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Review Paper

Impacts of Climate Change on West African Fisheries and its Implications on Food Production

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ABSTRACT

Fish constitutes as an important food, commodity and industry in the economies of West African countries. Forecasts of fish production in the future indicate that majority of the fisheries will be affected by climate change, and may cause food insecurity. This review discussed food security threats and other negative consequences associated with climate change in the fisheries production in West Africa. It discussed various aspects of the linkage between food security and fisheries production system in a changing climate and highlight areas of actions for policy makers. The impacts of climate change on most of the fish and fisheries of West Africa were not well understood. However, general knowledge on possible impacts suggests changes may be detrimental to fisheries production and food security from household to regional level. The study suggested that regional cooperation and governments need to focus on immediate and practical priority issues to effectively address long term issue such as climate change. Actions should be taken to improve awareness of fishers and fishing communities about the impacts of climate change on their livelihood. Furthermore, this review suggested thad Diversifying fish sources may enable the region's rural households to cope and adapt to climate change impacts.

Key words: *climate change, fisheries, food security, West Africa*

INTRODUCTION

The West African region is home to about 43% of the total population in Sub Saharan Africa (*OECD 2008*). The region consists of coastal and landlocked states with abundant and diverse fisheries resources (*FAO 2006*). The fisheries sector plays an enormous role on the national economies of the region and constitutes the main livelihood for a majority of people living along the coasts and in riparian areas (*Ajayi 1994; Béné & Heck 2005; Béné 2006*). The area of West Africa as defined in this article, refers to the countries of economic community of West African states (ECOWAS)- that is Benin, Burkina Faso, Ivory Coast, Guinea Bissau, Mali, Senegal and Togo; and includes the eight countries of West Africa Economic and Monetary Union, as well as Carpe Verde, Gambia, Ghana, Guinea, Liberia, Nigeria, Sierra Leone, and Mauritania (*Failler and Samba 2005*).

Countries like Senegal, The Gambia, Sierra Leone and Ghana largely depend on fisheries for their national economies and as a major source of foreign revenue (*Béné 2008*). In Benin, Ghana, Mali, Mauritania and Senegal, more than half of the population consume fish products daily (*Béné & Heck 2005*). High demand of fish and associated products led to more than five million fishers, fish processors and fish traders in the region, besides other jobs such as boat building and small scale business in the fisheries sector (*FAO 2006; Westlund et al. 2008*) (**Table 1**). Moreover, fisheries provide jobs for marginalized groups- mostly women who dominate processing, retailing and local trading of fish products (*Akrofi 2002*). Over the last two decades, West African fisheries underwent tremendous changes from a predominantly traditional canoe fleet to a mix of traditional and modern fleets (*Mensah et al. 2006*). Motorized canoes and boats increased the volumes of fish landed and exports went beyond the boundaries of Africa, particularly in Europe (*Alder and Sumaila 2004*). For example, Senegal, the most important fishing nation in West Africa; has fishing fleets operating both inside and outside of its territorial waters. In 2005, the top exporting countries by quantity were Nigeria (23%), Senegal (16%), Ghana (16%), Mauritania (10%) and Sierra Leone (6%) (*FAO 2006*) (**Table 2**). Total captured fisheries production for 2010 amounted to 2.3 M MT for both marine and inland waters (**Figure 1**).

With regional fish stocks already on the decline, per capita fish consumption has declined (*Atta-Mills et al. 2004; Koranteng and Pauly 2004; Palomares and Pauly 2004; Mensah et al. 2006*). Between 1973 and 1974 annual fish consumption per head was 11.4 kg, the current level of consumption is around 6.6 kg capita yr^{-2} (*Béné and Heck 2005*). Fisheries sector is likely unable to help meet the nutritional and protein requirements of the rapidly growing population in the coming decades.

The artisanal sector is the main supplier of fish production in this region and is estimated to contribute over 60% of the total marine catch (*Alder and*

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Sumaila 2004; Atta-Mills et al. 2004; Mensah et al. 2006). The industrial sector is mainly operated by foreign fleets (*Kaczynski 1989; Kaczynski and Fluharty 2002*). Catches by foreign fishing fleets make up a significant portion of the total catches in the region, generally representing between 10-15 percent of total catches (*MRAG 2010*).

Table 1. Employment, fishery contribution to GDP and government revenues for selected West African countries.

Country	Number of people employed	Contribution to GDP (%)	Government revenue (US$ million yr^{-1})	Contribution to government revenue (%)
Cape Verde	8800	1-2	0.9	N/A
Gambia	3100	2.4-12	N/A	7
Guinea	30000	1.3	4.3	2.5
Guinea Bissau	15000	7-10	12.7	40
Mauritania	30422	5.2	109.1	27
Senegal	125354	4.9	1.8	N/A
Sierra Leone	250000	9.4	6.2	N/A

Source: Compiled from FAO (2006)

Table 2. Fishery commodity trade in selected coastal countries of West Africa in 2006.

Country	Exports		Imports	
	Quantity (tons)	Value (US$ 1,000.00)	Quantity (tons)	Value (US$ 1,000.00)
Cape Verde	21101	13158	762	1691
Gambia	86	355	1940	579
Guinea	7352	25809	8924	7967
Guinea Bissau	5995	4246	282	269
Mauritania	95695	130131	321	171
Senegal	108516	277577	453	1085
Sierra Leone	5468	11081	631	1420

Source: FAO FISHSTAT 2008

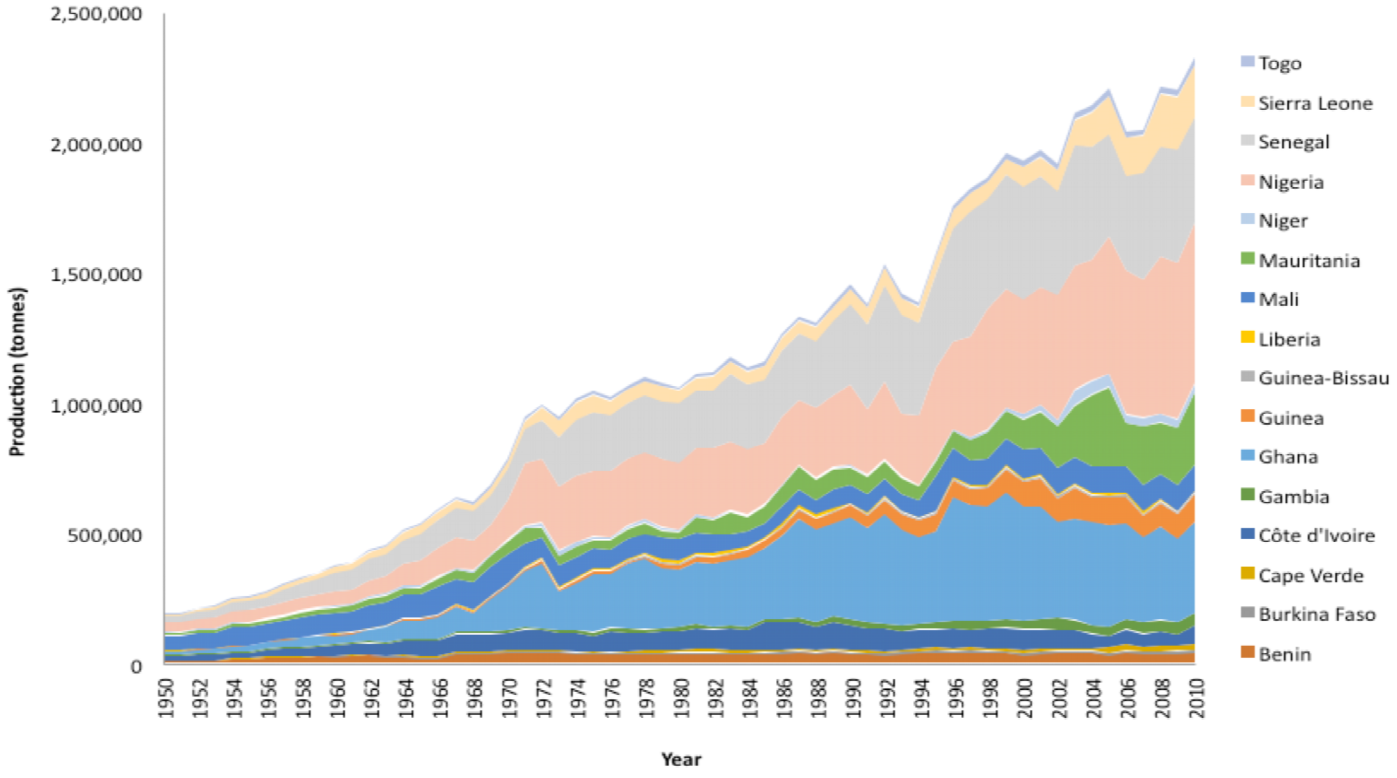


Figure 1. Total Fisheries Production for West African countries (1950-2008) (Source: FAO FISHSTAT).

Inland capture fisheries comprising lagoons, lakes, rivers and aquaculture, are entirely artisanal and make up for roughly 20% of the region's total fish production (*FAO 2011a*). In 2010, the total inland capture fisheries production amounted to 654,000 MT (**Figure 2**). Aquaculture is still at its nascent stage in West Africa but is becoming widespread in many countries in the region (*Brummett and Williams 2000; Brummett et al. 2008*). However, at this stage, it does not contribute significantly to the region's fish supply.

As the economies of many West African countries are closely tied to fisheries and the inhabitants are dependent upon fishing as a means of livelihood, any decline in fisheries resources poses serious implications for food and internal security in the region (*Palomares and Pauly 2004*). Estimations were made that by 2025, the population in West Africa will reach 430 million (*OECD 2008*), which would put additional pressure on the region's natural resources including fisheries (*FAO 2010a; 2010b*).

Furthermore, there is high speculation that demand for fish will exceed supply in West Africa, with an annual decrease in fish supply by 4% per year, leading to a supply deficit of 3.6 M t in 2015 (*Failler and Samba 2005*). Considering the importance of fisheries to food security in West Africa (**Table 3**), there is an urgent need to understand the outcomes of fisheries systems impacted by climate change. While considerable work has been done on how climate change will impact the agricultural sector in various regions, especially crop production and the resulting consequences for food security (e.g. *Roseinwerg and Parry 1994; Mendelsohn and Nordhaus 1996; Kurukulasuriya and Mendelsohn 2006*), few studies focused on fisheries. The eminent role of fish for food security particularly for the poor (*Worldfish Center 2005*) shows a clear need to further investigate the anticipated impacts of climate change on the sector.

In this review, future food security in West Africa in a changing climate from a fisheries perspective was assessed, as well as reviewed from the available literature on fisheries, climate change and food security. Further the linkages between them was analyzed. To complement the limited information, alternative studies about food security – mainly from the agricultural sector - were included. After which, the links between fisheries, food security and climate change are established.

This is followed by overview of impacts of climate change in West African region and the potential and projected impacts on the fisheries sector. Further, the climate change impacts on food production from the perspective of fisheries food system was also observed. The review culminated by providing a summary of key issues and challenges that climate change will bring to West African food security and indicated potential steps which can be taken by governments in the region to help fisheries to adapt to climate challenges.

Both capture fisheries and aquaculture have profound role in food security. Fisheries played a significant role in many countries and communities by contributing a significant amount of animal protein to the diets of millions of people. For example, in West Africa, on the average, fish currently provides almost 30 per cent of the total protein animal intake and the number could be larger if the poor can afford to buy more (*Westlund et al. 2008*).

In some countries of this region such as Senegal, the Gambia, Ghana, Mauritania and Sierra Leone, the importance of fish to food supplies is even greater (*Heck and Béné 2005*). Fish is highly nutritious and serves as a valuable supplement in diets lacking essential vitamins and minerals.

In Africa, fish generally contributes to food security as important supplement to maize, millet, and cassava (relish) based diets. Fisheries also make significant contribution to the process of improving food security through the opportunities the sector offers for employment and income to millions of people, either directly or indirectly (*FAO 2006*). The income generated from fisheries employment and financial revenues from the domestic sale of fish provide cash which can then be used to purchase other foodstuffs (*Worldfish Center 2005*). The foreign exchange earnings from fisheries, and increasingly, aquaculture are also making a growing contribution to the economy. The role of foreign exchange from fisheries exports is largely contested whether it should be devoted directly for improving food security or may be diverted to other purposes which could improve the economy (*Béné 2008; Béné et al. 2010*).

Climate change and its Potential impacts on Fisheries Sector of West Africa

A number of studies have already dealt with the physical and ecological impacts of climate change on marine and inland capture fisheries, and aquaculture (e.g. *Allison et al. 2005; Handisyde et al. 2006; Barange and Perry 2009; Daw et al. 2009; Allison et al, 2009; Barange et al. 2010*). However, information about the West African region is still scarce (*Perry and Sumaila 2007; Wiafe et al. 2008*). In general, physical changes in oceans, lakes and rivers attributed to global climate change will result into varied impacts on fish and ecosystems (*Brander 2009; Daw et al. 2009*) and to fishers, livelihood, trade and economies (*Allison et al. 2009; Badjeck et al. 2010*).

Climate change and variability affected fisheries and coastal communities throughout history (*Brander 2007; 2010*) including rare and extreme events such

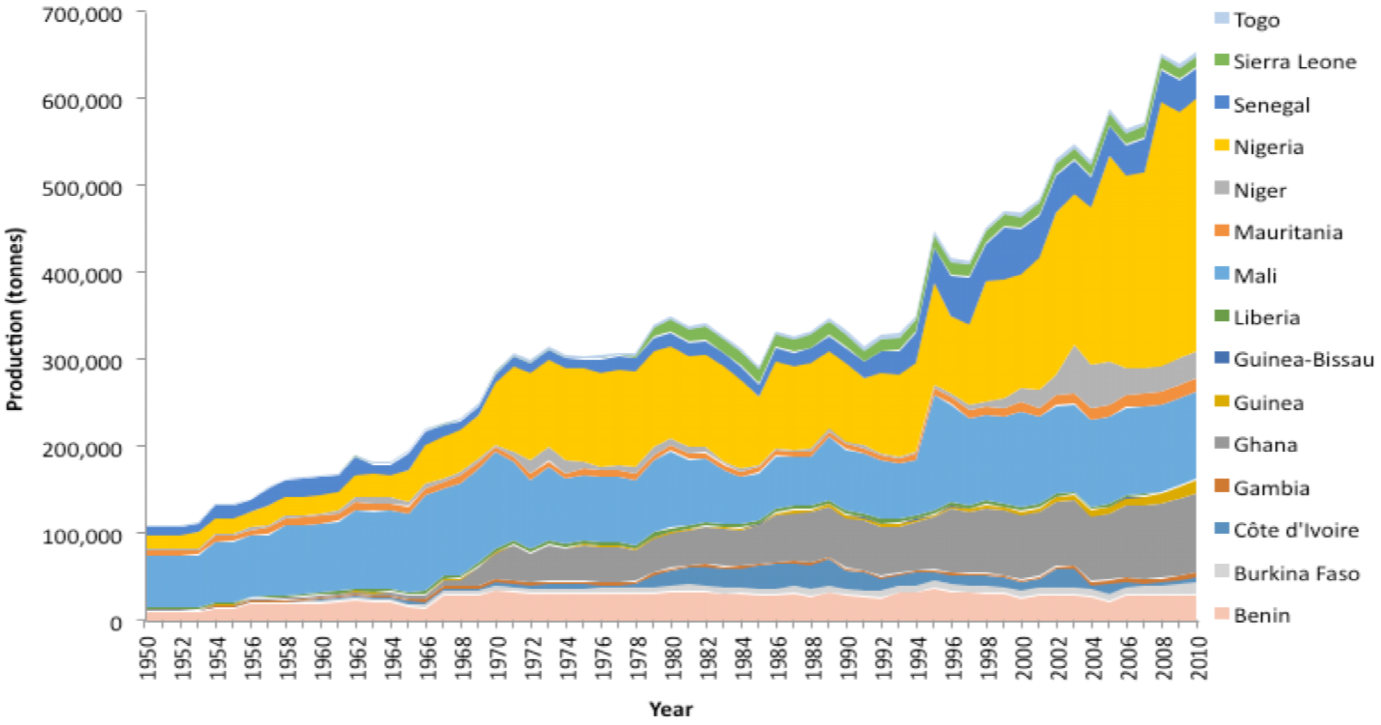


Figure 2. Total Inland Fisheries Capture Production for West African countries (1950-2008) (Source: FAO FISHSTAT).

Table 3. Fishery commodity trade in selected coastal countries of West Africa in 2006.

Country	Fish consumption (kg capita year^{-2})	Fish as percent of animal protein intake (%)
Cape Verde	18.8	15
Gambia	24	54
Guinea	1	0
Guinea Bissau	11	38
Mauritania	13	9
Senegal	27	42
Sierra Leone	14	63
Africa	7	17
World	16	14

Source: FAOSTAT online statistical services

as upwelling failures and flooding. Like in other regions of the world, fishing communities in West Africa were able to cope with such changes, for example by switching to alternative livelihoods and through geographical mobility (*Boko et al. 2007*). In many cases, this was sufficient to avoid larger economic losses. The impacts of the current process of climate change differ from those in the past in a number of ways. The expected rate of change is more rapid, and most fisheries are already under stress (*Lehodey et al. 2006*). Additionally, fishermen may not be able to use their adaptive strategies. Geographical mobility for instance is prevented by population increase in coastal and riparian areas, declining catches and institutional barriers (*Allison et al. 2005*).

Global studies have shown that climate change in aquatic systems can result to variations in temperature and wind. This could affect the stratification of water bodies and circulation of water masses leading to changes in productivity that may cause shifts in relative abundance of species throughout the food chains (*Ficke et al. 2007; Cheung et al. 2009*). This can lead to decline in fisheries production and even to the disappearance of some species.

Work by *Brander* (*2007*) affirms that changes in sea temperature are ultimately responsible for other impacts such as acidification, sea level rise, winds and tides which may radically change the whole ecosystems and hence affecting fisheries production. A recent study by *Cheung et al.* (*2010*) gave a useful prediction on how temperature increases from climate change may lead to large scale redistribution of global catch potential. The study found that there will be an average of 30-70% increases in catch in high latitude (temperate) regions and a fall of up to 40% in the tropics.

IPCC (*2007*) outlined that global climate change is likely to affect important coastal habitats such as mangroves ecosystem which support numerous fisheries. This can be through sea level rises and extreme weather events such as floods and increased storm severity thereby affecting fishing activities, fish farms and productive assets (*Allison et al. 2005*). Low lying coastal areas of West Africa (in particular deltas and estuaries) are rich in mangrove forests, therefore any losses of mangroves in this region will negatively affect the diversity of fisheries resources in such areas. As elaborated by *Munday et al.* (*2009*) the predicted increased frequency of extreme winds, storm and high-tides, will mostly disrupt

the lives of local coastal communities in the near future.

This may show through disruption of fishing patterns and behavior, reduced safety at sea for fishers and others, disruption and damage to aquaculture installations such as fish farms, and damage and loss to property and boat. Additionally, it will result to reduced high-tide functionality of jetties and destabilization of other coastal infrastructure and increased inundation of areas used as fishing harbors, fish markets, fishing camps and salt making. In association with this, there will be drop-off in fisheries activities which will have huge consequences on livelihoods of dependent communities and national economies (*Allison et al. 2009; Badjeck et al. 2010*).

Wetlands, floodplains, and shallow lakes and rivers in Africa are all susceptible to changes in precipitation and temperature (*FAO 2010a*). As explained by *Fick et al. (2007)*, global climate change will probably affect freshwater ecosystems and their fisheries in many regions of the world. These changes will eventually affect the supply and quality of freshwater lakes and rivers throughout the West African region, and consequently have an impact on its inland fisheries. The inner delta of the Niger River in central Mali exemplifies the impacts of changes in rainfall attributed to climate change. Since 1970 a decrease in the area flooded has led to a decrease in fish catch (*Oyebande et al. 2002*). Lake Chad, which supplies nearly 13 percent of Nigeria's inland fish catch, is also affected by changes in the size of the lake due to drought, as the lake's shoreline recede (*Oyebande et al. 2002*). The persistent drought that caused Lake Chad's decline wass associated with global climate change (*FAO 2010a*). Prolonged drought will reduce fish availability in these aquatic habitats and they may dry out completely resulting into total collapse of fishery activities (*Allison et al. 2007*).

This has a serious impact on the fisheries in the lake, which are already under pressure due to upstream damming and overfishing. Increased incidence of extreme rainfall events in wetland and other inland catchments may cause temporary drop in salinity, thereby affecting salinity-sensitive aquatic organisms such as crabs and prawn. Equally, reduced levels of rainfall in inland catchments over time may reduce sediment budgets reaching coastal waters, causing long-term erosion of mangroves and beaches thereby affecting supporting services provided by those ecosystems to fisheries. Climate change could also affect fisheries indirectly, such as increased fishing pressure due to declining agricultural productivity.

The impact of climate change on the aquaculture sector has been comprehensively presented by *Handisyde et al. (2006)*, with the general consensus being that climate change will have mixed implications for aquaculture. Climate change will likely impact aquaculture through increased air temperature, rising sea levels, altered ocean productivity, modified ocean circulation patterns, changed monsoon cycles, the frequency of extreme weather events, and modified hydrological regimes (*De Silva and Sotto 2009*).

However, because aquaculture occurs in freshwater, marine and brackish water, climate change is likely to influence aquaculture production in each environment in different ways. For example, it is expected that salinity and temperatures in brackish water habitats could be significantly altered due to climate change, thus affecting the biological productivity of these habitats (*De Silva and Sotto 2009*). As fisheries provide significant feed and seed inputs to aquaculture, the impacts of climate change on them will also, in turn affect productivity and profitability of aquaculture systems (*FAO 2008a*).

On the other hand, positive effects due to increased growth rates and food conversion efficiencies, longer growing season, range expansion, and the use of new areas could actually benefit the aquaculture sector (*Daw et al. 2009*).

Potential impacts on fish stocks

There is now a wealth of evidence of impacts of recent climate change on distribution, species composition, seasonality and production of marine and freshwater fish stocks (e.g. *Perry Ficke et al. 2005; 2007; Daw et al. 2009; Pörtner & Peck 2010*). The relative scale of these different impacts of climate change on fish stocks is expected to vary between and even within the regions. Not all fish species will be equally affected in all places. Nonetheless, the specific effects on particular fish species or stocks are difficult to predict and quantify. In the West African region there has been little research on the potential impacts of climate change to fish stocks and most of the researches done on this subject were still in early stages (e.g. *Perry and Sumaila 2007; Wiafe et al. 2008*).

Climate change is predicted to affect individual organism during all its life stages, consequently affecting population of species, communities and functioning of ecosystems (*Allison et al. 2005*). Climate change will also affect the abundance, distribution and assemblage of fish stocks, potentially disturbing the balance of aquatic food webs (*Barange and Perry 2009*). A comprehensive review of the pathways through which climate change affects fish stocks and aquatic ecosystems is given by *Allison et al. (2005)*.

The effects of climate change on fish stocks can be direct, through changing water temperatures and associated phonologies, the length and frequency of hypoxia events, through ongoing ocean acidification trends or through shift in hydrodynamics and in sea level rise (*Brander 2007; Pörtner and Peck 2010*). Increases in water temperature will affect fish physiological processes and thus their ecological fitness (*Brander 2007; Barange and*

Perry 2009). Many of the inland fish species will fail to enhance their distribution to the more suitable water conditions hence failing to survive (*Fick et al. 2007*). They could also be an increased risk of species invasions and the spread of vector borne diseases (*Brander 2007*).

Fish stocks in the GCLME are subject to interactions between species and fish communities, as well as to environmental forcing (*Hardman-Mountford & McGlade 2003*). Thus climate change will likely influence fish abundance and distribution in the GCLME solely due to the effect on climate-ocean regimes (*Roy et al. 2002*). In other cases, climate interactions with fish stocks will be indirect and mediated through direct effects on the key prey species which change the composition and dynamic coupling of food webs. One of the most widely documented impacts of climate change on fish stocks includes changes in fish habitat that will occur through different mechanisms (*Barange and Perry 2009; Daw et al. 2009*). Increased global temperature, for example, can affect individual fish by altering various functions such as thermal tolerance, growth, metabolism, food consumption, and the ability to maintain internal homeostasis in the face of a variable external environment (*Fick et al. 2007*). Decreased levels of dissolved oxygen will affect the metabolic rates of most cold-blooded aquatic organisms.

On a global basis, there is sufficient research to indicate that many, but not all, of impacts of climate change on fish stocks will be negative (*Daw et al. 2009*). There will be some positive effects due to increased growth rates and food conversion efficiencies, longer growing season and use of new areas. Inland fisheries production may increase due to increases in the size of flooded areas, due to increases in precipitation, which is expected to occur in some areas on account of global climate change. Also, while a rise in sea temperatures can negatively affect some species (as in the case of small pelagic fisheries in Peru), it may also bring a variety of tropical immigrants and expand the distribution zone of other species. Until now it is difficult to precisely forecast the direct impacts of climate change on the levels of fisheries production and fish stocks, and this gap in knowledge constitutes a barrier for countries trying to account for the potential risks and vulnerabilities posed by climate change. Though the impacts remain highly uncertain, we should not think that there is nothing to be done at local, regional or global level management.

Climate change, fisheries and food security in West Africa

Food security depends upon a set of circumstances that has political, social and economic dimensions at the household, national, regional and global levels. In recent years, international community, national governments and development agencies have fuelled more attention and actions on the issues facing food security. One crucial issue currently hitting the debates in global food supply is climate change impacts on food production systems. Climate change may impact negatively the sectors related to food security including agriculture (crop production), livestock, fisheries, water, health and infrastructure (*FAO 2008a; Funk and Brown 2009*). Research have shown that effects on food security through impacts on these sub-sectors is largely evidenced through increases in extreme weather events such as drought coupled with poor distribution of rainfall (*IPCC 2007*). Similarly, floods may affect crop yields, fishing activities, fish farms, and destroy infrastructure such as roads and railways, leading to reduced food production and availability (*Allison et al. 2005*).

Food security in West Africa

Food insecurity in Africa and in West Africa in particular is increasing as indicated by the rising levels of chronic hunger, severe malnutrition and growths of stunting in children (*FAO, 2010b; 2011b*). The highest prevalence of undernourishment is found in sub Saharan Africa (**Table 4**).

For instance, estimates have indicated an increase in the proportion of undernourishment from 28% in 2004-2006 to 29% in 2008 (*UN 2009*). The number of countries with capacity to produce "surplus food" in the region has decreased over the last two decades. A large proportion of people in Africa are food insecure. The standard of nutrition is still very low compared to other nations of the world (*FAO 2011b*), although this regional pattern is obscured by significant differences in the nutritional status in many West African countries.

In other words, the magnitude of the problem in terms of its severity and proportion of the population affected differ from country to country even at household level. Furthermore, food production has declined in countries such as Liberia, Sierra Leone, Ghana, and Senegal leading to their dependence on food aid (*Adejuwon 2006*). Aid came mainly in form of wheat products. The reliance on foreign food staples means that no country in the region is self-sufficient in terms of food production. *FAO* (*2011a*) estimates that Africa will need adequate food supplies for 18 million additional people each year and to improve the nutritional status of the 94 million people currently undernourished if it is to meet the Millennium Development Goal 1.

Fishery products and food security in West Africa

As noted elsewhere in the world, the West African fisheries sector contributes to food security in two ways: it provides food and forms the primary source of livelihood for millions of people. Through revenues generated from production and related processing activities, trade and exports, it also contributes indirectly to food security

Table 4. Proportion of populations that are undernourished in developing countries.

Region	Percent of population undernourished
Sub Saharan Africa	29
Latin America/The Caribbean	8
South Asia	21
South East Asia	15
West Asia	8
Oceania	15

Source: United Nations Inter-Agency and Expert Group for Millennium Development Goals (2009)

(*Worldfish Center 2005*). Recent reports on comprehensive food security and vulnerability analysis for some countries such as Ghana and Liberia, which provided an in-depth picture of food insecurity in those countries, indicated that artisanal fishing still provides the great majority of dietary animal protein in the region.

Aquaculture has a similar key role to play, both through its contribution to food supplies and to economic growth. Additionally, fish is an important source of income (*Béné et al. 2007*) used to purchase other food items such as maize, cassava and pulse food stuffs. Still, the exact extent to which fisheries contribute to food security is poorly understood (*Bostock and Walmsley 2009*). Aside from the annual fisheries statistical data submitted to international organizations like the FAO, other data that covers processing, distribution and transport of fish and related food products are inadequate. Information on most of its ecological resources, economy and demography that interplays with these industries are also significantly lacking, if not outdated.

Climate change and food security

In the ongoing debate about global climate change and world food supply there is consensus that climate change impacts are not the main threat to food security (*WMO 2003*). Literature on food security and hunger tend to single out population growth as the main existing threat (*Gilland 2002*). Climate change, however, is generally viewed as posing the greatest threat to food production systems of the relatively natural resource-based poor sub-Saharan countries (*Nellemann et al. 2009*). *FAO* (*2010a*) assents that the risk of food insecurity in the African continent will be compounded by the projected climate change impacts and decreases in production yields.

There have been several quantitative simulations of possible future relations of fisheries to other components of the world food supply (e.g. *Delgado et al. 2003*), but none of them accounted for climate change. Broadly, climate change is expected to affect both agriculture and fisheries production levels in several ways, ranging from direct effects on production (*Schmidhuber and Tubiello 2007*) to changes in markets, food prices and supply chain infrastructure (*FAO 2008a*). The relative importance of climate change for food security is not homogenous between regions or countries. In West Africa, the multiple socio-economic and biophysical factors that are known to affect food systems make it especially difficult to determine how exactly climate change could undermine food security.

As fisheries production is adversely affected by climate change, the livelihood of a large number of poor people in the region, in both rural and urban areas, will be threatened, with the potential to cause food insecurity, hunger and malnutrition on an unprecedented scale within the next decades. In general terms, the food security implications of changes in fisheries production patterns may be of two kinds: impacts that will have effects at the local, national and regional level and impacts at the personal level that affect people's critical food sources and primary income generating activities.

The main challenge is to know how much fish will be needed for future food security for the coming decades especially for the increasing population considering decrease of bumper catches and less fish supply from aquaculture. Currently, there are no clear estimates on the availability of fish per capita that will be needed in 2030 or 2050 for the West African population. Some regions of the world such as the Pacific already have plans for food security for the coming decades (*Bell et al. 2009*). In line with this, rigorous efforts need to be taken at household, national and regional level to sustain contribution of fishery resources and aquaculture in food security.

It is therefore important for future research to attempt to ascertain to what degree the region's fishery resources can in fact help meet the nutritional needs of the people in the future. It is also important to develop fisheries management regimes that ensure fisheries produce the greatest possible returns, while not overfishing and jeopardizing fish stocks. Management systems also need to account for the role of fishing as a critical income generating activity for people in the region. Sustainability should not just be a by-word among the people but a practice that would help maintain their nourishments and livelihoods.

Impacts of climate change on fish production, processing and consumption

Climate change affects fisheries and fish production in complex ways. It affects fish production directly through changes in habitats and indirectly by affecting individual's income and even potentially the demand for fish (*Allison et al. 2005; Badjeck et al. 2010*). Culture-based and integrated farming which offer enormous potential in sub-Saharan Africa to enhance the supply of fish may be

affected by irregular events of rainfall and droughts. Fisheries production in large lakes such as the Volta and Chad will be negatively affected by increasing water temperatures (*Allison et al. 2007; IPCC 2007*). The potential impacts have yet to be specifically determined in the region, despite such types of studies in other parts of the world (e.g. *Fick et al. 2007; Brander 2009; Munday et al. 2009; Perry et al. 2010*).

Fish processing methods available in West Africa are mainly traditional ones, though improved technologies are being introduced and gradually adopted (*Essuman 1992*). The famous traditional fish processing techniques include smoking, sun-drying, dried salting, fermenting and frying. These techniques vary from one country to the other, based on tradition, preferred tastes and market preferences (*Akrofi 2002*). Smoking is the most widely practiced method for preserving, processing and storing fish in most of the West African countries.

Climate change impacts may result to varying temperature and precipitation trends that could have direct and indirect effect on these techniques. For example, prolonged drought may render fish smoking difficult, by reducing the availability of fuel woods due to drying up of common trees used to smoke fish resulting into inadequate materials for fish smoking. This eventually may reduce the shelf life of smoked fish, increase waste in times of bumper catches, and reduce storage for the lean season thus decreasing protein availability to people throughout the year. Increased climatic variability may likely alter the length of time smoked fish products can be stored and remain edible. This will also affect the duration fish may be kept in sellers' stores or vehicles before delivery to the market.

Though highly uncertain, if climate change will cause the increase in fish catch, most of the fish processing techniques such as smoking may fail to cope with the large volume of fish landed. This will lead to high post-harvest losses contributing to fish scarcity in areas where fresh fish cannot be brought easily. Fish smoking is also the most common economic activity for women living in coastal towns and villages, as well as along lakes and rivers in fishing communities (*Akrofi 2002*). Any interruption to this activity will bring economic downturn to their lives.

Processed fish products form a highly significant part of the fishery commodities traded within the various countries of West Africa. The bulk of fish consumed is in smoked form, although artisanal fishery catches are marketed mainly according to consumer tastes, storage conditions, and supply and demand. Fish not sold in the same day are usually dried or smoked before distribution to various local and regional markets. Most fishing villages, for example, those around the Volta Basin do not have their own market and depend on a few larger lakeside towns for commercialization of their catch (*Béné and Russel 2007*). Most of such markets are inaccessible during the wet season.

Climate change impacts may especially increase precipitation in some areas and will likely affect the channels through which fish trade is distributed. According to *INFOFISH* (*2008*), selling of fresh fish from artisanal fisheries has increased due to better infrastructure which allows an enhanced distribution network towards hinterland areas. Despite these kinds of improvements of modernization, anthropogenic-induced climate change may cause damage to existing infrastructure such as fish markets, harbours, roads and fish-farms. and thus decrease market opportunities for fishermen. As noted by *Béné and Russell* (*2007*) some fish traders such as those from Bagré in Burkina Faso are known to sell their fish products as far away as Ouagadougou or even to markets at the Togo border (50 km away from Bagré).

Extreme drought or flooding may make roads impassable notably in the Sahelin zones of Mali, Niger and Burkina Faso. The fact that much of the region is already characterized by a lack of existing infrastructure for processing, transporting, and marketing fish, climate change is likely to reverse any recent improvements in this aspect. Impacts on distribution networks in countries like Senegal, where nearly one-third of the total fish catch is currently exported to markets in the neighboring countries of Côte d'Ivoire, Ghana, Mali, Mauritania and Nigeria will make economic effects localized and particularly severe for some nations.

Little is yet known about how climate change will bring impacts on preparation and consumption of fish in West Africa. In most cases fish prepared for local consumption in this region are done without sophisticated processing as in the USA and European countries. In Ghana for example, until the end of 1960s, smoked fishes were prepared using traditional ovens with low capacity and inefficient fuel usage, which caused poor quality smoked fish and significant post-harvest losses. Poor performance of these ovens, wasmore fuel wood than necessary for the smoking process, which contributed to the losses of forests.

The health of women fish smokers was also at risk as the smoke was getting into their eyes and lungs, their fingers were getting burnt and they were exposed to raw heat. Projected impacts of climate change especially rising temperatures and increased precipitations may bring indirect effects to such preparation processes for example longer time for smoking and inadequate fuel wood. It may also be difficult to sun-dry the fish especially during rainy season or in prolonged days of rains. On the other hand, climate change impacts may cause fish smoking more laborious than it used to be.

Wholesale fish traders particularly around Volta Basin are known to travel to fishing villages to purchase processed

fish and return to lakeside markets within 2-3 days with the fish already prepared for the journey to the urban center. Until now, it is not well known whether such pattern may remain because it may take much longer time for fish preparation due to increased events of erratic weather thus rendering difficulties for the traders to take fish to the markets. This in turn may affect consumption by decreasing fish availability to areas far from the coast and along rivers and lakes.

Consumption patterns may be altered following impacts on specific species. Small pelagic species such as sardinella, anchovy, chub and horse mackerel commonly consumed in Ghana (*Atta-Mills et al. 2004*) are sensitive to changes in ocean conditions. Any variations in these species would result into changes in consumption of fish for the majority of population in Ghana. Indeed, if climate change would pose serious changes on the income of people, consumption patterns will also change. Most scenarios of increased climate change impacts on fish production systems imply substantial trade-offs with fish consumption.

Impacts of climate change on food security components

Climate change impacts on fisheries sector will potentially cut across the four main essential components of food security, namely: increased availability of food, improved access to supplies, more effective food utilization and stability of food supply.

Availability

The impacts of climate change on food availability will be experienced differently, depending on the particular food sector. In agriculture, for example, moderate warming (1-3°C) may benefit crop and pasture yield in temperate regions, while in African tropical and seasonally dry regions, it is likely to have negative impacts, particularly for cereal production (*IPCC 2007*). Though not well covered in fisheries and climate change literature, some areas in sub-Saharan Africa (where many countries in West Africa are located) such as coastal plains, may become flooded or unsuitable to agriculture (and potentially aquaculture) due to increased salinity from sea level rise caused by global climate change (*IPCC 2007*). As explained by A*llison et al.* (*2005*), climate change could cause declines of fish production in coastal and inland fisheries of West Africa due to declining freshwater levels, and rising sea temperatures that could damage fish habitats.

Most of the fish eaten in this region currently comes from coastal stocks (*Ukwe et al. 2006*). The problem facing many coastal states in West Africa is that even well-managed coastal fisheries have not been able to adequately supply fish required for future food security. Reduced fisheries production will accelerate reduced fish availability and this will have additional direct implication for food accessibility. The gap between the fish available and the amount of fish required for food security will be even wider in a changing climate.

According to *FAO* (*2008a*) food availability relates to the overall ability of a production system to meet the people's basic food demands. Currently, some countries in this region such as Ghana, Nigeria and Côte d'Ivoire are known to be net importers of fish products to help meet the populace's nutritional protein demands. Nigeria for example, as in 2007, was still a large importer of frozen fish. Prices of imported fish are not low, a reflection of inadequate availability, meaning that any loss in availability will particularly affect poorer populations. Such a situation of unequal distribution of impacts could lead to food riots and social unrest (*FAO 2008b*).

Even without climate change, further decreases in fish production are already expected due to current overfishing of certain stocks. This increased the number of people at risk to hunger and malnutrition throughout developing countries where the calorie availability in 2050 is likely to have declined relative to 2000 levels (*FAO 2011b*). Climate change therefore has far-reaching implications for food availability, including the potential to undermine economic development initiatives, increasing poverty and jeopardizing the achievement of Millennium Development Goal 1 (eradicating extreme poverty and hunger).

Many countries in West Africa lack investment in market distribution systems for fisheries products. This is further constrained by a lack of institutional capacity to support such systems. Both of these impede marketability of fish from rural landing sites, and contribute to food insecurity for the people of both rural and urban areas (i.e., the fishing communities and their corresponding markets).

Accessibility

FAO (*2008a*) considers food accessibility as a measure of the ability to secure the set of resources (including legal, political, economic and social) that an individual sufficiently requires. From a fisheries perspective, climate change will affect food (fish) accessibility by impeding fish allocation and even restructuring different fishery livelihood strategies encountered by fishing communities. The number of active full time fishers may decrease following harsh weathers in the sea, seasonal opportunistic fishing activities (e.g. collective fishing) resulting to low catches.

In West Africa, intra-regional fish trade brings fish mainly from the northern portion of the region to the densely populated Gulf of Guinea (*INFOFISH 2008*). Climate change may distort the mechanisms through which fish are currently allocated. Fish trade routes such as Ghana to Togo and Benin for smoked sardinella (anchovy) and cured freshwater fish

species may be altered by damage to existing infrastructure. As noted by *FAO* (*2008a; 2010a*) climate change will also affect affordability by affecting income and also the ability of people to choose the fish they want to eat. When fish becomes scarce, prices go up and fish becomes inaccessible to a growing part of the population.

Utilization

Fish utilization is expected to be altered by changing supply quality and market chains disruptions (*FAO 2008a*). Climate change may cause new patterns of fish species, and emergence of pests and diseases posing new risks for food security, food safety and human health (*Schmidhuber & Tubiello 2007; Brown 2009*). This may lead to move to species that are not traditionally consumed. Flood-prone areas such as those around the Niger delta may experience increased incidence of diseases that could affect both food chain and people's capacity to catch fish. In general, less is known about the role of climate change on food utilization patterns.

Stability

Food system stability depends on availability of, and access to food. Climate change may result into persistent drought conditions in West Africa (as observed in areas around Lake Chad) and also the increased frequency of flooding. Climate variables such as droughts and floods are particular threats to food stability and are expected to become more frequent, more intense and less predictable as a consequence of climate change (*IPCC 2007*). Droughts in Africa and West Africa in particular can often lead to famine and widespread destruction of socio-economic well-being thus reducing the purchasing power to buy fish or any other food products.

CONCLUSION

The fisheries productivity of West Africa is highly vulnerable to projected impacts of climate change. The region is ill-prepared to safeguard the fisheries sector from these projections. Consequently, the traditional support provided by the fisheries such as food security is threatened if not in deterioration, and it is not well known whether the region would be able to meet its nutritional demands under the worst case scenario of climate change. It is important therefore that concerted efforts are taken from local to regional level to address adaptation to climate change. Fishers and fishing communities should be empowered to make them venture to other livelihood occupations and their fisheries should be climate-proofed.

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