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Implications of Climate Change on Fishers

Deepananda, KHMA
Department of Fisheries and Aquaculture, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna, Matara

Email: ashoka@fish.ruh.ac.lk

Abstract

Fishers, as an important part of the fisheries, are threatened by many effects of global warming, including changes in ocean currents, rainfall changes that affect lake levels and river flows, increasing frequency and severity of storms, extreme events such as El Nino and hurricanes, and extreme floods and droughts. It can, therefore, be predicted that global fishers can be significantly affected by climate change which can be worse in future. There are some peer reviewed articles on impacts of climate change on fish and fisheries, but limited synopsis have been found on impact of climate change on the fishers. The present work provides a concise rather than comprehensive review on the consequences of climate change on global fishers. However, fishers of African continent attract more attention in future than other countries in this context. Different types of climate change impacts on fishers can be linked to the various elements of livelihoods frameworks such as impacts on assets and impacts on livelihoods activities. Commonly cited consequence of climate change and variability is decreased revenues for fishers due to decline in total catch and stock abundance. This can also be the result of the closure of fisheries activities during a weather anomaly related to climate change or the reduction of fishing days due to increased weather variability such as increased frequency of storms. Fishers' vulnerability to climate change will largely be a function of their capacity to adapt. Fishers are mostly poor or very poor and often without access credit to cope with the shocks and trends. Their typically poor health and inadequate health care systems make them further vulnerable to extreme events and outbreaks of diseases. If so, climate change has some positive impacts on fisher communities, though this is not persistence. The climate change impacts on marine ecosystems cannot be easily controlled by engineering measures, and a general strategy to conserve the sensitive habitats both in quantity and in quality would be an appropriate precautionary adaptation to the climate change effects.

Key words: Climate change, impacts, fisheries, implications, fishers

Introduction

Climate change is a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years. It may be limited to a specific region, or may occur across the whole earth. In recent usage, especially in the context of environmental policy, climate change usually refers to changes in modern climate. The most fundamental measure of the earth's climate is the global mean annual surface air temperature. As discussed in many peer reviewed articles and reviewed in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC-AR4), climate change has been attended by sea-level rise due to; (i) reductions in mass of many of the world's glaciers and of the ice sheets of Greenland and Antarctica, (ii) a pronounced decline in the extent of the Arctic's floating sea ice, and (iii) warming and thawing of permafrost in Northern high latitudes (Mark, 2010). Though sea-level rise would be partially attributable to the melting of ice, the majority of sea level rise would occur due to the thermal expansion of seawater (ACIA, 2004). Climate change and variability have occurred throughout history and natural systems have developed a capacity to adapt, which will help them to mitigate the impact of future changes. However, two factors will limit this adaptive capacity of natural systems in future; i.e., (i) the rate of future climate change is predicted to be more rapid than previous natural changes and, (ii) the resilience of species and systems is being compromised by a number of concurrent pressures, including fishing, loss of genetic diversity, habitat destruction, pollution, introduced and invasive species and pathogens. Although the earth's climate changes naturally in response to differences in solar radiation, volcanic eruptions and aerosol concentrations, our modern climate is also subject to forcing from greenhouse gases (GHG), and this forcing will increase in importance as emissions continue (Mann *et al.*, 1998). Fisheries activities itself contribute to emissions of greenhouse gases which are responsible for human-induced climate change, both during capture operations and subsequently during the transport, processing and storage of fish. At short time scales, less than ten years, the anthropogenic component of climate change adds only a small increment, compared with normal variability. Even though the year-on-year rate of anthropogenic climate change may seem slow, this is very rapid compared with previous natural change and the accumulative value produces a significant difference from the "natural" state quite quickly. The evidence that our climate is changing more rapidly now than in periods in the past and is becoming overwhelming. During this century, the world is expected to continue warming, by between 1.4 and 5.8°C.Other predicted impacts by 2100 are a rise in global sea level of between 0.1 and 0.9m and changes in weather patterns, including an increased frequency and severity ofextreme events such as hurricanes, floods and droughts (IPCC, 2001). An expected characteristic of global climate change is a likely increase in the variability of environmental conditions including temperature, precipitation and wind patterns. For example, in 2007, the International Panel on Climate Change (IPCC) highlighted various risks to aquatic systems from climate change, including loss of coastal wetlands, coral bleaching and changes in the distribution and timing of fresh water flows, and acknowledged the uncertain effect of acidification of oceanic waters which is predicted to have profound impacts on marine ecosystems. The oceanic circulation system is also likely to be strongly influenced by warming, with increased frequency of El Niño Southern Oscillation (ENSO) events affecting current dependent upwelling fisheries, including the major industrial fisheries for small-pelagic fish, with consequences for global fish supplies. Climate change has both direct and indirect impacts on fish stocks that are exploited commercially. Direct effects act on physiology and behavior and alter the growth rate, development, reproductive capacity, mortality, distribution and migration. Indirect effects alter the productivity, structure and composition of the ecosystem on which fish depend for food and shelter. The magnitude and direction of climate change-specific stressors will vary from one aquatic system to another and climate change stresses will have complex pressure on fisheries and aquaculture and threatened the fish production and livelihood of the communities. These changes have major consequences for the productivity and species composition of fisheries resources in the region, and the nature of the impact will vary depending on the type of ecosystem and the fishery.

There is as yet an incomplete understanding of the link between climate change and fisheries. However, alongside the growing acceptance that global average surface temperature has increased by at least 0.6 ^{0}C during the last 100 years and, that this trend is expected to continue through the 21st Century, has been the understanding that fishery systems, fisher folk and other economic and food systems are vulnerable to climate variability. It has been assumed that fifty million people could be at risk by 2080 because of climate change and increasing coastal population densities. Projections suggest that these combined pressures could result in reef loss and a decline in fish availability for per capita consumption of approximately 15 percent by 2015 (FAO, 2007). There are some peer reviewed articles on impacts of climate change on fish and fisheries, but limited synopsis have been found on impact of climate change on fishers that as an important part of the fisheries. The objective of the present work is to synthesize a concise rather than comprehensive review on the consequences of climate change on fishers at the point at which they impact on fishing activities, fishers and their communities.

Most vulnerable fishers

Fishers are generally known as poor and, therefore climate-induced changes to resource flows can fundamentally affect the viability of the livelihoods of the poor (SEI *et al.*, 2003). The number of people directly employed in fisheries and aquaculture is conservatively estimated at 38 million, of which over 90 percent are small-scale fishers (FAO, 2005). The small-scale fisherfolk of developing countries are frequently identified as "the poorest of the poor" and fishing is often characterized as "the occupation of last resort" for those without skills, education, land and alternative livelihood opportunities. This deeper understanding of poverty in small-scale fishers has thus identified vulnerability to external shocks and trends (including climate change, variation and extreme events), rather than asset or income poverty, as a particular threat to the sustainability of fishing-based livelihoods. It can be predicted that global fishers can be significantly affected by climate change which can be worse in future. However, countries of African continent attract more attention in future than other countries in this context. Fisheries provide employment for up to ten million people in Africa and provide a vital source of protein to 200 million people. A recent study on the vulnerability of national economies and food systems to climate change impacts on fisheries has revealed that fishers in African countries are the most vulnerable to the likely impacts of climate change. This is in spite of over 80 percent of the world's fishers being in South and Southeast Asia and fish catches being greater in Latin America and Asia. Moreover, the analysis suggests that semi-arid countries with significant coastal or inland fisheries have high exposure to future increases in temperature (and linked changes in precipitation, hydrology and coastal current systems), high catches, exports and high nutritional dependence on fish for protein, and low capacity to adapt to change due to their comparatively small or weak economies and low human development indices. Therefore, it is speculated that fishers of African countries Including Angola, Congo, Mauritania, Mali, Niger, Senegal and Sierra Leone are more vulnerable to the climate change than other nations. Other vulnerable fisher nations are Rift Valley countries such as Malawi, Mozambique and Uganda, and Asian river dependent fishery nations including Bangladesh, Cambodia and Pakistan. Fishers' income and protein may be particularly limited in these countries resulting in high dependency on wild caught fish and bush meat. Countries such as Colombia, Peru and the Russian Federation are sensitive to climate change due to their high catches and reliance on exports or high employment from fisheries, but their larger economies and higher human development indices mean they are likely to have a greater adaptive capacity to deal with potential impacts (FAO, 2007). In addition, fishers in high latitudes may also affect due to expected climate change. For instance, Drinkwater (2005) reviewed that, due to future temperature and hydrodynamic changes, Cod stock throughout the North Atlantic are expected to disappear altogether by 2100, while those in the Southern North Sea and George bank will decline dramatically. Due to fact that fisher communities over the globe are vulnerable to climate change and the degree of vulnerability differs from one nation to other.

Potential impacts

Climate variability and fluctuating stocks and livelihood system can directly and indirectly affect on fisher communities. Different types of climate change impacts on fishers can be linked to the various elements of livelihoods frameworks such as impacts on assets and impacts on livelihoods activities. Small-scale fishers are particularly exposed to direct climate change impacts because they tend to live in the most seaward communities and they are at risk from damage to their property and infrastructure from multiple direct impacts such as sea level rise, increasing storm intensity and frequency. Commonly cited consequence of climate change and variability is decreased revenues for fishers due to decline in total catch and stock abundance (Callaway *et al.*, 1998; Luam Kong, 2002; Mahon, 2002). This can also be the result of the closure of fisheries activities during a weather anomaly related to climate change (Luam Kong, 2002; Siung-Chang & Lum Kong, 2001) or the reduction of fishing days due to increased weather variability such as increased frequency of storms (Broad *et al.*, 1999; Mahon, 2002). Erosion of income due to such impacts may erode the traditionally positive social interaction enjoyed by small fisher communities. Details of the potential impacts related to the climatic variables on fishers are separately discussed in this review here to forth.

Rise in water temperature

Temperate and polar regions are expected to experience larger changes in temperature than tropical areas, so fishes inhabiting these areas will be more affected by climate change, lowering the income of fishers. There are many reasons on this context which lowers the production in the area. Reproductive success of temperate fishes can be affected by global warming and low overwinter temperatures (cold-tempering) are often essential for the spawning success of temperate fishes such as salmonids. Oxygen solubility in water has an inverse relationship with water temperature, and fishes exposed to elevated water temperatures can face an "oxygen squeeze" and decreased levels of dissolved oxygen can reduce the growth and reproductive success of individual fishes. Therefore, it is possible that individual fish could be smaller, less fecund and less likely to survive. Even fishes thrive mostly in low latitudes also vulnerable to rise in water temperature. For instance, common carp cultured at 35 ^{0}C developed a vitamin C deficiency and grew more slowly than those cultured at 25 ^{0}C (Hwang & Lin, 2002). In addition, the toxicity of common pollutants (e.g., organophosphates and heavy metals) to fish generally increases at higher temperatures (Murty, 1986) and elevated toxicant concentrations in fish tissues can have sub-lethal effects, including the reduction of reproductive output, potentially elevating rates of natural mortality. Moreover, the problems due to increase in water temperature will become more serious as the size of remaining water bodies diminishes in response to increased evapotranspiration rates and dry season irrigation. Due to such effects, rise in water temperature lowers the productivity, thereby affecting fishers' income severely. On the other hand, Change in migration routes and biogeography of fish stocks can directly affect fishing effort of fishers; for instance, increased travelling time will lead to increased fuel and ice costs (Mahon, 2002). Reduction of catches and collapse of stock can lead to unemployment in fishers. In Connecticut, catches of lobster fell by 59% between 1999 and 2002. This was linked to increased sea surface temperature in the Gulf of Maine and resulted in the loss of 40% of the lobstermen (Donn, 2004). Additions to the marine fishers, freshwater fishers are affected by the species shift mediated by the rise in water temperature. For instance, China produces table-size fish primarily by stocking fingerlings in lakes and reservoirs early in the year and collecting them by organized capture later in the year (Martin, 2001). But, climate change may threaten this economy by northward shifting the ranges of target fish such as the lake trout, the valuable coldwater fish species of this area, leaving behind the local businesses such as resorts, restaurants and fishing equipment retailers that depend upon them. Moreover, changes in species abundance could also lead to changes in harvest and processing costs due to retooling (change of gear, boat etc.) to harvest the newly abundant species (Broad *et al.*, 1999; Knapp *et al.*, 1998). Artisanal fishermen with limited resources will be particularly affected to this due to their incapacity to quickly adapt to this new harvesting techniques and tools. Any net increases in overall fisheries yield and associated livelihood benefits such as improved earnings and food security are likely to come at the expense of reductions to species diversity and greater fluctuations in total annual landings potentially increasing livelihood vulnerability. As species distributions change in response to climate change, small-scale fishers may be less able to adapt by following them because of limited mobility. In addition, traditional area-based access rights institutions will become strained by the loss or relocation of local resources.

On the other hand, increasing global temperatures severely affect the fishers especially engaged in aquaculture industry. Changing global temperatures will affect fish susceptibility to disease. Rates of bacterial diseases (such as furunculosis) in aquaculture systems often peak at high temperature (Wedemeyer, 1996), and the changes in lake limnology accompanying climate change may also influence transmission rates. In lakes and reservoirs, the crowding of cool and coldwater fishes into a smaller hypolimnion could bolster parasite transmission (Marcogliese, 2001). Likewise, stream and river systems may also experience more frequent parasite epizootics. Fish migrating from warmer regions may serve as hosts or vectors for parasites and diseases that are novel to species in the receiving environment (Font, 2003), affecting native fish populations (Brouder, 1999). This may lead to reduced the productivity of the aquaculture ventures, and it severely affect on fishers involved in this industry. Therefore, it has no doubt that fishers engaging marine, brackish water and freshwater fisheries are detrimentally affected by rise in water temperature.

Storms and extreme weather events

Worsening storms increase the risks associated with working at sea, and changes in weather patterns may disrupt fishing practices that are based mainly on traditional knowledge of local weather and current systems, providing less viable livelihood option for the poor fishers. Moreover, skippers cannot direct their fishing vessels as in normal conditions, and cannot perform the optimum speed towards the target due to strong water currents, especially in multiday fishing vessels. Severe storms compel them to stay more days at seas which are lost due to bad weather. These may increase in vulnerability of fishers to risk of accidents at the sea. On the other hand, fishers face difficulties when setting fishing gears in a stormy weather at the sea and lakes. Such storms therefore, detrimentally affects on fishing activities, resulting the reduction of income and increasing in risk to the fishers. Safety while pursuing fishing activities is a significant issue in fishing communities because of predicted changes in weather and unexpected storm events or, in the case of Arctic communities, stability and safety of ice and snow can affect the fishers. Indeed, personal safety in Arctic communities practicing ice fishing is jeopardized by unpredictable ice conditions in winter, making travel dangerous (Berkes & Jolly, 2001). Presenting the impacts of climate change for Atlantic Canadian fisher communities, Catto (2004) also puts forward that changes in seasonality and storminess may necessitate operational changes by fishers, with implication for both health and safety search and rescue operations. Moreover, injury and death are the direct health impacts often associated with natural disasters linked to increased frequency and severity of extreme events. In the case of injury, there is an obvious impact on human capital through the reduction in the physical capabilities of fishermen to pursue their livelihoods. As with small-scale fisheries, fishing operations can be directly disrupted by poor weather, while extreme events can damage vessels and shore-based infrastructure. Disruption of other sectors, such as agriculture, tourism & manufacturing by such extreme events can lead to indirect socio-economic effects. City ports and facilities required by larger vessels can be affected by these extreme events. Storm and severe weather events can destroy or severely damage infrastructure and equipment such as port, landing sites and boats (Jallow *et al.*, 1999). Extreme weather events may also result in loss and replacement of fishing vessels and outboard engines. During hurricane Gilbert in 1998, for instance, Jamaican fishermen lost 90% of their traps resulting in a loss of revenue and high cost of repairs, as well as the inability to resume fishing activities promptly (Aiken *et al.*, 1992). In Antigua and Barbuda, 16% of the fishing fleet was destroyed or lost while 18% was damaged due to Hurricane Luis in 1995 (Mahon, 2002). Likewise, in Belize losses to the fishers as a consequence of Hurricane Mitch (1998) have been estimated at USD 1.2 million, in the form of loss of fishing gear and associated infrastructure (Gillet, 2003). An increasing number of large coastal cities are at risk from sea level rise discussed elsewhere here and from the extreme weather events, especially in rapidly developing Asian economies (Nicholls *et al.,* 2007). Moreover, Mahon (2002) observed that in Antigua and Barbuda, during Hurricane Luis in 1995 the destruction and damage of tourist infrastructures resulted in the transfer of workers from this sector into fishing for short term employment, adding pressure to fishing stocks and labor supply. The socio-economic impacts of such climate events can be largely influenced by availability of resources which will impact on fishing cost and income. The cost of many inputs into fishing could be affected by any decrease in availability of resources brought about by increase in frequency of storms and weather events. Increasingly poor weather can also increase the cost resulting from increased fuel cost due to rough seas, increased labor cost due to working conditions, increasing maintenance cost for vessel and fishing equipment (traps or shades) or cost associated with trap replacement following loss or destruction. The unavailability of resources will create further hardships to fishers who are socially and politically marginalized with limited access to finance, health care, education and other public services. Loss of income will also result when weather conditions are such that it prohibits fishers from going out to sea to fish. Fishers' inability to harvest fish resource may cause them to migrate to urban areas or to cities to increase their chances of earning for living. In addition, aquaculture installations such as coastal ponds and sea cages are more likely to be affected by storms and severe weather events. This lowers the profitability of large scale entrepreneurs in particular, thereby affecting employees, i.e., poor fishers. This increase in risk to the fishers and the assets lead to raise the insurance premiums to be paid by the fishers, extra money. The aquaculture industry is a major market for fishmeal from capture fisheries. Climate change impacts may affect this market by reduction of fisheries, although current projections are for fish meal and fish oil demands to continue to increase in the near future (Delgado *et al.*, 2003).

Sea-level rise and flooding

Though Climate change affect severely on freshwater and coastal fisher communities, coastal fishing communities face a double exposure of reduced fisheries resources and increased risks of coastal flooding and also storm surges. Fishing villages are most vulnerable to climate change as they may be severely impacted by sea-level rise and erosion as they typically occupy low coastal land. Similarly, fishing camp sites, particularly those on the outer cayes and atolls, fish landing sites and cooperative receiving and processing facilities are also vulnerable as the fishing villages, as they are also located on low coastal land. Increased sea-level changes the coastal profile and thereby loosing the harbors and homes for fishers. This particularly increased the vulnerability of coastal fisher communities and infrastructures to sea-level rise which increase in exposure of coastal areas to the storm damages. This increases in the cost to rebuild the damages and lead to increase in the insurance premium too. Moreover, this sea level rise severely affects the coastal aquaculture installations. Shrimp and brackish water aquaculture in many developing countries flourished in associated with mangrove forests. Increased sea level may severely damage and dislocate this industry, severely affecting the fishers.

Severe flooding due to heavy precipitations can hinder the capacity of fishing in most freshwater fisheries. This may directly affect the fishing communities in low land areas, and most times reduce the catch and revenue. This also disrupts the fishing nets/ gears. Predictions for consequences of flow regimes are uncertain but increased run-off and discharge rates during this process may boost fish yield through more extensive and prolonged inundation of floodplains, causing floorings in lake and river floodplain fisheries. Such positive impacts for floodplain fishers are discussed elsewhere in this review. However, these potential gains may be counter-balanced by greater dry-season losses due to lower dry-season flows and greater demands on water resources for irrigation, threatening fish survival and making them more susceptible to capture. In addition to heavy precipitation, Snow and glacier melt in the Eurasian mountains (including the Himalaya) may also result in changes in the flows of the Indus, Brahmaputra, Ganga and Mekong, which sustain major river and floodplain fisheries, severely affecting fishers. Damming for hydropower, irrigation and flood control may also offset any potential fishery gains (FAO, 2007), finally affecting the fishers.

Changing levels of precipitation and droughts

Inland fisheries are profoundly affected by changes in precipitation and run-off which may occur due to climate change. Fishers depend on lake fisheries in Southern Africa will likely be heavily impacted by reduced lake levels. That is, the African Great Lakes region harbor important fisheries that contribute to employment, food security, government tax revenues, domestic markets and exports. Changing levels of precipitation severely impacts on the fishers' income especially in low water levels. Allison and others (2007), for instance graphically illustrated the changes of total catch with the lake water level of Lake Chilwa, in Malawi. Time-series demonstrated that the fishery productivity is strongly tied to the amount of water in the lake. Lake Chilwa is a 'closed-basin' lake which periodically dries out when rainfall is low but supplies up to a quarter of Malawi's fish in good years. With declining levels of rainfall over Southern Africa in recent years, dry periods have become more frequent and fish yields are declining accordingly (FAO, 2007), thereby affecting the poor fishers. In addition, changing levels of precipitation can affect on transportation and marketing systems (Catto, 2004). In Peru, during the El Niño of 1997-98, many of the rural fishing villages were damaged by the heavy rains and were unable to get their products to markets due to washed out roads and bridges (Broad *et al.*, 1999). In addition, fishers engaged in aquaculture ventures too affect by changing levels of water in lakes. Fishers who set their aquaculture installations in brackish water environments may severely impact by dropping salinity with respect to heavy precipitations. There are many more examples on this context and especially rafts cultured mussels in lagoons may be completely destroyed by these salinity droppings. Moreover, river dependant fishers may severely be impacted by the changing levels of flow regime, especially in large rivers. Though some floodplain fishers accomplish additional revenue as discussed elsewhere here, most traditional fishers are severely impacted by the changing water regime in rivers. It also increase in vulnerability of riparian and floodplain fisher communities. In addition to the lake and river fishery, the most affecting fishers are those who engage in reservoir fishery. In some countries like Sri Lanka main inland fisheries sector is the culture based fishery. This was done in mainly minor perennial reservoirs, depending on the monsoon rains. Artificial water bodies, not built for fishery/aquaculture purposes but often built for irrigation purposes, are being used for the practice. The water retention period of the water body (8–9 months is optimum for fish reaching marketable sizes) and depth of water of the effective area (2.0–2.5 m is optimal) are important basic characteristics for culture based fisheries (De Silva *et al.*, 2006). Culture based fishery solely depend on the normal pattern of biological and physical factors, and therefore, indigenous knowledge can play a vital role in this context. As small reservoirs dry out in hot seasons, it is also important to consider during which months water is retained so that the selected fish have time to mature ready for harvesting. However, present climate variability changes the physical and biological factors of the reservoir due to heavy precipitations and evaporations, changing the depth and surface area of the reservoir which are important for determining the water retention period. This reduces the predictability to rain/ dry season by indigenous fishers, and this may lead to create inability to plan these livelihood activities of the fishers. The most affecting sector due to changing level of precipitation in culture based fishery is fingerling production. Because, culture based fishery in seasonal reservoirs is dependent on the natural event of reservoir-filling during the inter-monsoonal rains in the country. The composition of carp species used to stock in water-bodies depends on the availability of fingerlings which produced mainly through induced breeding. Fingerling production shows the seasonality for high fecund and the success in induced breeding of major carps is dependent on the rainfall patterns. However, present climate changes have affected the reservoirs through changing precipitation and drought season, and reservoir filling will not proceed with the breeding seasons of the brood stock. There are many fishers having mini-hatcheries to produce fingerlings, as their livelihood activities. There is no assurance that farmers who rear fingerlings will be able to sell. The fingerlings in the drought years when reservoirs do not fill. On the other hand, heavy rains in particular can generate floods causing reservoirs to over flow, which can enable the stocked fingerlings to escape. Due to the climate change, considerable degrees of risks and uncertainties are involved at virtually every stage of developing a culture-based fishery ranging from production of seed in hatcheries and stocking to harvesting and marketing. This increase the vulnerability of fishers involved in this industry. Therefore, there is no argument that changing levels of rainfall reduces the opportunity to farming, fishing and aquaculture practices, ultimately reducing the diversity of rural livelihoods.

Water bodies in dry areas which receive water mainly from monsoonal rains are more susceptible to unpredictable drought periods. Heavy evaporation in drought seasons increases the trophic state of the reservoir and thereby affecting the fish and fishery. Inland fishers are more susceptible for droughts and extended drought periods can affect culture-based fisheries, shortening the water retention period. Drought affecting agriculture may push people out of agriculture and into fishing (e.g. Senegal in the late 1990s). As observed as a result of hurricanes in the Caribbean (Mahon, 2002), the displacement of labor into fishing can lead to conflicts among fishers over labor opportunities and increase fishing pressure. Droughts and resultant agricultural failure forecast in some areas of sub-Saharan Africa may lead to so-called "environmental refugees" moving to coastal areas and creating an influx of surplus fishing labor (Conway *et al.*, 2005). This ultimately decreases the revenue to the genuine fishers who cannot find the alternative livelihood activities. This displacement of workers can lead to create a friction within fisher communities. Displacement and increased migration and increasing frequencies of droughts are forecast in Southern Africa, leading to greater variability in lake levels and river flows, affecting lakeshore and river floodplain livelihoods that incorporate fishing (Conway *et al.*, 2005). Under increasing uncertainty, migratory fishing (moving between water bodies) becomes a more rational livelihood strategy in fishers than investing in a stable village-based existence.

Other socio-economic impacts

There are many more socioeconomic impacts other than discussed so far on fishers by climate change, mainly due to reduce catch and low income. Any reductions in fisheries production will require fishers to further diversify their activities and flexibly exploit resources as they become available. Fishers' vulnerability to climate change will largely be a function of their capacity to adapt. They are mostly poor or very poor and often without access credit to cope with the shocks and trends. Their typically poor health and inadequate health care systems makes them further vulnerable to extreme events and outbreaks of diseases. Longer, deeper floods might benefit the landless and seasonal fishers, as access to the fishery will remain open for longer, but drainage congestion and resultant standing water may increase the risk of outbreak of cholera and other waterborne and diarrheal diseases such as malaria, dengue and dysentery. Studies have also shown that the El Niño cycle in certain areas is associated with changes in the risk of diseases transmitted by mosquitoes, such as malaria and dengue fever, and disease caused by arbodviruses other than dengue virus. The risk of malaria in South America, Central Asia and Africa (areas where the majority of small scale fishers are located) has been shown to be sensitive to variability in climate driven by El Niño (Patz & Kovats, 2002). Moreover, small rural coastal fisher communities often lack potable water, sewage and drainage: health sector problems are thus often enhanced by climatic events such as storms, floods and ENSO events. In addition, marine phytoplankton blooms caused by increased sea surface temperatures may result in red tides that cause diarrhoeal and paralytic diseases linked to shellfish poisoning (Hales *et al.*, 1999; Patz, 2000). The livelihoods of small-scale fishers are already vulnerable to a range of non-climate risks, including fluctuating resources, loss of access, HIV/AIDS, market fluctuations, conflict, political marginalization and poor governance (Allison *et al.*, 2008). This insecurity inhibits investment in long-term strategies for sustainable fisheries and will be exacerbated by additional insecurities caused by climate change impacts.

Positive impacts

Climate change has some positive impacts on fisher communities, though this is not persistence. Climate change increase revenues with increased in catches of certain species. For instance, the arrival of tropical species such as mahi-mahi and shark and the increased growth rate of octopus and scallops in Peru during the 1997-1998 El Niño event was initially highly profitable for the artisanal fishers (Broad *et al.*, 1999 & 2002). This was similar to population increases in the El Niño event of 1983 where scallop catches rose by 920% compared to 1980-82 (Palomino, 1985).However, several factors undermined potential benefits to fishermen on additional species in 1997-98: the market price of mahi-mahi dropped to below US$1 due to over-supply, the 'Asian crisis' decreased export demand, and there was lack of adequate gear (Broad *et al.*, 1999). If climate change limits fishing effort, this will result in reduced catch, and income or revenue derived from limited or reduced catch will be reduced. A positive outcome from this could be the recovery of the fishery stock, in the long run, particularly if the fishery was being over exploited. This positive outcome may also extend to increase in landing in the long term in spite of reduced effort. Increasing fuel costs are likely to continue to pressure the fishing industry to improve fuel efficiency in order to remain profitable; for example, switching to more efficient vessels or gears, such as from single to twin trawls. These will undoughtly help to minimize the contribution of fisheries to climate change. Some initial research has been conducted into the utilization of waste products from fish processing for producing biodiesel. Climate change may also offer win-win outcomes where adaptation or mitigation measures improve economic efficiency and resilience to climatic and other change vectors. For example, this could include decreasing fishing effort to sustainable levels, decreasing fuel use and hence CO_2 emissions, or reducing aquaculture dependence on fishmeal or oils (FAO, 2008). The major commercial input of climate change on fisheries has been to reduce the maximum sustainable yield of fish. In case of Cod, climate change has been estimated to have been eroding the maximum sustainable yield at a rate of 32000 tons per decade since 1980. Even if current stock rebuilding measures are effective, it cannot be expected that the fishery could be restored to its past sate. Conversely, it seems likely that significant new fisheries will develop in the future. On the other hand, climate change enhances the fisheries production to some extent. Therefore, conservation of available resources will contribute to food security in future.

Due to uncertainties caused by climate change, fishers have learned to look forward for securing their livelihood. That is, due to increasing uncertainty of income over the time, fisher communities are trying to secure their requirements in difficult economic situations. For example, In Peru, at the time of the 1997-98 El Niño event, a percentage of the catch was put into a recently privatized social security and health organization to cope with the difficult economic situation (Broad *et al.*, 1999). Some fishers are used to buy gold in good economic situations to secure their livelihood at difficult situations. In basins where run-off and discharge rates are expected to increase, the seasonal inundation of river floodplains such as those in the Ganges Basin in South Asia, fish yields may increase as larger areas of ephemeral spawning and feeding areas are exploited by lateral migrant species. In Bangladesh, a country globally acknowledged as being extremely vulnerable to climate change, a 20 - 40 percent increase in flooded areas could raise total annual yields by 60,000 to 130,000 tones (Allison *et al.*, 2005). Longer, deeper floods might benefit the landless and seasonal fishers, as access to the fishery will remain open for longer. Climate driven changes in species distribution also positively affects on some fishers. While some fisher folk will see the disappearance of their target species, others could see an increase in landings of species of high commercial value. For example, in the Humboldt Current system during El Niño years, landings of shrimp and octopus increase in Northern Peru while in the south, tropical warm-water conditions increase the landings of scallops. These species have higher market values than more traditional species and international markets have developed for them (Badjeck, 2008). Moreover, input of fresh water in estuaries may favour the appearance of brackish water species. For instance, during the El Niño of 1997 to 1998, increased rainfall in Northern Peru changed salinity patterns in estuaries, favouring the mullet fishery (Badjeck, 2008) and in Columbia during the La Niña event of 1999 to 2000, a tilapia fishery bloom was observed (Blanco *et al.*, 2007). Those increase the income of fishers and such positive impacts have been shown in many areas of the world. Dalton (2001) linked fluctuations in sea surface temperatures, including El Niño events with fishing effort in the albacore tuna, Chinook salmon, sablefish and squid fisheries in Monterey Bay, California, using a predictive model. Under a scenario of sea surface temperatures corresponding to the ENSO events of 1983 (increase of 1.2 ^{0}C), fishing effort decreases by 60% for the sablefish fishery and 400% for squid fishery.

Conclusion

Climate changes are components of other stresses on the environment and produce actual and potential impacts on fisheries resources. The impacts of physical and biological changes of aquatic environments on fishers will be as varied as the changes themselves. Strength of the impacts depends on the vulnerability of each community, combination of potential impacts (sensitivity and exposure) and adaptive capacity. Impacts can be felt through changes in capture, production and marketing costs, changes in sales prices, possible increases in risks of damage or loss of infrastructure, fishing tools and housing. Therefore, fisher communities may face increased vulnerability in terms of less stable livelihoods, decreases in availability or quality of fish for food and safety risks due to fishing in harsher weather conditions. Impacts on food security related to access and availability of important traditional food species can be significant in a scenario of decreased catches due to climate change events. The risk of malnutrition and under nutrition for communities highly dependent on fish as a source of protein (Ogutu-Ohwayo *et al.*, 1997), combined with changes in diet (reduction of protein from fish source) are some of the possible effects. Decline in commercial fisheries, leading to decrease in income of fishers can dramatically reduce the ability to purchase store-bought food during periods of natural resource scarcity (Callaway *et al.*, 1998). Fishers located in the high latitudes and those that rely on climate change-susceptible systems, i.e., upwelling or coral reef systems, appear to have most potential exposure to impacts of climate change. The climate change impacts on marine ecosystems cannot be easily controlled by engineering measures. Therefore, a general strategy to conserve these habitats both in quantity and in quality would be an appropriate precautionary adaptation to the climate change effects. Furthermore, the better the condition of these habitats, the more resilient they will be. Additionally, the greater the quantity of sensitive coastal habitats such as mangroves, sea grasses and reefs that are important for fisheries, the less likely it will be that climate change will reduce these habitats below critical levels for fisheries. Recognizing the value in reducing the negative impacts of climate change, promotion of marine protected areas (MPAs) and environmental conservation thus becomes a focus of the adaptation strategy. The under utilization of "fish reserves" as an adaptation tool in response to climate change is globally recognized.

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