Climate change impacts on fisheries production in Land-water interface

Yemi Akegbejo-Samsons
University of Agriculture
Dept of Aquaculture & Fisheries Mgt,
Abeokuta, Nigeria

Abstract

It has been considered that the impacts of climate change are likely to be considerable in tropical regions. Developing countries are generally considered more vulnerable to the effects of climate change than more developed countries. This has been attributed to a low capacity to adapt in the developing countries.

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

Introduction

Climate change is environmental change, but given that human societies are affected directly and indirectly by the climate system – and given that human activities are driving climate change – it is fundamentally a human problem. Climate change cuts across boundaries. The impacts of climate change are expected to seriously (and disproportionately) affect the livelihoods, health, and educational opportunities of people living in poverty, as well as their chances of survival, both locally in specific areas and globally in general.

As a global environmental challenge, the drivers of which are inextricably linked with high-consumption lifestyles, climate change lies firmly outside the sphere of influence of poor communities and poor countries, which have little say in how the challenge will be addressed. Those with special burdens and/or vulnerabilities such as women, ethnic minorities, and people living with HIV/AIDS are feeling yet another pressure in global warming – one that is fundamentally unjust. The impacts of climate change will affect everyone; some have calculated that the costs associated with overcoming climate impacts could even exceed global economic output within a few generations.

The general scenario

The UN's Intergovernmental Panel on Climate Change (the IPCC - a high-level, independent, scientific advisory body) developed a scenario for 2080 that predicts the following types of impacts, assuming there is no action to limit greenhouse-gas emissions:

(a) Sea levels could increase by 50cm – Almost twice as many people as now would be exposed to severe flooding from storm surges - 18 million people. The majority of people who would be affected live along the coasts of South and South East Asia

(b) Water availability could decline – Over three billion people in the Middle East and the Indian sub-continent could be facing acute shortages of water;

(c) Seasonal rainfall patterns could be severely disrupted – Drought and floods could increase, but the most damaging shifts would likely be relatively small changes in rainfall which, cumulatively, could dramatically decrease global crop yields; areas such as sub-Saharan Africa, South East Asia, and tropical areas of Latin America could face major food shortages

(d) The frequency and intensity of extreme-weather events could increase – Leading to loss of life, injury, mass population dislocations, and economic devastation of poor countries.

(e) Human health could suffer from a combination of effects – People's resistance to disease could be weakened by heat stress, water shortages, and malnutrition. Increases in air pollution could lead to a rise in respiratory illnesses. In these conditions infectious diseases such as malaria, dengue fever, and schistosomiasis could proliferate rapidly.

(f) No one will be immune, but climate change will have a disproportionate effect on the lives of people living in poverty in developing countries.

(g) Between 1990 and 1998, 94 per cent of the world's 568 major natural disasters, and more than 97 per cent of all natural disaster-related deaths, were in developing countries. Most eke out a precarious economic existence - subsistence farming or fishing - and have no savings or assets to insure them against external shocks

(h) They lack sanitation and their limited access to clean water, poor diet, and inadequate health-care provision undermine their resistance to infectious diseases

(i) Their lack of social status and the informal nature or remoteness of their settlements means that they do not receive adequate warnings of impending disasters

Climate change and the fisheries sector

The majority of the world's 200 million full and part-time fisherfolk (fishers, fish processors, traders and ancillary workers) and their dependents live in areas vulnerable to human-induced climate change, or depend for a major part of their livelihood on resources whose distribution and productivity are known to be influenced by climate variation. However, relationships between the biophysical impacts of climate change and the livelihood vulnerability of poor fishing communities have seldom been investigated. Information has been lacking on the areas and people that are likely to be most vulnerable to climate-induced changes in the fisheries. This information is required for the effective prioritisation of development interventions to reduce vulnerability to the impacts of adverse climate change on fisherfolk living in poverty. The fisheries sector makes important contributions to local development in coastal, lakeshore, floodplain and riparian areas, through employment and multiplier effects. Maintaining or enhancing the benefits of fisheries in the context of a changing climate regime is an important development challenge.

Pathways of impact of climate change on fisheries

Climate change will impact on fisheries through a diversity of direct and indirect pathways whose importance will vary depending on the type of ecosystem and fishery. Inland fisheries, particularly important for small-scale fishers in developing countries and an integral part of many rural

livelihood systems will be severely impacted by changing water levels and flooding events, while coastal marine fisheries dependent on sensitive ecosystems such as coral reefs will be impacted by rising water temperature that affects ecosystem functions (Allison et al, 2005).
Some of the pathways identified in the report of Allison et al, 2005 are impacts of:
(i) Sea temperature change on aquatic ecology: shifting range of fish species, change in ocean currents affecting upwelling zone fisheries, coral bleaching affecting reef fisheries, disruption to fish reproductive patterns and migratory routes;
(ii) Precipitation and evapotranspiration change on hydrology of inland waters: river flows and flood timing and extent change, affecting fish reproduction, growth and mortality, as well as other elements of wetland-based livelihoods (agriculture, pastoralism, forestry etc);
(iii) Increased frequency of extreme events: more frequent loss of fishing days due to bad weather, increasing loss of nets, traps and long lines, damage to boats and shore facilities, increased loss of life among fishermen, increase damage to coastal communities – houses, farmland etc.

Climate change and the marine environment

Climate change impacts on the marine environment and on its living resources and ecosystems are issues that require sound and unbiased research, and translation of research results into advice for policymakers and information for the general public. While some of these impacts have been identified and monitored, many questions remain about how marine (ocean) processes will change in the future and what effects these changes may have on the ocean environment. Impacts on the various land-water interface on freshwater (rivers, lakes) and marine environment will be discussed in details in the preceding units.

It has been much published that the possible impact of climate change on fisheries will be through a diversity of direct and indirect pathways with varying importance depending on the type of ecosystem and fishery. Inland fisheries, particularly important for small-scale fishers in developing countries and an integral part of many rural livelihood systems will be severely impacted by changing water levels and flooding events, while coastal marine fisheries dependent on sensitive ecosystems such as coral reefs will be impacted by rising water temperature that affects ecosystem functions.

Impacts on freshwater (land-water) fisheries and aquaculture

(a) Higher inland water temperatures

Higher inland water temperature will impact on fish stocks in diverse ways. Increased stratification of water in lakes will lead to reduction in productivity and reduction in fish population. This phenomenon could possibly enhance fish stocks for capture fisheries or else there will be reduced growth where the food supply does not increase sufficiently in line with temperature. Where the fish species experience raised metabolic changes, potential productivity will be affected. The diversity of insects in a river has often been used as an indicator of overall ecosystem health because they are critical in the food chain. A reduction in their abundance could have a serious knock-on effect for species such as fish, which rely on these insects as a food source. Most of the species and communities in rivers have a limited range of temperature tolerance. An increase of 2-3 degrees Celsius in temperature, along with changes in flow, could see some species, such as larval insects like stoneflies or mayflies, change distribution, decline in population or even become extinct by the 2080's. Fish, including shellfish, respond directly to climate fluctuations, as well as to changes in their biological environment (predators, prey, species interactions, disease) and fishing pressures.

Although this multi-forcing sometimes makes it difficult to establish unequivocal linkages between changes in the physical environment and the responses of fish or shellfish stocks, some effects are clear. These effects include changes in the growth and reproduction of individual fish, as well as the distribution and abundance of fish populations. In terms of abundance, the influence occurs principally through effects on recruitment (how many young survive long enough to potentially enter the fishery) but in some cases may be related to direct mortality of adult fish. All species are adapted for life over a relatively moderate range of temperatures compared with the extremes experienced form the poles to the tropics. Temperatures below the optimal range slow the rate of metabolism and, if too low, can become lethal. Temperatures above the optimal range increase metabolism and, because warmer water contains less dissolved oxygen, a thermal threshold is reached where respiratory demand exceeds the capacity for oxygen uptake, sometimes referred to as the “temperature-oxygen squeeze” (Portner and Knust 2007). Hence, temperature is one of the primary environmental factors that determine the geographic range of a species. Minimum winter temperatures often determine the high-latitude boundary (the northern boundary in the northern hemisphere) while summer maximums determine the low-latitude limit of a species. Even within the normal range of a species, the dynamics of populations often show strong correlations with temperature trends (Conover, 2007).

(b) Changes in precipitation

Changes in precipitation quantity, location and timing that alter water availability will collective alter abundance and composition of wild stock, and impact on seed availability for recruitment. Changes in lake water level will alter spawning and recruitment of endemic fish species. Lower water level will lead to low water quality due to reduced productivity capacity of photosynthetic balance. Fish often seek optimal temperature or salinity regimes or avoid suboptimal conditions. Thus, ocean and freshwater changes as a result of projected climate changes can lead to distributional changes. In suboptimal conditions, performance is reduced, leading to starvation or increased predation. The biology and ecology of fish in large rivers are strongly linked to the hydrological regime in the main channel and the regular flooding of their adjacent floodplains. The absolute and relative abundance and biomass of species of fish inhabiting large rivers are predicted to change in response to both natural intra-annual variations in flooding regimes as well as long-term climatic shifts. Changes in precipitation averages and potential increases in seasonal and annual variability and extremes are likely to be the most significant drivers of change in inland aquaculture and fisheries. While a relationship exists between greater flooding extent and higher production in capture fisheries, potential benefits may be offset by a range of factors including reduced success of pelagic river spawners arising from higher river flows, reduced fish survival in lower dry season flows, and loss of habitat to new hydraulic engineering projects and other human responses. Damage to other livelihood and food production resources may also occur. In many African lakes, water level determines stock fluctuations more than any other factor. This is especially true of lakes that periodically go completely dry, such as Mweru Wa Ntipa, Chilwa/Chiuta and Liambezi. In Lake Mweru and Lake Turkana, for example, catch rates decline when the lake level is low (World Fishcentre, 2007). Understanding how fisherfolks have adapted to variability through, for example, mixed livelihood strategies and the absence of barriers to entering fisheries, and how fisheries interact with other economic sectors may usefully guide responses to future climate variation and trends. Flexible management is the key to ensuring benefits flow from an unstable and uncertain resource. Reduced annual rainfall, dry season rainfall, and growing season length are likely to have implications for aquaculture and create greater potential for conflict with other agricultural, industrial and domestic users in water-scarce areas (World Fishcentre, 2007)

Impacts on land-water interface on Lakes

Over 90 per cent of lakes in the developing countries harbour important fisheries that contribute to employment, food security, government tax revenues, domestic markets and exports. The production systems of these lakes are known to be climate-sensitive. Livelihoods around these lakes combine farming and fishing, and with both negatively affected by rainfall reduction, if regional climate forecasts are accurate, it seems likely that rural livelihoods in lakeshore regions will become more precarious and less viable over time. Migration from lake to lake, and from lakeshore regions to cities and other areas of economic opportunity is already common in the region.

For the extensive shallow lake-wetland complexes such as Lakes Chad, Kyoga and Chilwa, analyses of links between rainfall variation, lake levels and fish catches indicate that predicted reductions in rainfall in some regions are likely to result in significant reduction of lake and wetland area, with resulting large reductions in fish production and supply, particularly in the case of wetlands in arid and semi-arid areas. With the resilience of these production systems partly dependent on the existence of dry season refugia for fish, increasing duration of the dry seasons and increased number of drought years, forecast in some regional climate models, is likely to result in reduced resilience of these lakes and increased pressure on dry season refugia (Allison *et al*, 2005).

Impacts on coastal (land-water) fisheries

Coastal and marine ecosystems are intimately linked to climate. Thus, climate change will exacerbate the problems already occurring in these vulnerable ecosystems due to increasing coastal populations, habitat loss, nutrient pollution and invasive species. Climate induced environmental changes on estuarine and marine ecosystems include: Temperature changes that alter ecological processes and species interactions; Increase in frequency of extreme ocean warming events, with implications for coral reef bleaching; changes in precipitation that alter freshwater run-off of nutrients, sediment, and contaminants; accelerated rates of sea level rise; alteration of oceanic wind and water circulation patterns; continued losses of sea ice over large areas of the Arctic basin; ocean acidification caused by reaction of increasing CO2 with seawater (NCCOS,2007).

(a) Sea level Rise and Coastal erosion

The IPCC Fourth Assessment Report (2007) reports that global sea level is expected to rise between 18 and 59 cm by the end of this century, not accounting for changes in ice flows in Antarctica and Greenland, which could boost that figure. Local rates of sea level change depend not only on the overall global warming and ice melt, but on regional changes in ocean and wind circulation patterns. With strong growth in coastal populations worldwide, sea level rise has strong and direct impacts on low-lying areas through increased coastal flooding and erosion, contamination of groundwater supplies, and increased vulnerability to storm surges. Sea level rise will lead to reduced area available for mariculture and aquaculture. Changes to estuaries' ecosystems, salt water infusion have the tendency to influence shift in species abundance, distribution and composition of fish stocks. In some coastal areas, damage to freshwater capture fisheries and reduced freshwater availability for aquaculture and a shift to brackish water species could be negatively predicted. Loss of coastal forest ecosystem will alter the ecosystem balance between the riparian and freshwater interaction.

(b) Impacts of Extreme events and worsening risk

Extreme events such as cyclones and their associated storm surges and inland flooding can wreak sudden and severe havoc on fisheries, and particularly on aquaculture, through damage or loss of stock, facilities and infrastructure. Institutional responses such as constructing artificial flood defenses and maintaining natural ones can provide protection that is significant but incomplete. (ICLARM, 2006). Poor communities in exposed areas are unlikely to be able to build substantial defenses, so the most realistic and economic strategy will be to roll with the punches. In countries where floods are common, short culture periods and minimal capital investment in aquaculture help reduce stock loss and its cost. Building greater adaptive capacity will entail considering means, such as mixed livelihood strategies and access to credit, by which aquaculturists can cope financially with sudden losses of investment and income. Other considerations for coping strategies in high-risk areas include monitoring and assessing risk and promoting aquaculture species, fish strains, and techniques that maximize production and profit during successful cycles.

Impacts on Coral reefs

Coral reefs are a major source of ecosystem goods and services, particularly for small island developing states. Tens of millions of people in over 100 countries are likely to depend on coral reefs for part of their livelihood or for part of their protein intake. Thermal bleaching along with fisheries exploitation, pollution and disease are the greatest threats to coral reefs. The indirect effects of acidification on fisheries will include loss of reef habitat constructed by marine calcifiers. Many fishes depend on the physical structure provided by coral skeletons or shell-building organisms such as oyster reefs as essential habitat for one or more life stages. In addition, food web alterations will likely affect harvested species through bottom-up effects on the food chain resulting from pH-induced shifts in the plankton community.

Fisheries and ecosystem impacts

Marine organisms will be influenced by changes in circulation, ventilation, and stratification through changes in temperature, light, and nutrient supply. Alterations of any of these drivers may lead to changes in species abundance and composition, possibly leading to large-scale regime shifts and species migrations. Such changes will affect marine organisms higher up on the food chain in ways that are not yet fully understood. Naturally-occurring climate phenomena, such as ENSO and NAO, have significant impacts on marine ecosystems and fisheries, but these links remain poorly understood. Habitat loss, resulting from sea level rise and invasion by non-native species will also perturb marine ecosystems, including marine mammals and sea birds, affecting the health and biodiversity of marine ecosystems. What are the main drivers and impacts of climate variability on marine ecosystems? How can we improve understanding and predictability of impacts on ecosystems of natural climate phenomena such as El Nino and NAO? Can we define "acceptable" levels of change and critical breaking points for climate effects on marine ecosystems?

Implications for management

Resource managers need to recognize that local populations of species near the limits of their distributional ranges will need additional precautionary measures to protect them from extinction. Warming and acidification represent additional stresses that make populations less resilient to the effects of harvest. We may need to reduce harvest of some species in certain areas to enable them to withstand the additional stress. Transitional regions are where the impact of climate change will first be evident. These regions are also conduits for species exchange. The certainty of climate change and its potential impacts on ocean ecosystems underscore the need for a comprehensive ocean observation system. Our ability to unravel the causes and consequences of ecosystem change is directly dependent on the availability of a continuous time series of many different kinds of environmental data. Gradual trends in highly variable environmental parameters like temperature, oxygen, salinity, pH, chlorophyll, wind, circulation patterns, and others become evident only after many years.

Fish food production and climate change in Africa

Over the years, different views and discussions have shown that there is considerable uncertainty about the physical changes and response of the various freshwater and marine species; however, it is possible to suggest how certain species may respond to projected climate changes over the next 50-100 years. The uncertainties highlight the importance of research to separate the impacts of changing climate from natural population fluctuations and fishing effects. Many commercial finfish populations already are under pressure (e.g., overexploited), and global change may be of minor concern compared with the impacts of ongoing and future commercial fishing and human use or impacts on the coastal zone. Further, changes in the variability of climate may have more serious consequences on the abundance and distribution of fisheries than changes in mean conditions alone and changes in future climate variability are poorly understood at this time. The impacts of physical and biological changes on fisheries communities will be as varied as the changes themselves. Both negative and positive impacts could be foreseen, their strength depending on the vulnerability of each community, the combination of potential impacts (sensitivity and exposure) and adaptive capacity. This phenomenon will carry a high risk in Africa. Impacts would be felt through changes in capture, production and marketing costs, changes in sales prices, and possible increases in risks of damage or loss of infrastructure, fishing tools and housing. Fishery-dependent communities abound in Africa and may also face increased vulnerability in terms of less stable livelihoods, decreases in availability or quality of fish for food.

Adaptation strategies for Africa

The extent to which people and systems are affected by climate change (their vulnerability) is determined by three factors: their exposure to specific change, their sensitivity to that change, and their ability to respond to impacts or take advantage of opportunities. Coastal adaptation for developing countries will be more challenging than for developed countries, due to constraints on adaptive capacity. The non-linear interactions of these factors mean that vulnerability is unevenly distributed, sometimes in surprising ways. It is important to understand patterns of vulnerability to specify and prioritize adaptation interventions. It is a general opinion that more needs to be known about Africa's climate, impact of climate change on ground water and energy systems. Above all, there is a need to support more regional strategies for adaptation and at the same time mainstreaming climate change concern into developmental policies and plans by all the African governments.

It is a known fact that the impact of climate change on coasts is exacerbated by increasing human-induced pressures. Most African coasts are experiencing the adverse consequences of hazards related to climate and sea level. African governments need to do the following: (a) enhance social capital and reduce the vulnerability of developing countries; (b) increasing income levels, education and technical skills of its citizenry; (c) promote good governance including responsible policy and decision making and communities empowerment; (d) increase agriculture adaptive capacity and at the same time modifying farming practices and (e) massive restoration and re-establishment of vegetation.

Conclusion and Recommendations

A wide range of adaptations is possible, either carried out in anticipation of future effects or in response to impacts once they have occurred. In general, responses to direct impacts of extreme events on fisheries infrastructure and communities are likely to be more effective if they are anticipatory, as part of long-term integrated management planning. However, preparation should be commensurate with risk, as excessive protective measures could themselves have negative social and economic impacts FAO, 2008). There is a critical need for well informed public policy to address mitigation of GHG emissions to limit and minimize impacts of climate change. The safeguarded benefits in the fisheries sector are an important factor to be considered. Sound public policy also will be required for climate change adaptation in order to reduce ecosystem vulnerability, provide information for planning and stimulating adaptation, and ensure that adaptation actions do not have negative effects on other ecosystem services and the longer term viability of fisheries and aquaculture.The paper recommends (a) the strengthening of capacity including that of African scientists, governments and civil society; (b) supporting adaptation by rural /urban people particularly the most vulnerable and (c) adding value to existing adaptation initiatives to enable African scientists to apply expertise and carry out research in support of adaptation projects in land-water interface ecosystem.

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