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Chapter 4

IMPACTS OF CLIMATE CHANGE ON FISHERIES: IMPLICATIONS FOR FOOD SECURITY IN SUB-SAHARAN AFRICA

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ABSTRACT

This chapter seeks to examine the contribution of fisheries to poverty reduction and food security, and portray the potential impacts of climate change on the already strained resource in Sub-Saharan African (SSA) countries. Fish is a major source of food for the majority of poor and vulnerable communities in SSA. The sector also provides jobs to many men and women and is one of the most traded food commodities in the region. Fish trade supports economic growth in many developing countries in general and most SSA countries, in particular by providing an important source of cash revenue to service international debt, funding the operations of national governments, and importing food for domestic consumption, thus contributing to national food security and diversification of diets. However, the benefits gained from the sector are often overlooked in national economic planning. While the importance of fisheries to national economies is often understated, the impacts of climate change on the sector and its implications for the socio-economics of the coastal and riparian communities are difficult to ignore. This chapter provides a review of potential physical and biological impacts of climate change on fisheries by giving specific examples from SSA countries. In addition, the importance of fisheries to poverty reduction is demonstrated using empirical data from 42 SSA countries. It is clear that the higher the production level and per capita food supply from

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fishery products, the lower the prevalence of hunger. Nonetheless, the fisheries sector continues to lack sufficient attention by policy makers. This is mainly because well above half of the fish produced in SSA are supplied by small-scale or artisanal fisheries which are not accounted for in national statistics and thus their contribution to the economy and food security remains invisible. This chapter intends to uncover the invisibility of the sector and argues that fisheries should come at the forefront of the process of adaptation in policy formulation, and sufficient investments should be made to boost sustainable fish production in the region. It is recommended that increased and sustained investments in market development, fisheries governance and provision of economic incentive mechanisms are crucial in order to minimize the potential impacts of climate change on fisheries and food security and increase the resilience of many poor fisher communities in SSA.

Keywords: Climate change; fisheries, food security, Sub-Saharan Africa

1. INTRODUCTION

The underlying objective of this chapter is to highlight the contribution of fisheries to poverty reduction and food security and portray the potential impacts of climate change on this already strained resource. Climate change will exacerbate existing physical, ecological, and socioeconomic stresses on the African coastal zone (IPCC, 2007). It also poses significant and long-term risks to fisheries in many tropical developing countries in general and Sub-Saharan African (SSA) countries in particular. The benefits gained from the development of fisheries are significant. From local to global levels, fisheries and aquaculture play important roles in food supply, income generation and nutrition (Cochrane et al., 2009). Globally, some 43.5 million people work directly in the sector, with the great majority in developing countries. Adding those who work in associated processing, marketing, distribution and supply industries, the sector supports nearly 200 million livelihoods (Barange and Perry, 2010). In SSA, fisheries are a source of employment for around 10 million people and the main or only source of animal protein for 20 per cent of the population. Thus, the sector plays a significant role in boosting the availability of food, thereby tackling risks to food security in several agrarian and highly food-insecure countries in the region. For example, in Senegal the proportion of dietary protein coming from fish is as high as 75 per cent (Ndiaye, 2003), in Ghana per capita consumption of fish is 22 kg per year which is equivalent to 15 per cent of protein derived from fish (World Resource Institute, 2001), and in Sierra Leone fish supplies 63 per cent of the total animal protein consumed (Anon, 2004).

Fish is one of the most traded food commodities in the region. Fish trade supports economic growth processes by providing an important source of cash revenue to service international debt, funding the operations of national governments, and importing food for domestic consumption, thus contributing to national food security and diversification of diets. However, the benefits gained from the sector are often ignored or understated in national economic planning. This is mainly because well over half of the fish produced in SSA are from small-scale artisanal fisheries which are often not accounted for in national statistics and thus their contribution to the economy and food security remains invisible.

While the importance of fisheries is often understated, the implications of climate change for these sectors and for coastal and riparian communities in general are difficult to ignore

(Barange and Perry, 2010). Climate change poses significant threats to fisheries on top of many other concurrent pressures such as overfishing, habitat degradation, pollution, introduction of new species and so on (Brander, 2010). Globally, relative to the level that would support maximum sustainable yield, 20 per cent of targeted fishery resources are moderately exploited, 52 per cent are fully exploited with no further increases anticipated, 19 per cent are overexploited, 8 per cent are depleted and 1 per cent are recovering from previous depletion (FAO, 2009). Changes in biophysical characteristics of the aquatic environment and frequent occurrence of extreme events will have significant effects on the ecosystems that support fish. This will affect food security in multiple ways.

Firstly, extinction of some fish species means lower fish production for local consumption. Secondly, migration of many fish species to aquatic environments with optimal climatic condition will have a tremendous effect on fishers who are not able to follow fish due to political (borders) and economic reasons. Finally, since most of the fish harvested for export in many developing countries is supplied by small-scale fisheries this will lead to reduced fish production thus lower earnings from fish export, and consequently reduced capacity to import food and exacerbation of national food insecurity.

SSA is given special attention in this chapter because (1) the region is home to more than 300 million people who live under the poverty line and it is projected to be inhabited by half of the world's poor by 2050; (2) there is very limited literature on the potential impacts of climate change on fisheries in the region; (3) existing economic problems limit the capacity of the countries in the region to adapt to or insulate themselves from the impacts of climate change; and (4) most of the people who rely on fisheries for their livelihoods are poor,thereby contributing to the food security of countries. Nonetheless, as mentioned earlier, the sector continues to receive minor attention by policy makers. Thorpe et al. (2004) in their analysis of poverty reduction strategy papers produced by 29 SSAs found that the fisheries sector has been a significant motor of economic growth or likely poverty refuge, and yet the sector was effectively mainstreamed in only three national Poverty Reduction Strategy Papers (PRSPs) namely: Ghana, Guinea and Senegal. In addition, with increasing evidence of the impacts of climate change on aquatic ecosystems, the resultant impacts on food security and fisheries livelihoods are likely to be significant, but remain a neglected area in climate adaptation policies (Badjeck et al,. 2010).

2. Climate Change, Fisheries and Food Security Nexus

2.1. Overview of the Impact of Climate Change on Fisheries

Natural climatic fluctuations, particularly those at medium (decadal) scale, have always affected fisheries as well as their management performance (Garcia and Rosenberg, 2010). The atmosphere and the ocean will continue to warm over the next 50–100 years, sea level will rise due to thermal expansion of water and melting of glaciers, ocean pH will decline (become acidic) as more carbon dioxide is absorbed, and circulation patterns could change at local, regional and global scales (Bindoff et al., 2007 in Munday et al., 2008)

The major aquatic habitats in SSA include the Great Rift Lakes such as Lakes Malawi and Victoria; man-made reservoirs such as Lake Kariba; large river and floodplain systems such as the Nile and Zambezi Rivers; and coastal habitats including estuaries, mangrove swamps, and deltas (Hlohowskyjl et al., 1996). The diversity of the habitats and the species they support respond differently to different impacts of climate change.

Even though it is not possible to generalize the impacts of climate change on fisheries in SSA, they share something in common – climate change is very likely going to lead to fluctuations in fish stocks. Fluctuations in fish stocks will have major economic consequences for many vulnerable communities and national economies that heavily depend on fisheries (Brander, 2010).

The impacts of climate change on fish stocks in SSA can be classified as physical and biological changes. Physical changes include sea surface temperature rise, sea level rise, changes in salinity and ocean acidification. Biological changes include changes in primary production, and fish stock distribution. These factors when combined together will have adverse impacts on the already strained resource.

2.1.1. Physical Changes

2.1.1.1. Water Surface Temperature Rise

The oceans play a significant role in regulating global climate. Their heat capacity (and thus net heat uptake) is about 1000 times larger than that of the atmosphere (Barange and Perry, 2010) and they therefore absorb significant amount of heat emitted globally. Such changes in ocean temperatures can change the dynamics of aquatic environments of the region. Changes in ocean dynamics could lead to changes in migration patterns of fish and possibly reduce fish landings, especially in coastal fisheries (African Action, 2007).

For example, increased ocean temperature may affect upwelling along the Gulf of Guinea, which can make the ocean waters become unsuitable for fisheries, causing a reduction in and possible collapse of fishing activities (African Action, 2007 in Urama and Ozor, 2010). Inland waters are also equally vulnerable and could be impacted strongly by climate change (IPCC, 2007). The international Dialogue on Water and Climate (2004) noted that water stress will increase significantly in those regions that are already relatively dry, such as SSA. One of the stresses that inland waters of SSA are facing is increasing water surface temperature.

According to Christensen et al. (2007 in Barange and Perry, 2010) warming in Africa is very likely going to be larger than the global annual mean warming throughout the region and in all seasons, with drier subtropical regions warming more than the wetter tropics with a consequent decline in rainfall.

Rising water temperature also threatens biodiversity. Generally, fish have a thermal preference that optimizes physiological processes (Abowei, 2010). If water temperature rises above the maximum tolerable threshold of a species, then its existence is threatened. Urama and Ozor (2010) provide an example from the Lebialem Highlands in Cameroon where women have started to hunt for tadpoles and frogs because there are no fish in most of Bangwa Rivers.However, even the number of tadpoles and frogs have significantly declined (partly) due to the warming rivers that have increased the amount of predator fish in an area they have never inhabited before.

2.1.1.2. Sea Level Rise

Globally, sea level has already risen by 10 to 20 cm during the 20th century, largely due to thermal expansion, and by 2100 a global rise in sea level of between 9 cm and 88 cm has been predicted, based on the Intergovernmental Panel on Climate Change's full range of 35 climate projection scenarios (Church et al., 2001 in OECD, 2010). In coastal areas, sea level rise may alter the salinity of estuarine habitats, inundate wetlands, and reduce or eliminate the abundance of submerged vegetation, adversely affecting those species which rely on these coastal habitats for reproduction and recruitment (Hlohowskyjl et al., 1996). In addition, with high sea levels, sea ports, existing fishing facilities like jetties and fish storage centers built on the coastal fringes slightly above the mean high tide line will be subjected to more frequent tidal and storm inundation (Ibe and Awosika, 1991). Therefore, sea level rise is very likely going to have a negative impact on fishery production (due to salt stresses on the fish stock and its habitat) and fish landing, processing and marketing facilities.

There are very limited studies done to assess the impacts of sea level rise in the coastal zones of SSA. There is, however, some information on the impact of sea level rise in some of the most populous coastal cities in West and East Africa. For example, Nigeria's 800 kilometer low-lying coastline from Lagos to Calabar makes the region prone to seawater intrusion into coastal freshwater resources. This will have a negative impact on inland fisheries and aquaculture. The people in the coastal areas who used to depend on fishing have seen their livelihoods destroyed by the rising waters (Urama and Ozor, 2010). In another report by the UN-HABITAT (2008), a sea level rise in Abidjan is likely to swamp 562 square kilometers along the coastline of the region, as lowland marshes and lagoons dominate the coastal zone. The same report also predicts that Mombasa, in the East African coastal zone, could be submerged by a sea level rise of 0.3 meters, with a large area becoming uninhabitable and less productive due to salt stresses.

2.1.1.3. Increasing Water Salinity

Climate change can cause an increase or decrease in water salinity in multiple ways. While tropical oceans are increasingly becoming saltier, oceans closer to the poles have become fresher. This highlights that tropical oceans are very likely to suffer more from the potential impacts of increasing water salinity relative to waters in higher latitudes.

Changes in water salinity have different effects depending on the tolerance level of the organisms and the nature of their ecosystem – whether freshwater, marine or estuarine. The salinity of some freshwater ecosystems are predicted to increase as a result of anthropogenic climate change (IPCC, 2001). Such physical changes will negatively impact the population of both plankton and bigger prey fish species by affecting the organisms' ability to osmoregulate (Schallenberg et al., 2003).

Some empirical studies illustrate that change in salinity has a negative impact on zooplankton population, particularly in freshwater ecosystems. Schallenberg et al. (2003) depict that zooplankton communities of low-lying, coastal, tidal lake and wetlands are adversely affected by small increases in salinity levels. They further warn that such changes in zooplankton abundance may further disturb the ecological functioning of these valuable but vulnerable ecosystems. As is discussed in the subsequent section, changes in zooplankton populations or other planktonic primary and secondary producers disrupt the food chain, thus having a considerable negative impact on fishery.

Salinity is also considered one of the most important variables determining the survival of organisms in estuarine ecosystems; either by having a direct impact on the organisms or indirectly by destroying their habitat, including their breeding and nursery grounds (Marshall and Elliot, 1998 in Abowei, 2010). Blaber (1997) states that all estuarine fish are euryhaline (able to cope with salinity fluctuations), but their ability to do so varies from species to species and hence changes in salinity may influence their distribution. Even though salinity changes may not have a direct negative impact on estuarine fish species per se, it can have a negative impact on their habitat. For example, increase in water salinity has contributed to destruction of 60 per cent of mangrove areas in Senegal (IPCC, 2007). According to Parkins (2000), each acre of mangrove forest destroyed leads to an estimated 300 kg loss in marine harvest. Therefore, change in water salinity are going to have a tremendous negative impact on fishery in the region, threatening the livelihoods of many impoverished coastal communities.

2.1.1.4. Ocean Acidification

Oceans are believed to have the capacity to absorb most of the anthropogenic CO_2 emissions (Caldeira and Wickett, 2003). CO_2 is soluble in water and reversibly converts to carbonic acid. As a result of this chemical reaction, the world's oceans are acidifying at an alarming rate (Dupont and Thorndyke, 2009). While this has a positive impact in slowing down global warming, increased acidity as a result of dissolved CO_2 in seawater has negative a impact on ocean ecosystems. The impact to the ecosystem is difficult to estimate as different species at different stages of life history respond differently to different pH changes. According to Dupont and Thorndyke (2009), ocean acidification research is in its infancy and although the field is moving forward rapidly, good data is still scarce. Although the science base is still limited, there is a clear need to provide timely advice and a balanced perspective on the possible impacts on marine fisheries (Le Quesne and Pinnegar, 2011).

Quantifying the effects of ocean acidification on human communities requires assessing the direct and indirect chemical impacts on valuable marine ecosystem services such as fisheries (Cooley et al., 2011). According to Le Quesne and Pinnegar (2011), direct effects include changes in physiological processes such as reduced growth of calcified structures, otolith development, and fertilization success. These may ultimately lead to direct impacts at the whole-organism level, including reduced growth and reproductive output, increased predation and mortality, alteration in feeding rates and behavior, reduction in immunocompetence and reduced thermal tolerance. Indirect effects include alteration in predator or pray abundance, effects on biogenic habitats such as coral reefs, and changes in nutrient recycling. While adult fish seem well-equipped to deal with low pH waters, or higher levels of CO2 in seawater, their egg and larval life stages may not be so fortunate (Painting, 2011). For example, increased CO2 level in oceans can potentially narcotize male gametes indicating that acidification may impair fertilization, exacerbating problems of sperm limitation, with dire implications for marine life (Byrne et al., 2010). Ocean acidification could potentially slow the growth of plankton and invertebrates that are at the bottom of the food chain. Thus acidification can alter the productivity at certain trophic levels, thereby disrupting the complex food chain of aquatic ecosystems with effects on the productivity of fisheries. One of the very likely socio-economic impacts of ocean acidification in SSA is a decrease in populations of calcifying organisms such as mollusks. This may have tremendous socio-economic effects either by (1) lowering export earnings of net mollusk exporting nations; (2) reducing jobs for many fishers involved in mollusk farming and harvest; or (3) increasing mollusk prices which may exclude marginal consumers – further widening protein and wealth gaps between the rich and poor. A study done by Cooley et al. (2011) to assess the vulnerability of nations to ocean acidification-driven decreases in mollusc harvests, suggests that countries with low adaptability, high nutritional or economic dependence on mollusks, and rapidly growing populations will be most vulnerable. These are common characteristics of most SSA countries. Thus, the region is very likely to be more, if not the most, vulnerable to ocean acidification.

2.1.2. Biological Changes

Climate change is already affecting the trends of some important biological processes, resulting in changes in primary production (Taucher and Oschlies, 2011) and changes in fish distribution (Sumeila et al., 2011). Climate induced changes in primary production and fish-stock distribution have negative implication on food security in many tropical coastal states in general and SSA in particular.

2.1.2.1. Changes in Primary Production

The relationship between climate change and future ocean primary production is likely to be a key constraint on fish and fisheries production (Dulvy et al., 2010). Survival of fish larvae during the planktonic stage is thought to depend strongly on the availability of sufficient and suitable food. Therefore, in addition to effects of changes in production, climate induced changes in distribution and phenology of fish larvae and their prey can also affect recruitment and production of fish stocks (Brander, 2010). Even though there are some studies done to assess the impact of climate change on primary productivity of aquatic environments in high latitude waters, there is very limited study done in the tropics. One of the very few studies available is the case of Lake Tanganyika.

Lake Tanganyika has historically supported one of the world's most productive pelagic fisheries, which provided an annual harvest in recent years of between 165,000 and 200,000 metric tons, representing 25–40 per cent of animal protein supply for the populations of the surrounding countries (Molsa et al., 1999). A rise in surface-water temperature coupled with a regional decrease in wind velocity has increased the stability of the water column restricting mixing and deep-water nutrient upwelling and entertainment into surface waters (O’Reilly et al., 2003). This has led to a decrease in primary production by about 20 per cent over the past 80 years (Bates et al., 2008). According to O’Reilly et al. (2003), a 20 per cent reduction in primary productivity can be translated as a roughly 30 per cent decrease in fish yields. The decline in catch was accompanied by breakdown of the previously strong seasonal patterns in catch, suggesting decoupling from ecosystem processes driven by the weakening of hydrodynamic patterns. These changes in the pelagic fishery are consistent with a lake-wide shift in ecosystem functioning (Brander, 2010).

Even though there are multiple factors that affect primary production in aquatic environment, one of the main factors is surface temperature rise. O’Reilly et al. (2003) suggest that if air temperature increases by about 1.7 degrees, as predicted for the next 80 years, there will be further increases in thermal stability and reductions in productivity in these large lakes. They further warn that the human implications of such faint but progressive environmental changes are potentially dire in this region of the world, where large lakes are essential natural resources for regional economies.

2.1.2.2. Changes in Fish Distribution

Change in fish distribution is among the most commonly reported ecological responses of marine species (Sumaila et al., 2011). Fish species are believed to respond to environmental changes such as warming water temperatures by shifting their latitudinal and depth ranges. Changes in ocean dynamics could lead to changes in migration patterns of fish and possibly reduce fish landings, especially in coastal fisheries of many African countries (African Action, 2007 in Urama and Ozor, 2010). Marine fisheries are an important food source, and therefore, changes in the total amount or geographic distribution of fish available for catch could potentially affect food security (Cheung et al., 2009).

The effects of changes in fish-stock distribution vary across latitudes. Some fish species will migrate due north in search of habitats with optimal water temperature and thus potentially increasing fish harvest in higher latitudes. On the other hand, counties in lower latitudes such as SSA are very likely going to lose some fish species and stocks. Cheung et al. (2009) depict that changes in fish-stock distribution could range from a 30–70 per cent increase in high latitude regions to a drop of up to 40 per cent in the tropics. This poses a tremendous challenge to the predominantly artisanal fishers in SSA mainly because it is economically prohibitive to follow the fish-stock, i.e. restricted to economic exclusive zones. Therefore, according to OECD (2010), such changes in fish stock distribution will change the distribution of benefits and costs of fisheries with some winning and some (including fishers from Sub-Saharan African countries) losing.

2.2. Fisheries and Food Security in Sub-Saharan Africa

2.2.1. Food Security Defined

With a growing population and recurrent problems of hunger and malnutrition plaguing many communities in SSA, food security is of major societal and international concern (Garcia and Rosenberg, 2010). Food security is widely defined as “when all people at all times have access to sufficient, safe, and nutritious food to maintain a healthy and active life” (World Bank 1986; FAO, 1996). Such understanding of the concept of food security reflects the widely cited definition of what the terms signifies and what factors it constitutes to indicate the level of its achievement, or challenges faced thereof towards addressing the “in” in food insecurity (Webb and Rogers, 2003).

Identification and analysis of the indicators and measurements of food security can be at the national, regional, household or individual levels. The national level seeks to understand aggregate status of countries for classifying specific countries for external intervention and appraisal of international efforts towards addressing the problem.

Regional level analysis focuses on identifying discrepancies between and among the spatial distribution of scarcity and vulnerability for the purpose of central and regional governmental organizations, as well as aid agencies, to design policies and guidelines for targeting regions. Household food security analysis assumes the household provides the core reflections and patterns of food security status despite its potential weakness in disguising individual preferences and status. Individual level is the lowest unit of analysis that examines each individual’s idiosyncratic values and positions towards access, control and consumption of food within a household.

Table 1. Nutritional value of catfish (per 100 g)

Nutrient	Quantities	Unit
Protein	18.2	G
Iron	0.82	Mg
Calcium	9.0	Mg
Iodine	0.1	Mg
Potassium	321	Mg
Vitamin A	0.02	Mg
Vitamin B	2 0.1	Mg
Vitamin B6	0.2	Mg

Source: the US Department of Agriculture (2002).

2.2.2. Food Security and the Millennium Development Goals (MDG)

The first indicator of food security used in the MDG is the prevalence of underweight children below five years of age (UCBF). The percentage of underweight children refers to the weight of children between the age of zero and 59 months with less than two standard deviations below the median weight for age of a reference population. The standard for this reference population is found in the National Center for Health Statistics (NCHS) and the World Health Organization (WHO). Globally, South Asia accounts for 46 per cent of underweight children followed by SSA at 28 per cent (UNICEF, 2006). Underweight includes both stunting (height-for-age) and wasting (weight-for-height). Obviously the main cause of underweight children is deficiency in essential and non-essential proteins and vitamins. Fish has traditionally been used as the main supplement of vitamins and animal protein in many impoverished SSA countries. As can be seen from Table 1, fish contains a rich source of nutrients, the lack of which causes serious health deficiencies mainly in children. For example, it is estimated that vitamin A deficiency kills half a million children annually in Africa (World Fish Center, 2005: 2).

The second indicator is the proportion of a population below the minimum level of dietary energy consumption. Taking 2,350 Kcal as the commonly agreed calorie intake threshold, it is estimated that populations of more than 50 countries of the world fall below this standard, which accounts for food items including concentrated energy sources of fat and oil (Sacquet, 2005: 18). In 2006, populations of 30 countries had less than 2,200 Kcal access per day. High population growth, limited agricultural resource base and a history of hunger prevalence were singled out as major causes (FAO, 2006). The omission of fat and oil from the calculation puts the average minimum calorie intake at 2,100 Kcal (FAO/WHO, 1973). Despite the criticism of its failure to take into account the interpersonal differences of sex, age, daily activity, and physical size (see Ehrlich et al., 1983), the FAO estimate is a weighted average, which was clearly spelled out in the technical annex of The State of Food Insecurity in the World 2008.

De Onis *et al*. (2004) estimated that the prevalence of underweight children worldwide would fall by 31 per cent from 163.8 million in 1990 to 113.4 million in 2015 (with 95 per cent CI of -40 to -20). FAO (2006: 5) also estimated that the number of undernourished people would fall close to 700 million people by 2015.

While South Asian countries, such as Afghanistan, Bangladesh, India and Nepal, showed improved calorie intakes from the 1980s, and by 2015 are projected to be a little over 2,500

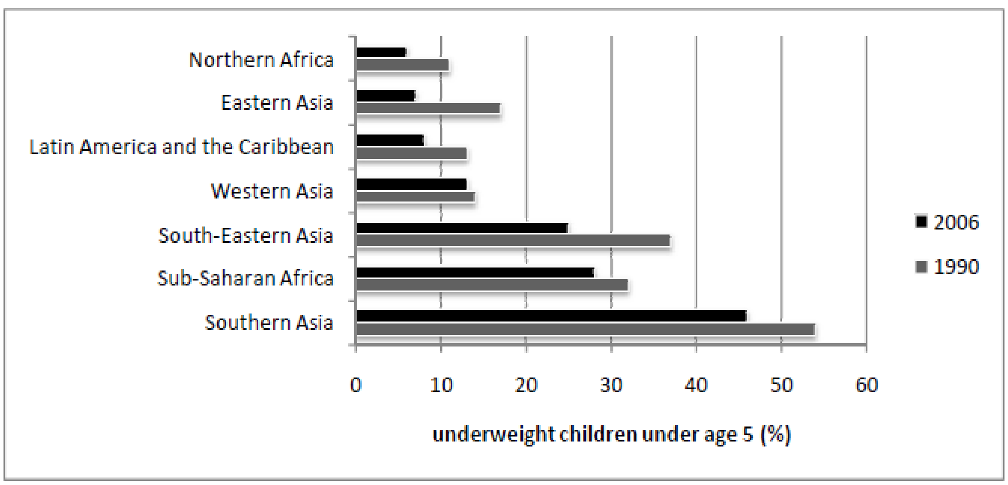
Kcal per day, SSA did not show any substantial changes for three decades, and the trend after 2001 is estimated to increase close to 2,400 Kcal per day. More than 33 per cent of the population in SSA, which is close to 200 million people, are undernourished (Kidane et al, 2006: xii).

Causes of food insecurity in most countries of SSA are, by and large, explained by: population growth and consequent pressures on resources; water scarcity and recurring drought (Hanjra et al., 2009); weak rural infrastructure and services; and poor governance structure (Uraguchi, 2012). These are very likely to be exacerbated by climate change.

Moreover, continued high food price spikes, due partly to reduced food production, and corresponding economic instabilities coupled with vulnerability to climate change, are expected to exacerbate the state of food insecurity in the coming years for many of the countries in SSA. With very low foreign currency reserves for importing food, the number of countries dependent on food aid is highest in SSA. Most of the food aid given to SSA countries is not properly-timed, which fails to cushion food problems, leading quite often to instability in prices and food availability. Therefore, in order for SSA countries to address food insecurity, they will need to boost their food production and tackle the potential impacts of climate change on their food production systems.

2.2.3. Fish Production and Poverty

Fishery resources are an important source of proteins, vitamins and micronutrients, particularly for many low-income populations in rural areas, and their sustainable use for future global food security has garnered significant public policy attention (Garcia and Rosenberg, 2010). The authors further argue that sustainable fisheries may contribute to poverty reduction through generation of revenues and wealth, operating as a socio-economic "lift" at community level and contributing to economic growth at national level. This sections attempts to demonstrate the link between total fish production and poverty in SSA countries.



Source: United Nations (2008). Development Goals Report.

Figure 1. Proportion of children under age five who are underweight, 1990 and 2006 (Percentage).

Data on fishery production totals from both aquaculture and capture fisheries for most SSA countries (for which data is available) was extracted from FAO FISHSTAT. Total for all species refers to the combined total of aquaculture and capture production of all aquatic plants, fish, mollusks, crustaceans, and other aquatic animals in inland and marine areas. The Global Hunger Index (GHI) is used as a proxy for poverty level. The index is calculated each year by the International Food Policy Research Institute (IFPRI) and is designed to comprehensively measure and track hunger globally and by country and region (IFPRI, 2011).

GHI combines three equally weighed indicators, namely: undernourishment, prevalence of underweighted children under the age of five and child mortality. According to IFPRI's GHI report (2011), such a multidimensional approach offers several advantages, it takes into account the nutritional situation of not only the population as a whole, but also of a physiologically vulnerable group – children – for whom a lack of nutrients creates a high risk of illness, poor physical and cognitive development, and death. The GHI ranks countries on a 100-point scale.

Less than or equal to 4.9 is considered low; 5.0 to 9.9 moderate; 10.0 to 19.9 serious; 20.0 to 29.9 alarming; and greater than 30 extremely alarming. GHI for 42 SSA African counties, for which data on the three components are available, is estimated.

Figure 2 shows that hunger index in SSA is negatively correlated with total aquaculture and capture fishery production. This can be translated as; the higher the fish production (in volume), the lower the prevalence of hunger and malnutrition. This signifies the importance of fisheries to poverty reduction. Nonetheless, the sector continues to lack sufficient attention by policy makers. This is mainly because well over half the fish produced in SSA is from small-scale artisanal fisheries which are not accounted for in national statistics and thus their contribution to the economy and food security remains invisible.

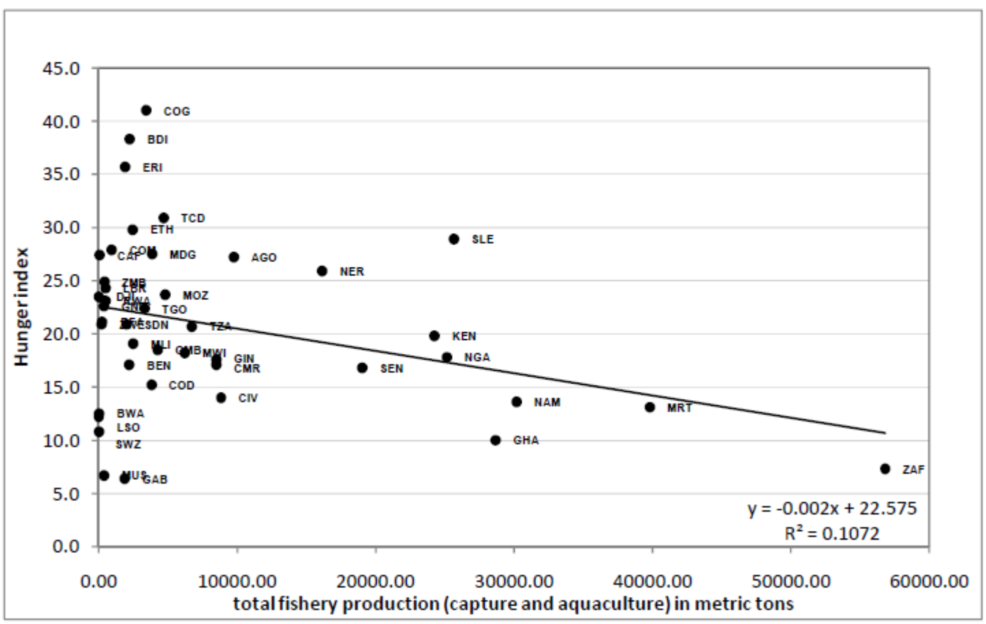


Figure 2. Total fish production and hunger index in sub-Saharan Africa.

Such correlation between fish production level and hunger index should highlight the importance of fisheries, and thus the sector should be placed at the forefront of adaptation policy formulation, and sufficient investments should be made to sustainably increase fish production in these regions.

2.2.4. Fish and Food Supply

A further attempt is made to examine whether food supply per capita from fish and fishery products contributed to poverty reduction. Annual food supply per capita from fish and fishery products is defined as the quantity of both freshwater and marine fish, seafood and derived products available, per person, for human consumption over the course of that year (FAO FISHSTAT, 2007).

FAO estimated this by taking a country's fish production plus imports of fish and fishery products, minus exports, minus the amount of fishery production destined to non-food uses (i.e., reduction to meal, etc.), and plus or minus variations in stocks, which is known as “apparent consumption” (Esteban and Crilly, 2011). The result is then divided by the total population of the country to estimate per capita food supply. Average values from the latest four years i.e. 1999 to 2001, were used.

The graph below shows a negative relationship between hunger index and annual food supply per capita from fish and fishery products.

As shown in Figure 3, countries with low annual food supply per capita from fish have hunger index values beyond “alarming” level. Such trends are very likely to continue and become exacerbated by climate change, unless drastic measures are taken to augment per capita food supply from fish. While per capita food supply from fish and fishery products is increasing in the developing world in general, it is declining in SSA (see Figure 4).

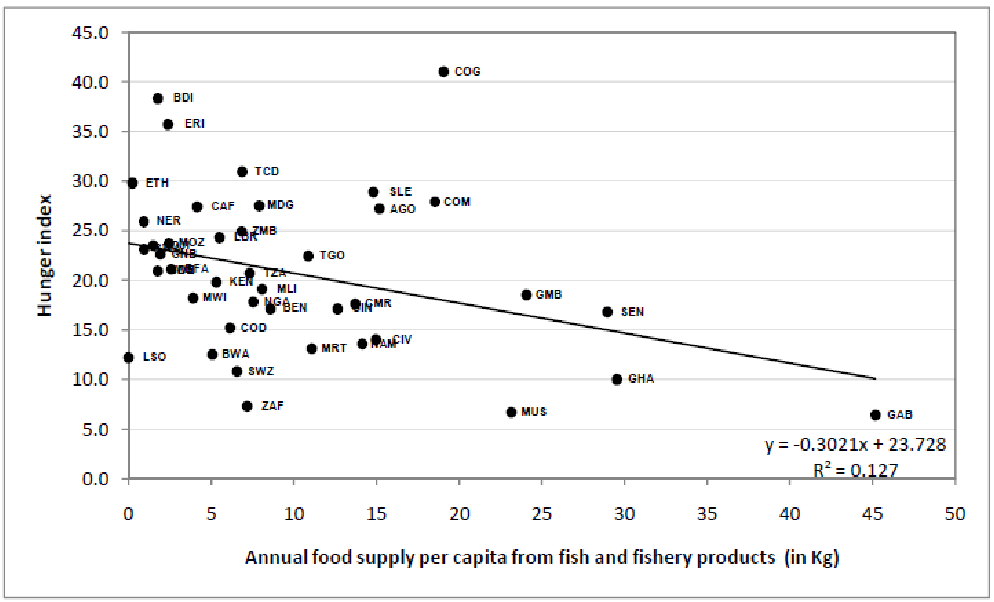
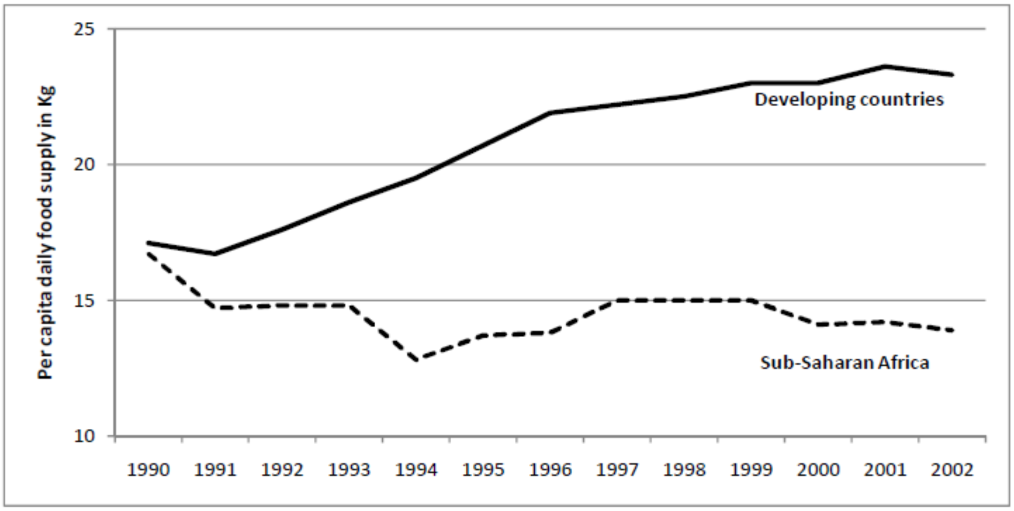


Figure 3. Annual food supply from fish and fishery products and hunger index.



Source: FAO FISHSTAT (2007).

Figure 4. Per capita food supply from fish and fishery products in Sub-Saharan Africa and developing countries.

Table 2. Impact of fisheries sector on hunger index (food insecurity) in sub Saharan Africa.

Variable	Coef (std. Err)
Production	-0.00017* (0.00008)
Pcfoodsupply	-1.134** (0.267)
Proteinsupply	1.789** (0.499)
Const	23.672** (15.14)
R^2	0.401

*,** Indicate that the parameter is significant at 0.05 and 0.01 level, respectively.

N = 42. Where: Production = total fishery production; pcfoodsupply = annual food supply per capita from fish and fishery products (kg); and proteinsupply = Protein supply from fish and fishery products as a per cent of total protein consumed.

In a further attempt to examine the potential impact of fisheries on hunger eradication or on tackling food insecurity in SSA, the hunger index was regressed against total fishery production, food supply per capita from fish and fishery products, and protein supply from fish and fishery products as a per cent of total protein consumed for 42 SSA countries.

The result shows that all explanatory variables significantly affect the hunger index in varying magnitude and direction. Fishery production level and per capita food supply from fish and fishery products affect the hunger index negatively. This means that the higher the production level and per capita food supply, the lower the hunger index and hence the lowerthe prevalence of hunger.

Astonishingly, it was found that the higher the protein supply from fish and fishery products (as a per cent of “total” protein consumed), the higher the prevalence of hunger and malnutrition. This could principally be due to the fact that, according to World Fish Center (2005), the share of protein intake can be extremely high (often more than 50 per cent) in the poorest countries especially where other sources of animal protein are scarce or expensive. Therefore, high share of protein supply from fish rhymes with poverty. While dietary diversification is needed, it is evident that higher catch level and per capita food supply from fish reduce hunger in the region. For example, a reduction in fish production by 10,000 metric tons (partly due to climate change) in Ghana would increase the prevalence of hunger and food insecurity from *moderate* to *serious* level. In Kenya the same reduction in catch level could drive Kenya and Ethiopia from the current serious level to *alarming* and *extremely alarming* respectively. Thus, a potential impact of climate change and consequent reduction in food supply from fish could exacerbate food insecurity in the regionregion, which already suffers from non-climatic stresses such as overfishing and habitat degradation.

3. The Way Ahead: Investments to Climate-Proof Fisheries

Fisheries conservation in light of climate change means (1) reducing stress on the already strained fishery resources, (2) allowing fish species to adapt and settle successfully, and (3) enhancing the adaptive capacity and resilience of fisher communities.

Climate change impacts on fisheries could potentially affect the four dimensions of food security; *availability* of aquatic foods will vary due to changes in habitats, stocks and species distribution; *stability* of supply will be impacted by changes in seasonality, increased variance in ecosystem productivity and increased supply variability and risks; *access* to aquatic foods will be affected by changes in livelihoods and capture or farming opportunities; and *utilization* of aquatic products will be impacted, for example, some societies and communities will need to adjust to species not traditionally consumed (Barrange and Perry, 2010).

To minimize the potential impacts of climate change on fisheries and food security and increase the resilience of many poor fisher communities in SSA, increased and sustained investments in market development, fisheries governance and provision of economic incentive mechanisms are crucial.

3.1. Market Development

Market development through private sector engagement and development is one of the strategic policy interventions that most SSA countries should design and implement, and further integrate into national economic planning frameworks. Over 60 per cent of the fish supply in SSA both to domestic and international markets comes from artisanal fisheries (FAO, 2009); in some countries it can be as high as 90 per cent. This is expected to shore up the potential of fisheries as a contribution to the well-being of communities and households (in production, income and consumption) involved in the sector and to the growth of local economic development. Two strategic issues can be identified as core areas of interventions.

3.1.1. Investments to Support Sustainable **Artisanal Fisheries** *Businesses*

Small-scale fisheries or *artisanal fisheries* businesses in most SSA countries are quite dynamic. They have the potential for sustainable investment. For fishers, there is good potential to sell their products at good prices at local, regional and national levels, whilst maintaining improved mechanisms of fish production that address over-investments in fishing and excessive water uses and environmental degradation. Mechanisms also need to be suitable to *lower running costs and fuel consumption, adopt less expensive technology, and have lower ecological impact, with greater potential for higher employment opportunities.*

However, these opportunities are rarely tapped. Accessing potential and higher markets - and accordingly better price - remains an obstacle for various reasons. The producers more often sell their products to middlemen, at landing sites. The low prices they then get do not enable them to invest in quality business which are viable in the long term. The fishers are not well organized so they do not buy inputs in bulk or sell products collectively, which would otherwise reduce production costs and increase sale prices. The organization between small-scale fisheries and other private sector organizations is almost nonexistent, leading to a weak competitive position for them.

Small-scale fishers also have problems accessing loans, amounts are often not high enough and repayment schedules not adapted to the cash flow of the business. A number of small-scale businesses have to start with small loans, sincegood credit-worthiness or collateral is a condition to access bigger loans. As a consequence, they subsist with their own minuscule savings. In addition, the repayment schedules are often not adapted to the cash flow of the business: repayments are weekly but the income of most of these businesses is seasonal. Seasonal loans are not available in many of the countries and the amounts provided are only small, as the risk for lenders is higher. In most of the countries, the typical problem of the "missing middle" can be observed.

Artisanal fisheries also lack access to low cost fishing technologies appropriate for the various commercial species, *and the skill to use them. Adopting low cost technologies, for example, includes modernizing* fishing techniques and operations through better fishing boats, fishing gear and post-harvest technology. At a higher level, competitiveness and income can be increased through introduction of fish processing technologies, which increase the value of products. *All these require efficient extension* services, which provide: advice and research, regulatory and quality ensuring standards, business development, and information and training, in order to transform subsistence fishing into activities capable of generating significant economic opportunities.

3.1.2. Market Infrastructure to Address Post-Harvest and Income Losses

An assessment of post-harvest loss among artisanal fisheries shows three types of losses. First, the physical loss is related to fish that are disposed or thrown away. Second, quality loss is associated with change or physical damage due to lack of proper handling leading to a decline in the value of fish. Third, market loss is caused by sudden market changes which force fish operators to sell their catch at lower prices (Ward and Jeffries 2000).

For most of the artisanal fisheries in SSA, supplying fresh fish fetches more income than cured fish (dried fish). Supplying large quantities of fresh fish, however, requires infrastructure for establishing marketing space, insulated storage facilities, availability of ice and refrigeration, well-functioning transportation facilities, access from landing sites to main roads, potable water supply wells, pumps, and fish reception and cleaning. It is estimated that post-harvest losses in SSA countries are between 20 and 25 per cent (Ames, 1992; FAO, 1998).

Consequently, the condition of onshore fish handling by small-scale fisheries is poor and disorganized, often using archaic and time-consuming methods, such as scooping fish out of the boats with buckets and other locally made materials. This is unhygienic due to contamination, exacerbated by the large quantities of fish left in poorly constructed sheds for open market auctions. With high temperatures, the quality of fish delivered to the market deteriorates and thereby constrains artisanal fisheries as a good source of revenue and quality products. Fish contains high unsaturated fatty acid and extended periods of exposure to outside conditions increases the likelihood of free radical oxidation. Traditional methods of fish preservation, using salting, sub-drying and smoking contribute to post-harvest losses due to bacterial breakdown, color change, mould and insect infestation, and pilferage by birds and animals.

3.2. Governance Structure

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 event such thinking into management models (Clark, 2006), and mainstream fisheries governance into adaptation policies. Fisheries governance develops policy instruments and regulatory measures, and links government with stakeholders, including communities, civil societies and the private sector, to manage fisheries resources effectively. It is crucial in determining whether or not the potential negative impacts of climate change on fisheries can be mitigated and whether the sector will continue to provide economic, livelihood and food security benefits. Pinstrup-Andersen and Pandye-Lorch (1998) argue that governments should facilitate food security for all households and individuals, not by physically delivering the needed food to all citizens but by facilitating a social and economic environment that provides all citizens with the opportunity to ensure their own food security. The same argument can be made with regard to enhancing the resilience of communities to cope with and adapt to the impacts of climate change and promote both economic and ecological sustainability of fisheries resources.

Adaptation is a dynamic social process where the ability of societies to adapt is determined, in part, by the ability to act collectively (Adger, 2003). In aquatic environment, co-management or co-operative management - where a range of stakeholders share responsibility for decision-making and management of marine resources - can promote building of resilience of local communities to climate change (Hoshino et al. 2011). Therefore, governments must make investments to strengthen and utilize the social capital of fisher communities, which is the primary asset of the poor. This could create conditions that enable fishers to participate in adaptation policy formulation and effectively manage their resources through active participation in implementing and monitoring regulatory measures that are aimed at improving their livelihood.

As discussed in the previous section, heavy reliance on fisheries for animal protein tend to characterize communities with poverty and malnutrition. Therefore, efforts must be made to diversify the sources of livelihoods of fisher communities and reduce their dependence on the sector. Such efforts will reduce the vulnerability of communities to unprecedented climate change impacts in the future. This can be done through increased and sustained investment by government in SSA countries to foment co-management of fisheries and provision of economic incentives to communities to relax stress on the resource.

3.3. Economic Incentive Mechanisms

Many have argued for the provision of economic incentives, primarily as a practical means to internalize environmental costs where the effectiveness of regulatory measures has been deficient (Begossi et al., 2011). Economic incentive mechanisms, widely known as payments for ecosystem services (PES), reward resource users for improved natural resource use practices or compensate for the benefits forgone from complying with certain natural resource use regimes. The scheme has been employed in several terrestrial ecosystems, primarily in forest ecosystem services. Recently, attempts are being made to apply the same approach to marine and coastal ecosystems. Some existing examples include the "*defeso*" scheme in southeast Brazil where communities are compensated for loss of income during off season (spawning or reproductive period) and creation of marine protected areas (Begossi et al, 2011); and the community development fund which protects grey whale habitat in Laguna San Ignacio,Mexico; or the provision of alternative livelihoods and creation of no-take areas in Kubulan in Fiji (Niesten and Gjertsen, 2010). There are, however, very limited examples of such mechanism in SSA countries.

Unlike terrestrial ecosystems, the application of incentive mechanisms in aquatic ecosystems can be very challenging. Aquatic resources and ecosystems are mobile and ownership or property rights of aquatic environments are often (if not always) ill-defined and unrecognized, which makes implementation, monitoring and enforcement very challenging. Nonetheless, these mechanisms can play a significant role in incentivizing fisher communities to co-manage and restore their fisheries resources by helping them diversify their means of livelihood and providing better community services such as development of post-harvest technology and value addition.

Co-management at the community level refers to the involvement of fishers in management of their fisheries to improve their livelihoods. However, according to Sunde and Isaacs (2008), experiences so far indicate that existing co-management arrangements have primarily focused on conservation and management of fish resources, rather than on using them to facilitate economic development in fishing communities, or as an instrument for poverty alleviation. As a result, the effectiveness of co-management approach to fisheries has been faulty in several places. Economic incentives provided to fisher communities could solve the problem. Economic incentives could compensate fisher communities for the short-term loss of benefits from limited fishing activities. This, in addition to incentivizing communities to conserve their fisheries resources, could deliver livelihood benefits too; and thus address the problems of food insecurity.

CONCLUSION

Fisheries are a major source of food for the majority of poor and vulnerable communities in Sub-Saharan African countries. The sector also provides jobs to many men and women and is one of the most traded food commodities in the region. Fish trade supports economic growth processes in developing countries in general and SSA countries in particular, by providing an important source of cash revenue to service international debt, funding the operations of national governments, and importing food for domestic consumption, thus contributing to national food security and diversification of diets.

However, climate change poses a significant threat to fisheries in the region. The potential impacts of climate change on fisheries are categorized as physical and biological changes: physical changes include water surface temperature rise, sea level rise, increasing water salinity and ocean acidification; biological changes include changes in primary production and changes in fish stock distribution. Such changes could lead to disruptions in the food chains of aquatic flora and fauna, habitat destruction, depletion in food stock and prey-predator composition, destruction of coastal fish landing, and risk to processing and marketing sites. These negative effects when combined together are going to have adverse impacts on the already strained resource, thereby reducing fish production. Depletion of fish-stock and reduction in fish production could threaten the livelihoods of many vulnerable fisher communities and the food security of many countries in the region.

Nonetheless, the benefits gained from the sector are often ignored and continue to lack sufficient attention by decision makers in both adaptation to climate change and food security policy formulation. This is mainly because over half of the fish produced in SSA are from small-scale or artisanal fisheries which are not accounted for in national statistics and thus their contribution to the economy and food security remains invisible.

In an empirical analysis of data from 42 SSA countries, the importance of fisheries to poverty reduction is demonstrated. The data analysis indicates that hunger index is negatively correlated with total aquaculture and capture fishery production. In addition, a regression of hunger index against total fishery production, food supply per capita from fish and fishery products, and protein supply from fish and fishery products as a per cent of total protein consumed shows that all explanatory variables significantly affect hunger index in varying magnitude and direction. Fishery production level and per capita food supply from fish and fishery products affect hunger index negatively. This means that the higher the production level and per capita food supply from fish, the lower the prevalence of hunger and malnutrition. For example, a reduction in fish production by 10,000 metric tons partly or mainly due to climate change in Ghana would raise the prevalence of hunger and food insecurity from *moderate* to *serious* level. In Kenya, the same reduction in catch level could drive the country from the current *serious* level to *alarming*; according to IFPRI’s categorization of the prevalence of hunger and malnutrition global hunger index (GHI). It was also found that very high dependence on fish for animal protein is positively related to the prevalence of hunger and malnutrition. This could principally be due to the fact that the share of protein intake from fish can be extremely high (often more than 50 per cent) in the poorest countries especially where other sources of animal protein are scarce or expensive. Therefore, while dietary diversification is needed, it is evident that higher catch level and per capita food supply from fish can reduce hunger in the region.

Therefore, it is argued that fisheries should come at the forefront of the process of adaptative policy formulation, and sufficient investments should be made to boost sustainable fish production in Sub-Saharan African countries. It is also recommended that in order to minimize the potential impacts of climate change on fisheries and food security, and to increase the resilience of many poor fisher communities in SSA, increased and sustained investments are needed in: *market development* through investments that support sustainable artisanal fisheries businesses and market infrastructure, in order to address post-harvest and income losses; and *fisheries governance* to provide economic incentive mechanisms. Such investments combined together would strengthen the resilience and adaptive capacities of many poor and vulnerable communities and nations, and enhance food security.

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