, perhaps related to El Niño-type forcing. The results of this study show the usefulness of infrared remote sensing for tropical oceanography, despite high levels of cloud cover and atmospheric water vapour contamination, and they provide evidence for theories of westward movement of the upwelling against the Guinea current and remote forcing of the upwelling.

*Keywords: tropical Atlantic, equatorial Atlantic, continental-shelf, West Africa, El-Niño, circulation, ocean, Ghana*

**Hlohowskyj, I., Brody, M.S. & Robert T., L., 1996. Methods for assessing the vulnerability of African fisheries resources to climate change. *Climate Research*, 6, 97-106.**

Because of the dietary and financial importance of fisheries resources in many African countries, concerns have been expressed regarding the potential for adverse impacts to fisheries resources from climate change, and a need has been identified for assessment tools that can evaluate the potential for impacts in a timely and cost-effective manner. This paper presents a framework and set of methods for assessing the potential effects of climate change on fisheries resources in Africa. The framework identifies the need to first link predicted climate changes to changes in the aquatic environment, and only then can potential impacts to aquatic resources be evaluated. The approach developed for Africa was constrained by several factors, including availability of existing data and assessment technologies, and the need for a rapid evaluation of potential climate impacts. The assessment approach employs a variety of methods including empirical models which predict changes in mortality, maximum sustainable yield, and yearly catch, a bioenergetics model, and a habitat suitability model. Previously developed or newly derived site-specific empirical models can be used to compare mortality, yield, and annual catch estimates among historic, current, and predicted climate conditions. Similarly, bioenergetics modeling can be used to compare growth rates and biomass production among different climate conditions. Habitat suitability models can be developed for current climate conditions, and the effects of changes in climate-driven habitat variables such as water depth, temperature, and current velocity on habitat suitability can be evaluated for different climate conditions. Use of these approaches is recommended

because they can utilize existing ecological data and do not require extensive new data collection activities, they are not technologically complex, and they can provide evaluations of potential climate change impacts in a timely and cost-effective manner.

*Keywords: Bioenergetics model, climate change, empirical models, fish yield, habitat suitability index, tropical freshwater fisheries*

**Koranteng, K.A. & McGlade, J.M., 2001. Climatic trends in continental shelf waters off Ghana and in the Gulf of Guinea, 1963–1992. *Oceanologica Acta*, 24(2), 187–198.**

Using time series analyses, some physical parameters of the continental shelf waters of the Gulf of Guinea were examined. Analysis of coastal sea surface temperatures from Ghana and Ivory Coast, and offshore sea surface temperatures from the Gulf of Guinea clearly shows spatial and inter-annual patterns of cooling in coastal waters of West Africa. The behaviour of the decomposed trend of coastal and offshore sea surface temperatures, sub-surface temperature measured at 100 m depth off Ghana and salinity showed that the observational period (1963–1992) could be divided into three climatic periods: the period before 1972, from 1972 to 1982, and the period after 1982. In the first period, sea surface temperature at both coastal and offshore areas and bottom temperature declined and coastal salinity was relatively low. The second period was a cold one with less than average sea surface and sea bottom temperatures. The mixed layer was narrow with the thermocline remaining shallower than its long-term average position. Coastal and bottom salinity (measured at the 100 m depth) were relatively high but the seasonal variation was minimal. This period of significant change in the physical components of the ecosystem of the Ghanaian shelf waters has hitherto not been documented in the literature. In the final phase, temperatures were high, and salinity was low and erratic. The observed localised environmental changes are consistent with global changes in the Gulf of Guinea and possibly in the tropical Atlantic basin.

*Keywords: marine environment, West Africa, time series*

**Laë, R., 1994. Climatic and anthropogenic effects on fish diversity and fish yields in the Central Delta of the Niger River. *Aquatic Living Resources*, 8, 43-58.**

For last 20 years, the fish communities in the Central Delta of the Niger River have been subjected to: (i) two drought periods in 1973 and 1984, (ii) a dramatic increase of fishing and, (iii) the building of an electric-power dam in 1984. At different levels, these various factors modified the biological cycle of the fish which are adapted to the former hydrological cycles of the Niger and the Bani rivers. The Sahelian drought is responsible for a decrease in both flood duration and of the inundated area of floodplain which varies from 20000 km<sup>2</sup> to 5 000 km<sup>2</sup>. From 1968 to 1989, fish landings declined from 90000 metric tons to 45 000 metric tons. During the same period, as fish catches fell, yields per hectare increased from 40 kg in 1968 to

120 kg in 1989. This phenomenon is linked to the decrease of the average age of the fish (69% of fish catches are under one year old) in response to the increased fishing mortality and natural mortality which is higher during the drought period. The increase in fish productivity is characterized by a depletion of species such as *Gynzizarchus niloticus*, *Polypterus senegalus*, *Gnathoneinus niger*, whose reproduction are linked to the floodplains and of species like *Citharinus cithzarus* and *Clarotes laticeps* which visit frequently flooded areas. Concurrently, families such as the Cichlidae or Clariidae, which are resistant to low oxygen concentration, increase. Species which are under one year old at first reproduction and have several spawning periods per year are the more abundant in fish communities.

*Keywords: Central Delta, Niger River, floodplain, hydrology, fish communities, fishing yields, adaptation*

**Loeuff, P. & Cosel, R.V., 1998. Biodiversity patterns of the marine benthic fauna on the Atlantic coast of tropical Africa in relation to hydroclimatic conditions and paleogeographic events. *Acta Oecologica*, 19(3), 309-321.**

Five different hydroclimatic regions are recognized in the tropical eastern Atlantic: the northern alternance region (Cape Blanc - Cape Verga), the atypical tropical region (Cape Palmas - border Benin/Nigeria), the southern alternance region (Cape Lopez - Cape Frio), all with periodical upwelling of colder water, and two intercalated typical tropical regions with warm water and reduced salinity. The faunal richness in the regions with upwelling is higher than in the typical tropical regions because many benthic species avoid warm and reduced salinity water. Faunistic exchange and affinity are greater between the upwelling zones and the bordering temperate zones. The cold regions are also more similar in faunal composition. Benthic communities in both tropical and temperate eastern Atlantic are not fundamentally different. Species diversity of benthic invertebrates in tropical West Africa is about the same order of magnitude as in Europe and the Mediterranean. Hydroclimatic conditions (upwelling, salinity reduction and internal waves with drastic temperature changes) and absence of coral reef formations do not favour the establishment and thriving of a warm stenohaline and stenotherm fauna in West Africa. Paleozoogeographic events, such as the formation of a large Euro-West African tropical province during the Miocene after the breakup of the Tethys, repeated climate deteriorations during Pliocene and Pleistocene with reductions of the tropical zone, sea level changes and large-scale extinction of warm-tropical species, are also factors responsible for the current low biodiversity in the tropical eastern Atlantic. Some species survived in two major relict pockets in Senegal and southern Angola with particular ecological conditions.

*Keywords: Tropical West Africa, marine benthic fauna, biodiversity, hydroclimate, paleozoogeography*

**McGlade, J., Koranteng, K.A. & Cury, P., 2002. The EU/INCO-DC Project: Impacts of Environmental Forcing on Marine Biodiversity & Sustainable Management of Artisanal & Industrial Fisheries in the Gulf of Guinea. In *McGlade, J.M., Cury, P., Koranteng, K.A., Hardman-Mountford, M.J., (eds.), The Gulf of Guinea Large Marine Ecosystem. Amsterdam: Elsevier Science, pp 3-7.***

The European Union Gulf of Guinea collaborative research project on the impacts of environmental forcing on marine biodiversity was supported by the International Cooperation with Developing Countries Programme (INCO-DC). It was a natural sequel to three earlier international research projects on environmental variability and pelagic fishery resources in West Africa. At its conclusion, the project was able to provide an assessment of the impacts of upwelling and other forms of environmental forcing on marine biodiversity, with particular reference to demersal fish, and the basis for a fisheries information and analysis system for the sustainable management of fisheries in West Africa. It also facilitated the retrieval of important fisheries and survey data that had previously been inaccessible to scientists in the region. The major achievements of the project were presented at an international workshop on "Sustainable Management of the Fish Resources in the Gulf of Guinea" held in Accra in 1998.

*Keywords: environmental forcing, marine biodiversity, European Union, Gulf of Guinea*

**Meiners, C., Fernández, L., Salmerón, F. & Ramos, A., 2010. Climate variability and fisheries of black hakes (*Merluccius polli* and *Merluccius senegalensis*) in NW Africa: A first approach. *Journal of Marine Systems*, 80, 243-247.**

Fish populations and fisheries fluctuations are closely linked to climate dynamics through environmental variability that determines distribution, migration, and abundance. Fisheries science has largely focused on the larger fisheries of the northern hemisphere, some of which fluctuate at decadal time scales and show patterns of synchrony with low frequency signals, as reflected by climatic indices such as the North Atlantic Oscillation (NAO). However, there is limited information on these patterns for the NW African coast, where important international fisheries have been established for decades. In order to improve our understanding of the impacts of climate variability (in particular the NAO) on black hake dynamics in northwest Africa, we used catch-based relative abundance indices from commercial fisheries off Mauritania and Senegal as dependent variables in correlation analyses with the NAO index. Then we tested the mechanistic dependence between the NAO index and north-south ( $v$ ) component of the wind stress as a proxy of upwelling variability. Black hake abundance was highly and negatively correlated with the NAO index, with a time lag of 3 years. The NAO explained around 40 to 50% of abundance variability between 1960 and 2003. At the same time, the wind stress fields were positively correlated with NAO during the same year, which was responsible for 53% of their variability. In contrast to what we expected, these

results suggest that black hake abundance is inversely related with intensified and extended upwelling processes along the Mauritanian and Senegalese coast, causing the cold oceanographic season to extend more southwards than normal.

*Keywords: Climatic changes, Gadoid fisheries, time-series analysis, Eastern boundary currents*

**Minta, S.O., 2003. An assessment of the vulnerability of Ghana's coastal artisanal fishery to climate change. MSc Thesis. University of Tromsø. 83p.**

Considering the fact that nearly 25% of the Ghanaian people live in the coastal zone and about 10% depend on the coastal fishery for livelihood, it is likely that any changes in the production of the fishery may impact on the socio-economic lives of the people. For the past four decades, climatic conditions have been found to be changing in the country. This period coincided with the conspicuous fluctuations in the landings of the most significant pelagic species exploited by the canoe fleet. This study provides an assessment of the influence of precipitation and sea surface temperature changes on yield and catch of Round Sardinella (*Sardinella aurita*), anchovy (*Engraulis encrasicolus*), Flat Sardinella (*S. maderensis*) and Guinea Shrimp (*Parapenaeopsis atlantica*). The abundance of these stocks is believed to be correlated with upwelling and sea surface temperature conditions and a local manifestation of global scale climatic changes is suspected to be taking place. It was hypothesized that climate as represented by sea surface temperature (SST) and precipitation affects either catchability or the population growth rate of each species. Forty years of climatological data (mean air temperature and precipitation) were assessed; 38 and 33 years each of hydrological data (sea surface temperature and salinity) were then used to investigate the possible relation between climatic changes and species production. Forecasts of future climate scenarios were made, and stock dynamics were simulated with an environmentally coupled dynamic surplus production model. Stock production and, to a lower extent, catchability were found to be closely tied to climatological factors. Lower catch rates of the Round Sardinella coincided with years of higher SST and the reverse was true for the anchovy. For the shrimp and flat sardine, precipitation was found to have the most substantial effect on production and total annual catchability. It was concluded that changes in climate directly affect the productivity of the ecosystem as well as its catchability and most importantly, the population growth rate of the species. For sustainable management of the fishery resources, it is imperative that climatic and hydrological parameters be incorporated into fishery management models.

*Keywords: coastal, pelagic fishery, Ghana, vulnerability, climate change*

**Niang, I., Dansokho, M., Faye, S., Gueye, K. & Ndiaye, P., 2010. Impacts of climate change on the Senegalese coastal zones: Examples of the Cap Vert peninsula and Saloum estuary. *Global and Planetary Change*, (in press)**

Following a first study made to assess the impacts of sea level rise on the Senegalese coastline (Dennis et al., 1995), this vulnerability and adaptation (V&A) study tried to

determine the impacts of climate change on two representative coastal zones, the Cap Vert peninsula and the Saloum estuary as well as potential adaptation options. The Intergovernmental Panel on Climate Change (IPCC) Methodology (Carter et al., 1994), completed by the United Nations Environment Programme (UNEP) Handbook (Feenstra et al., 1998), were used together with different models (like the Bruun rule, the FEFLOW model), geographical information system and economic data to determine the physical and socio-economic impacts of different climate change scenarios on these coastal zones. Land losses are expected due to sea level rise that will enhance coastal erosion and increase inundation levels, the second phenomenon being responsible for most of these losses, especially in low lying areas like the Saloum estuary (27% of the total area lost with a 1 m inundation level). The combination of sea level rise and decreased precipitation will increase the salt water intrusion in a number of coastal aquifers, especially around Dakar and in the Saloum estuary. Population at risk of inundation in the Cap Vert peninsula could represent between 1 and 12% of the total population of this area. Economic values at risk were estimated by considering socio-economic scenarios and discount rates. For a 1 m inundation level by 2050, this could represent (for the two areas) 14.1% of the actual Gross Domestic Product. While housings represent more than 90% of this value in the Cap Vert peninsula, in the Saloum estuary, it is the agricultural production which represents the dominant form of value at risk (55%). Only two adaptation options, protection works (sea walls and groins) and afforestation of littoral dunes, were evaluated and costed. For a 1 m inundation level by 2050, this will represent 7.3% of the actual Gross Domestic Product. The main result of this study is the demonstration that protection costs will be lower than economic value at risk contrary to the results of the previous study. This is mainly attributed to the consideration of socio-economic scenarios and a better economic evaluation of the goods and services at risk of inundation.

*Keywords: climate change, sea level rise, Senegal, coastal erosion, inundation, salt water intrusion, adaptation*

**Njock, J. & Westlund, L., 2010. Migration, resource management and global change: Experience from fishing communities in West and Central Africa. *Marine Policy*, 34, 752-760.**

Migration constitutes one of the strategies that fishing communities often use in order to secure their livelihoods. This paper analyses the patterns of migration in West and Central Africa based on case studies from selected countries. It attempts to shed light on migration flows and the reasons behind mobility, and what the main challenges are with regard to integration of migrants in local communities. Migration in the light of global change is discussed as well as how the interests of residents and migrants can best be accommodated for mutual benefit in the context of resource management and poverty reduction. The experience of the Sustainable Fisheries Livelihoods Programme on migrants and co-management is referred to and

the need for inclusive governance and social development approaches emphasized.  
*Keywords: Central Africa, co-management, fisheries governance, global change, migration, West Africa*

**Perry, R.I. & Sumaila, U.R., 2007. Marine ecosystem variability and human community responses: The example of Ghana, West Africa. *Marine Policy*, 31(2), 125–134.**

This study describes variability in the marine ecosystem of Ghana, West Africa, on several temporal and spatial scales and discusses how the human communities using this ecosystem respond to this variability to cope socially and economically. Ghanaian marine waters are part of an upwelling system with strong seasonal and inter-annual variability. Much of this variability is forced at large spatial scales in the tropical Atlantic and by El Niño—Southern Oscillation events in the Pacific Ocean, which influence inter-annual variability of sea surface temperature and pelagic fish landings off Ghana. At decadal scales, Ghanaian marine waters experienced cool sea temperatures and low fishery landings during the 1960s, rapid warming and increases in fishery landings during the late 1970s and 1980s, and variable temperatures and fishery landings during the 1990s. In the late 1990s, pelagic and demersal fish populations appeared to be declining, partly due to over-fishing, although the per capita supply (domestic production plus net imports) of fish was kept high by increased imports. Artisanal fishers and fishing communities in Ghana have devised strategies to deal with variability on seasonal and inter-annual scales. These livelihood strategies include: (i) exploiting marine and terrestrial natural resources more intensively, initially at local scales but expanding to regional scales; (ii) ensuring multiple and diversified income sources; (iii) investing in social relationships and communities for support; and (iv) undertaking seasonal or permanent migrations. In addition, the national government imports fish to deal with shortages. However, these strategies may be less adapted to variability at decadal scales, and may not be sustainable when viewed at the larger scales of environmental change.

*Keywords: Fisheries, Guinea Current, livelihood strategies, spatial scales, temporal scales, upwelling, West Africa*

**Roy, C., Cury, P. Freon, P. & Demarcq, H., 2002. Environmental and Resource Variability off Northwest Africa and in the Gulf of Guinea: A Review. In J.M. McGlade, P.Cury, K.A. Koranteng, & Hardman-Mountford, N.J. (eds.), *The Gulf of Guinea Large Marine Ecosystem*. Amsterdam: Elsevier Science, pp 121-139.**

Environmental monitoring off West Africa relies mainly on a set of coastal stations, on the COADS data base and on satellite imagery. This provides useful information on a limited set of variables such as SST and wind. These variables can be related to fish population dynamics at different scales of observation including short-term changes in fish availability, year to year abundance or lower frequency regime shifts. Tools such

as multiple time series analysis, GAM (General Additive Models) and IBM (Individual Based Models) can help to track time lags, non-linear relationships and discontinuities that exist between environmental variables and fish populations. These methods can help to further understand ecological processes in relation to environmental variability. Relatively few oceanographic surveys have been done off West Africa and the existing oceanographic data are difficult to access. As new information on environment, resources, fisheries and their interaction are needed for management purposes and research, particular attention should be devoted to process oriented studies. Given constraints on human and financial resources, the challenge is to achieve an appropriate balance between monitoring and process-oriented studies.

*Keywords: environmental variability, marine resources, West Africa*

**Roy, C. & Reason, C., 2001. ENSO related modulation of coastal upwelling in the eastern Atlantic. *Progress in Oceanography*, 49(1-4), 245–255.**

An index of ENSO in the Pacific during early boreal winter is shown to account for a significant part of the variability of coastal SST anomalies measured a few months later within the wind driven West African coastal upwelling region from 10°N to 26°N. This teleconnection is thought to result from an atmospheric bridge between the Pacific and Atlantic oceans, leading to warm (cold) ENSO events being associated with a relaxation (intensification) of the Atlantic trade winds and of the wind-induced coastal upwelling. This ENSO related modulation of the wind-driven coastal upwelling appears to contribute to the connection observed at the basin-scale between ENSO and SST in the north Atlantic. The ability to use this teleconnection to give warnings of large changes in the West African upwelling several months in advance is successfully tested using data from the 1998 and 1999 ENSO events.

*Keywords: ENSO, coastal upwelling, eastern Atlantic, West Africa*

**Trape, S., Durand, J.D., Guilhaumon, F., Vigiola, L. & Panfili, J., 2009. Recruitment patterns of young-of-the-year mugilid fishes in a West African estuary impacted by climate change. *Estuarine, Coastal and Shelf Science*, 85(3), 357-367.**

With the persistence of the sub-Saharan drought since the 1970s, the Sine Saloum estuary (Senegal) – the second largest coastal Biosphere Reserve of West-Africa – has become an “inverse estuary” and hypersaline (salinity > 60) in its upstream part. A one-year survey was conducted from April 2007 to March 2008 at eight sites distributed along the salinity gradient, to investigate the recruitment patterns of young-of-the-year mugilids in such an impacted ecosystem. Fishes were sampled monthly with a conical net and a beach seine in salinities ranging from 31 to 104. Samples were identified to the species level. For the smallest individuals (<20 mmSL) a PCR–RFLP technique, developed on the mitochondrial 16S ribosomal RNA region, was used for identification. A total of 8438 juveniles belonging to six of the eight species of mugilids known for the tropical Eastern Atlantic were collected:

*Mugil bananensis*, *Mugil cephalus*, *Mugil curema*, *Liza dumerili*, *Liza falcipinnis* and *Liza grandisquamis*. One species, *L. dumerili*, represented 89% of the total catch. Length–frequency distributions revealed that *M. cephalus* and *L. dumerili* preferentially recruited during the dry season whereas the recruitment of *M. curema*, *M. bananensis* and *L. falcipinnis* generally occurred during the wet season. Minimal size at recruitment ranged from 9 to 19 mmSL depending on the species, the smallest size being that of *L. dumerili*. Despite the general salinity increase in the estuary, most parts of the Sine Saloum were suitable for the juveniles. Only the hypersaline area in the uppermost part of the estuary presented very low fish abundance for all species. According to the species, small recruits (12–20 mmSL) were collected at salinities up to 47–78, suggesting that osmoregulatory capacities had been gained early during ontogenesis, possibly resulting from an adaptation of these populations to changing environmental conditions.

*Keywords: inverse estuary, hypersaline, Mugilidae, juveniles, habitat use, West Africa*

**Verstraete, J., 1992. The seasonal upwellings in the Gulf of Guinea. *Progress in Oceanography*, 29(1), 1-60.**

Observations as well as numerical experiments show that Ekman divergence neither at the equator nor at the coast can explain a significant part of the annual upwellings in the Gulf of Guinea. The remote forcing theory is tested by analyzing both historical data and the FOCAL hydrographic stations (1982-84). The meteorological data base is analysed as well. Analyses of the thermocline show that waters with the same characteristics as those of the South Atlantic Central Water (SACW) are carried by the equatorial under current (EUC) and the South Equatorial Undercurrent (SEUC) from the western-central equatorial Atlantic at 35-degrees-29-degrees-W towards the thermocline regions in the Gulf of Guinea. The thermocline water is then carried back westward in the two geostrophic compensation flows flanking the EUC at 2-degrees-3-degrees-N and 2-degrees-3-degrees-S. The cooling of the subthermocline waters off Abidjan (5-degrees-N) and Pointe-Noire (5-degrees-S) is related to the advection and vertical spreading of SACW between 500m and 50m in May-June-July. An exceptional warm event occurred in early 1984 in the Gulf of Guinea. The winds collapsed nearly completely all along the equator in January-April 1984. The onset of the African monsoon was late (in July-August 1984), then the monsoon was weaker than climatology in August-October 1984. The equatorial thermocline was observed 50m deeper than climatology in February 1984, then near the surface in July 1984. Sea levels rose over the equatorial Atlantic, the surge reaching about 13cm at 6-degrees-E in February 1984, when the western-central equatorial Atlantic was nearly flat. Minimum sea levels occurred in June-July 1984 at 6-degrees-E, before the African monsoon. During this event, the maximum speed in the shallow core of the equatorial undercurrent at 4-degrees-W and 6-degrees-E was nearly insensitive to large changes in the thermal structure (downwelling or upwelling situations). In February-May 1984, we have observed distinct increasing eastward

flows at the equator below 250m and minimum equatorial thermocline thickness. In May 1984, a deep eastward jet was observed at 4-degrees-W carrying about  $3 \times 10^{16}$  m<sup>3</sup>s<sup>-1</sup> within one second mode Rossby radius of deformation and below the base of the thermocline, clearly separated from the EUC. Then, maximum thermocline development was found in July 1984, related to the shoaling of the deep jet and of the EUC. The top of the deep jet had shoaled to about 200m and its transport increased to about  $4.6 \times 10^{16}$  m<sup>3</sup>s<sup>-1</sup> within 1-degrees-30'N - 1-degrees-30'S. The spreading of the isotherms from about 300m is indicative of a geostrophic balance. Simultaneously, the equatorial thermocline was uplifted near the surface, although the base of the thermocline (13-degrees-C isotherm) remained nearly stationary. Analysis of the perturbation temperature field shows that variations of the 19-degrees-C isotherm depth as well as the thickness of the equatorial thermocline were strongly equatorially trapped, with scales associated with the second baroclinic mode. In the absence of local forcing in the Gulf of Guinea from January to July 1984, the only causal effect to explain these large perturbations in the upper 400m lies in the changes in the zonal wind stress to the west of the Gulf. The distinct semi-annual cycle observed in the thermal and salinity structures in the Gulf could be attributable to the semiannual signal in the zonal wind stress to the east of 30-degrees-W. Numerical experiments by PHILANDER and PACANOWSKI (1986a) confirm that remote forcing by changes in zonal wind stress in the western-central equatorial Atlantic is the main process in seasonal changes in the thermocline depth in the eastern equatorial Atlantic, and a secondary process along the coasts. The thinning of the thermocline in July 1984 at 3-degrees-4-degrees-N associated with a strong Guinea current, concomitant with its thickening at the equator associated with a deep eastward jet, suggests that the upwelling along the coast is essentially a consequence of the equatorial adjustment in response to the zonal wind stress in the equatorial zone 10-degrees-W-35-degrees-W. Continuous observations of wind stress at St Peter and St Paul rocks (1979-1988) indicate that the trade winds relax and strengthen through a series of strong bursts superimposed on the seasonal cycle, and that an impulse forcing is appropriate from intraseasonal to seasonal time scales. Since the equatorially trapped waves theory is now able to explain many aspects of both the 1984 winter warm event and the annual cycle, it is very likely that the remotely-forced equatorial dynamics govern not only the annual cycle but also the “quasi El Nino” in the eastern equatorial Atlantic Ocean.

*Keywords: tropical Atlantic ocean, equatorial Atlantic, sea-level, subsurface countercurrents, thermal structure, trapped waves, pacific ocean, low latitudes, wind stress, heat-budget*

**Wiafe, G., Yaqub, H.B., Mensah, M.A. & Frid, C.L.J., 2008. Impact of climate change on long-term zooplankton biomass in the upwelling region of the Gulf of Guinea. *ICES Journal of Marine Science*, 65(3), 318-324.**

We investigated long-term changes in coastal zooplankton in the upwelling region in the Gulf of Guinea, 1969–1992, in relation to climatic and biotic factors. We considered the role of hydrographic and climatic factors, i.e. sea surface temperature

(SST), salinity, sea level pressure, windfield, and Southern Oscillation Index (SOI), in the long-term variation of zooplankton in a multiple regression analysis, along with the abundance of *Sardinella*. Annual variation in zooplankton biomass was cyclical, with the annual peak occurring during the major upwelling season, July–September. Over the 24-year period, there was a downward trend in zooplankton biomass (equivalent to 6.33 ml per 1000 m<sup>3</sup> per year). The decomposed trend in SST during the major upwelling revealed gradual warming of surface waters. This trend was believed to be the main influence on the abundance of the large copepod *Calanoides carinatus* (sensitive to temperatures above 23°C), which appears in the coastal waters only during the major upwelling season. The warming trend associated with global climate change could affect zooplankton community structure, especially during the major upwelling season. Global warming coupled with “top–down” (predation) control by *Sardinella* might be responsible for the long-term decline in zooplankton biomass in the upwelling region of the Gulf of Guinea.

*Keywords: Calanoides carinatus, climate change, global warming, Gulf of Guinea, Sardinella, upwelling, zooplankton*

**Zeeberg, J., Corten, A., Tjoe-Awie, P., Coca, J. & Hamady, B., 2008. Climate modulates the effects of *Sardinella aurita* fisheries off Northwest Africa. *Fisheries Research*, 89(1), 65-75.**

The fluctuating abundance of round sardinella (*Sardinella aurita*) in Mauritanian waters over the past ca. 20 years can be related to environmental dynamics off Northwest Africa. Trends in the fishery are evaluated using FAO data, acoustic surveys, and catch statistics from the EU fleet (1996–2006). Remote sensing data demonstrate rising annual sea surface temperatures, up to 3 °C higher than the long-term average in 2002–2003, following a shift in ocean climate in 1995. Fish abundance and repeated expansion of the sardinella population in the past 10 years are attributed to favorable oceanographic conditions and increased recruitment success. *Sardinella* thrives with intense upwelling and high primary production during spring, and retention of waters over the shelf during summer and autumn. The stock of *S. aurita* over the Northwest African shelf oscillates with the cold–warm states of the habitat. Favorable hydrographic conditions and extended habitat has resulted in unprecedented rise of sardinella abundance in the late 1990s, which was counterbalanced by the impact of fisheries. A backshift to a cold-state ecosystem, with extensive regional upwelling and decreased sardinella habitat, would topple that balance.

*Keywords: Pelagic, sardinella, remote sensing, oceanography, Northwest Africa*



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