Global Climate Change: How Might it Affect the Fisheries of the Caribbean's SIDS?

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ABSTRACT

Climate change represents an important additional stress to the many ecological, social, and economic systems already affected by pollution, increasing resource demands, globalization, and non-sustainable management practices in the Small Island Developing States of the eastern Caribbean. Climate change is expected to occur at a rapid rate relative to the speed at which ecosystems can adapt and re-establish themselves. The principle effects on fisheries will be felt at national and local levels, as centers of production are altered and changes to the ecosystems occur. Notwithstanding, the relatively minor impacts on fisheries initially suggested by the global community of climate change scientists, in this contribution we give consideration to some of the direct and indirect impacts on the sector as a whole. We note that to remove the suggested impacts of climate change out of the realm of speculation and into that of probability, there is need for a fully integrated approach to vulnerability assessment. We suggest that it is also important to take into consideration the value of non-marketed goods and services such as subsistence assets, community structure, traditional skills and knowledge which would also be at risk from climate change. Policies and development programmes which seek to use natural resources in general, and fisheries resources in particular, in a sustainable manner, and which can respond effectively to changing conditions such as climate change need to be put in place as soon as possible if eastern Caribbean States are to survive any of the impacts of global climate change.

KEY WORDS: Climate change, eastern Caribbean, vulnerability of fisheries

INTRODUCTION

In 1993 it was generally believed that prosperity and technical progress would make both mitigation and adaptation to global climate change affordable and avert the associated dangers (Ausubel 1993). However, it is now fairly much accepted that human induced climate change represents an important additional stress in Small Island Developing States (SIDS) to the many ecological, social, and economic systems already affected by pollution, increasing resource demands, and non-sustainable management practices. The SIDS of the eastern Caribbean are no exception. Changes in climate have the potential to affect the geographic location of ecological systems, the mix of species that they contain, and their ability to provide the wide range of benefits on which the societies rely (Watson et al. 2000).

The Intergovernmental Panel on Climate Change (IPCC) has noted that the primary influence of anthropogenic climate change on ecosystems is expected to be through the rate and magnitude of change in climate means and extremes (Watson et al. 2000). Climate change is expected to occur at a rapid rate relative to the speed at which ecosystems can adapt and reestablish themselves and through the direct effects of increased atmospheric carbon dioxide concentrations (*ibid.*). Some coastal ecosystems are particularly at risk, including mangrove ecosystems, coastal wetlands, sandy beaches, and coral reefs (IPCC 1996a). Changes in these ecosystems would have major negative effects on tourism, freshwater supplies, fisheries and biological diversity (*ibid.*). In particular it has been suggested that globally marine fisheries production is expected to remain about the same in response to changes in climate, with high-latitude freshwater and aquaculture production being likely to increase if natural climate variability and the structure and strength of ocean currents remain about the same (Watson et al. 2000). The principle effects on fisheries will be felt at the national and local levels, as centers of production shift. The apparent positive effects of climate change in higher latitudes (longer growing seasons, lower natural winter mortality, faster growth rates) may be offset by negative factors such as changes in established reproductive patterns, migration routes, and ecosystem relationships (*ibid.*)

GENERAL IMPACTS ON SIDS

Habitats and Ecosystems

Climate change will lead to changes in sea level, increasing it on average, and also could lead to altered ocean circulation, vertical mixing, and wave climate. As a result, nutrient availability, biological productivity, the structure and functions of marine ecosystems, and heat and carbon storage capacity may be affected, with important feedbacks to the climate system (IPCC 1996b). Low-lying island States are especially vulnerable to climate change and associated sea-level rise because in many cases much of the land area rarely exceeds three to four metres above present mean sea level. Many islands with greater variation in topography are also vulnerable to climate change effects, particularly in their coastal areas, where the main settlements and vital economic infrastructure almost invariably are concentrated (Watson et al. 2000).

Some small island States will confront greater vulnerability (Figure 1 and Figure 2) because their existing sea and coastal defense systems are not well established (IPCC 1996a). The relatively recent impacts of Hurricane Luis in 1995 and Hurricane Lenny in 1999 on the eastern Caribbean has shown this clearly (Cambers 1996, Bythell, Cambers and Hendry 1996, Lawrence and Magloire 1999, Smith Warner International 1999a,b, James 2000). Hurricane Luis caused widespread and intensive damage throughout the coastal environment of Anguilla (Cambers 1996, Bythell et al. 1996). Damage was severe in all major coastal and marine ecosystems with sand dunes unlikely to recover except perhaps over a time scale of decades, and even this is doubtful against a background of predicted increased hurricane frequency and sea level rise (*ibid.*).

Given current projected rates of increase, sea-level rise *per se* is not expected to have widespread adverse effects on coral reefs. Some researchers argue that a rising sea level actually may be beneficial because the new conditions would be favourable for inducing vertical growth (Watson et al. 2000). The climate change effect of greatest potential significance to coral reefs is likely to be an increase in seawater temperatures. Some species of corals in the Caribbean live near their limits of temperature tolerance. Elevated seawater temperatures will impair biological functions and lead to increased mortality. Corals will also continue to be subjected to increasing anthropogenic stresses that will, however, limit the innate capacities of the corals to adapt to the effects of climate change (*ibid.*).

Figure 1. Greater vulnerability shown in Soufriere Saint Lucia because of inadequate sea and coastal defense systems

Figure 2. Settlements like Baron's Drive in Soufriere Saint Lucia are likely to be at risk given their location at or near present sea level

The adaptive capacity of mangroves in all likelihood varies with species, as well as with the presence or absence of sediment-rich, macrotidal environments and the availability of adequate fresh water to maintain the salinity balance (Watson et al. 2000). A decrease in rainfall in the Caribbean would reduce mangroves' productive potential and increase their exposure to full-strength seawater. Additionally, their adaptive capacity is likely to be reduced by coastal land loss further exacerbated by the presence of, and increased concentration of, infrastructure in coastal areas (*ibid.*). Climate change will add to stresses such as pollution and further compromise the long-term viability of these ecosystems.

It has been suggested (Edwards 1995 cited in Watson et al. 2000) that seagrass meadows, which exist in shallow, intertidal coastal environments, are the ecosystems most likely to be negatively affected by climate change effects, particularly sustained elevation of sea-surface temperatures or increases in freshwater runoff from land. However, there is growing consensus that the main threats to seagrasses are likely to come from human induced disturbances such as dredging, overfishing, water pollution, and land reclamation (Watson et al. 2000.).

Higher rates of erosion and coastal land loss are expected as a consequence of the projected rise in sea level. Watson (2000) has noted that sea level is expected to rise about 15 – 95 centimeters by 2100. Elevated sea levels will alter littoral currents, and the higher reach of waves on the shore will alter the pattern of sand distribution, contributing further to the decline of beach profiles. Low-lying islands are also expected to experience increased sea flooding, inundation, and salinizations of soils and freshwater lenses as a direct consequence of sea level rise (Watson et al. 2000).

Tourism and Infrastructure

It is suggested that even if there is no increase in the frequency and intensity of extreme weather events there may be shifts in their geographic location to places less prepared and more vulnerable to such events (*ibid.*). The passage of "left-handed" Hurricane Lenny in late 1999 demonstrated this quite clearly (Lawrence and Magloire 1999, Smith Warner International 1999a and b, James 2000). Gray (1993 cited in Watson et al. 2000) has reported that, based on historical data for the Caribbean Sea, increases in sea-surface temperature of 1.5°C have been associated with an increase in hurricane frequency of some 40%. In a number of islands, vital infrastructure and major concentrations of settlements are likely to be at risk, given their location at or near present sea level (see Figures 1and 2) and their proximity to the coast. Vulnerability assessments also suggest that shore and infrastructure costs could be financially burdensome for some small island States (Watson et al. 2000). Hurricane Lenny caused extensive damage to coastal infrastructure in Antigua and Barbuda, St. Kitts/Nevis, Anguilla, Dominica, St. Lucia, St. Vincent and the Grenadines, and Grenada ranging from damage to fisheries and tourism related coastal infrastructure (Lawrence and Magloire 1999, Smith Warner International 1999a and b) to inland landslides and road damage (James 2000).

Economic Activity

Tourism is the dominant economic sector in some of the Caribbean States, accounting for example for 69% of Gross National Product in Antigua and Barbuda in 1995 (Watson et al. 2000). Climate change and sea-level rise would affect tourism directly and indirectly due to loss of beaches to erosion and inundation, increasing stress on coastal ecosystems, damage to infrastructure from tropical storms, and an overall loss of amenities. An increase in severe floods and droughts as a result of increased frequency and magnitude of the El Nino Southern Oscillation (ENSO) phenomena is projected (Watson 2000). This can jeopardize the viability and threaten the long-term sustainability of the fishing industry (*ibid.*), which is seen as becoming more important to the economies of eastern Caribbean States.

In general, socioeconomic systems such as human settlements, agriculture, forestry, water resources, and fisheries are vulnerable to changes in climate, including the magnitude and rate of climate change, as well as changes in climate variability (Watson 2000). The draft third assessment report of IPCC working group II (IPCC 2001a) has clearly noted with medium confidence that for SIDS "declines in coastal ecosystems would negatively impact reef fish and threaten reef fisheries, those who earn their livelihoods from reef fisheries, and those who rely on the fisheries as a significant food source". This contribution considers some of the types of impacts that may also need to be considered by the fisheries industries of eastern Caribbean islands.

IMPACTS ON THE FISHERIES OF EASTERN CARIBBEAN ISLANDS

Fishing, although largely artisanal or small-scale commercial, is an important activity on most of the small islands of the eastern Caribbean. While marine fisheries only account for approximately 1% of the global economy, many coastal and island States are far more dependent on this sector than this statistic would suggest (IPCC 1996, WG II, Section 16.1.1). For example, the annual yield of lobsters from the shelves and banks of the Caribbean islands (excluding the U.S. Virgin Islands) has a retail value in restaurants of approximately US$40 million (Vicente 1996 cited in Watson et al. 2000). Similarly, marine fish account for 16% of global animal protein consumption, but the contribution to protein intake is much greater in developing countries, where animal protein tends to be relatively expensive (IPCC 1996a).

Habitats, Ecosystems and Biology

While the modest temperature increases projected for regions such as the Eastern Caribbean are not anticipated to have a widespread adverse effect on small island fisheries (Watson et al. 2000), a temperature rise could have a negative effect on productivity in areas such as shallow lagoons like that of Codrington in Barbuda (Van der Meerin 1998). The lagoon serves as an important habitat for lobsters, more particularly juveniles. Severe fluctuations in salinities or temperature would compromise reproductive processes or larval survival, possibly proving to be a severe detriment to the survival to the population (Alm et al. 1993 cited in Watson et al. 2000). On the other hand, warming-induced changes in current patterns could conceivably increase upwellings at sea, bringing more nutrients to the surface and providing more food for the fish.

Fisheries in the small island States were not expected to be adversely affected by sea-level rise *per se*, but it was recognised that a higher sea level would be a critical factor for fisheries if the rate of rise is higher than the projections at that time suggested (IPCC 1996a). In such circumstances, the natural succession of coastal ecosystems on which some species depend (e.g., mangroves, seagrasses, corals) and which function as nurseries and forage sites for a variety of commercially important species would be disrupted (IPCC 1996a). Fish production thus would suffer if these habitats were endangered or lost (Costa et al. 1994). It is estimated, for example, that Antigua and Barbuda is currently losing its mangrove systems at an average annual rate of about 1.5 - 2.0% with a sea level rise of 3 - 4 mm per year (Government of Antigua and Barbuda 2001). Thus, there would be little or no mangroves in Antigua by 2075, since the coastal slopes of most areas do not allow for landward retreat. However, if the sea level rise were 10 mm per year, this condition would be reached as early as 2030 or 2035 (*ibid.*).

Recent studies in three countries in the Caribbean, conducted through the auspices of the Caribbean Planning for Adaptation to Global Climate Change (CPACC) project's component five – Coral reef monitoring for climate change impact, have indicated that significant amounts of coral bleaching are observable on the coral reef systems of the region (CPACC unpublished reports). This coupled with stresses of an anthropogenic nature can impact on the species composition of Caribbean fisheries as the coral reef ecosystem is degraded. Increased mortality of snapper and grouper species, such as that observed at the end of the warm season in Sénégal in 1987 (Caverivière and Touré 1996), is also possible. Reproductive biology of snapper species may also be impacted by increased sea temperatures, given the "impression" of extended seasons and affect reproductive seasonality (c.f. Grimes, 1987) of snappers. In contrast to the possible negative effects on mortality, it is suggested that higher temperatures may lead to increased growth of somatic tissue in snappers (Hekimoglu, Luo and Ault, in press); additionally, it has been shown (Rakocinski et al. in press) that within-site variability in growth of juvenile white trout is primarily (and positively) driven by water temperature.

The extent to which global climate change may increase the incidence of disease in fish, was highlighted in late 1999 when a number of islands in the southern Caribbean suffered mass mortalities of several species of reef-associated fish. Studies carried out in Barbados showed that the fish died due to the effects of infection by *Streptococcus iniae* (Willoughby et. al. in press). A plume of water originating in the region of the Orinoco River in South America and characterized by high chlorophyll-a concentrations and low nocturnal oxygen levels, in addition to atypically high seawater temperatures, were recorded in south and central Caribbean at the time of the kill. It is suggested that the fish had not been previously exposed to the pathogen and that the atypical environmental conditions, including elevated seawater temperatures, high phytoplankton concentration, and reduced oxygen levels worked in concert to stress the fish and increase susceptibility to the bacteria (*ibid.*). This occurrence is consistent with the suggestion of the draft third assessment report of the IPCC Working group (IPCC 2001a) which has indicated that sea surface warming would result in increased frequency of marine diseases. Placed within the context of global climate change, this raises an ominous red flag for the fisheries of the region.

The Sub-committee on Environment of ICCAT's Standing Committee on Research and Statistics (SCRS) in 1996 noted that "thermal anomalies have significant effects on the catchability of tunas (and) cause major variations in recruitment (thus, these and other) environmental anomal(ies) could have ... negative effects and be a potential danger to conservation of (tuna) resources" (author's parentheses; ICCAT 1997). The 1999 meeting of the Sub-Committee noted that "strong inter-annual fluctuations in tuna abundance ... are more likely to be linked to the effects of environmental conditions than to changes in stock abundance" (ICCAT 2000). Thus, climate change is also likely to have a significant, and possibly negative, impact on tuna, and we also suggest, other pelagic fisheries in the region.

Infrastructure and Vessels

In most of the eastern Caribbean States more than 50% of the population reside within two kilometres of the coast (Watson et al. 2000). Projected sea level rise, which may conceivably be accompanied by inundation, increased flooding, coastal erosion with consequential losses especially during extreme events (Watson et al. 2000), places most of the (coastal) infrastructure associated with the fisheries sector at risk. In fact, significant damage to fish landing sites, fish markets (Figure 3), fishermen's locker rooms, and other onshore facilities (which have recently been constructed with foreign aid?), could result from any increase in the frequency of intensity of extreme events such as floods, tropical storms and storm surges (Pernetta 1992, Alm et al. 1993, both cited in Watson et al. 2000). About 16% of Antigua and Barbuda's fishing fleet was either destroyed or lost as a result of Huriccane Luis and another 18% was damaged (Government of Antigua and Barbuda 2001). The severe and costly damage caused by Hurricane Lenny (1999) on fisheries infrastructure in the islands of Dominica and St.Lucia is testimony to the above fact. (Lawrence and Magloire 1999, SMMA 1999).

Preparedness for the Impacts of Climate Change

In preparing for the impacts of climate change, the cost of insurance is an important factor that must be taken into consideration (Watson et al. 2000). Insurance costs are highly sensitive to the effects of catastrophic events such as hurricanes and floods. High-risk locations usually face higher insurance premiums, and thus the increased likelihood of extreme events resulting from climate change would thus be likely to raise costs of insuring fisheries infrastructure, a direct increase in costs to the industry.

Fishing vessel owners are at present hard pressed to obtain insurance coverage for their vessels. Since most of the vessels in the region are less than 12m in length, the actual design and construction methods in use evolved from experience rather than from a structured approach to fishing vessel development and safety. The industry led initiatives to develop new vessel designs or to modify old vessels have been implemented without professional advice in naval architecture or marine engineering. This has led to a perception of fishermen's vessels as high insurance risks. This perception will be reinforced within the context of increased frequencies or intensity of extreme weather events. To adapt to this likelihood, fishermen would be constrained to ensure that their vessels are more resistant to the vagaries of the weather. This would perforce be associated with the adoption of building codes and other design and construction standards (whether for infrastructure or for vessels). This may mean a consequential increase in vessel and other construction costs, again increasing the overall costs to the fisheries sector.

Adaptation and Mitigation

It is hard to predict the quantum of damage or the cost of adaptation. That would vary depending on the kind of mitigation needed, the area to be protected, the design specifications to be adopted, and the availability of the necessary construction materials. What is fairly well accepted, however, is that the overall cost of infrastructure protection or damage mitigation is likely to be beyond the financial means of the island States of the eastern Caribbean islands.

A study that estimated loss potential of hurricane events associated with 50-year return periods and done as part of the Caribbean Disaster Mitigation Project illustrates this. The average estimated loss to wharves for the three countries studied (50% upper prediction limit maximum likelihood estimate) was on the order of EC$ 5.7 million (Vermeiren and Pollner 1999). Since in the eastern Caribbean islands, wharves and piers are invariably not distinguished between those used for fishing vessels as opposed to other vessels, if one were to equally prorate this estimate based on the numbers of different types of vessels (say trading, fishing, transportation, tourism, recreation) utilizing these onshore facilities, the rough estimate of the value/loss to the fishing industry would be on the order of EC $ 1.1 million (the replacement costs estimated similarly would be on the order of EC$ 124.1 million; *ibid.*). While this median (too low half the time and too high the other half the time) estimated costs might not be excessive in the context of large economies, they represent considerable financial resources that the eastern Caribbean islands may have to reallocate (Watson et al. 2000). In addition to the coast of replacement and repair to fishing vessel and gear caused by a hurricane, there is a loss of revenue due to the disruption of the fishing industry. After hurricane Luis in Antigua and Barbuda, many individuals who became unemployed as a result of the closure of hotels and businesses sought short-term employment in fishing (Government of Antigua and Barbuda 2001). Most of this short-term effort was probably directed at already over-exploited near-shore resources (*ibid.*), thus the immediate response to increased intensity and frequency of hurricanes may be a concomitant increase in the level of overexploitation of near-shore resources. In Dominica after Hurricane Lenny, much of the employment generated by the fishing industry was temporarily compromised in light of the losses to infrastructure, equipment, coastal habitats, and the (forced) decommissioning of one west coast fishing fleet (Lawrence and Magloire 1999).

The implications of severe changes in the fisheries sector, is not to be underestimated or overlooked. Of major concern should be the question of how would fishers adapt to possible changes in fish populations, and consequently the potential for exploitation. If marginal fishers are not able to adapt to the change, then the question of their re-deployment in other already stressed sectors may pose a daunting challenge for administrators and governments. If as already indicated that change is likely to take place faster than the ability to adapt, then the question of retooling the adaptable fishery can be an expensive one, given that the appropriate fishery can be readily identified, and that the appropriate training provided in a timely manner.

Traditional fishing methods such as seine fishing rely on a certain type of physical near-shore environment that may be changed as a consequence of sea level rise. This can conceivably mean that this type of fishing may no longer be possible. In a number of OECS Member States, the beach seine fishery contributes a significant part of the landings and fishing effort (as much as 40% in Dominica). In a number of communities where often it is the share of the catch from this fishery, given to persons who assist in hauling the seine, that provides their daily protein. Included in the social cost may be the need to retrain or provide alternative employment for beach seine fishermen, as well as alternative sources of animal protein for those who depend on this fishery for subsistence.

As seen the world over, recreational fisheries also exist where persons cast hand held lines directly from shore. While little economic gain accrues from this, the social benefits of recreation cannot be discounted. The cost to the economy of mitigating the impacts of reduced opportunity for recreation may not yet be quantifiable, but as for sport it is fairly well established that the absence of this social safety valve can have a (negative) ripple effect on the society.

Changes in the biology of fish populations can be detected through identifiable indicators in the short term, but the extent to which these changes occur is not easily determined. This would make it difficult for the resource manager to employ measures aimed at the sustainable exploitation of fish populations simply because the resources to do so are not readily available to assist in these determinations. Management of the use of fishery resources then takes on a new and complex dimension, further taxing the already limited capabilities or capacities of fisheries departments. However, issues of fisheries management take on a totally different complexity if potential impacts are to be elevated to new dimensions. Consider not only changes in biology but in the behavior of schools as a consequence of alterations in oceanographic conditions. Changes in thermoclines, for example, as a result of influences of increased ocean temperatures are likely to influence the vertical migratory patterns of schools to the extent that accessibility to fishers is compromised. The extent to which behavioral changes are influenced will be dependent on the magnitude of changes in the thermal envelope, changes in oceanographic conditions as a result of alterations to the temperature regime, and the persistency of such changes. The temporal persistence of such changes may result in permanent alterations in the behavior and physiology of populations.

It is suggested that the seasonal changes now evident in the fisheries of the region are the result of changes in physical oceanographic conditions. An analysis of climatic variables in the western tropical Atlantic from 1978 - 1985 (Muller-Karger 1990) point to the possibility of temperature playing a significant role in migratory patterns in fish, recognizing that "temperature changes are associated with the seasonal movement of different water masses into the region and erosion of the seasonal thermocline by winds." The link between changes in circulation patterns and the appearance/disappearance of fish populations around the Lesser Antilles (Muller-Karger 1990, Mahon 1990), support the argument that changes in ocean temperatures will affect fish movements either directly or indirectly through other temperature dependent variables. It is further surmised that as a result of the influence of elevated sea temperatures, changes in the patterns of global mass movements of water masses such as the El Nino-Southern Oscillation and the North Atlantic Oscillation will play a significant role in enhancing localized impacts of climate change.

The consideration of all these factors possibly paints a grim picture of fisheries management and development in a region not known for its ready adaptability to change. A comprehensive analysis of possible changes in the behaviour of fish stocks as a consequence of climate change is beyond the scope of this paper as space and time will not permit discussion on all factors that are likely to have an effect on fisheries. The major question remains - how does one develop a management strategy when changes in the characteristics of fisheries take place at a rate greater than the ability to adapt to change?

Fisheries management and development agencies must take this question into consideration for long-term planning strategies for fisheries development — to determine priorities for action, to steer development away from the areas likely to exhibit the greatest rate of change, and to provide a greater concentration on the more resilient fisheries. However any shift towards resiliency will be costly both in terms of retooling the industry and in the manpower requirements for securing that change, a hard fact that must be absorbed into the planning for change.

CONCLUSIONS

To remove the suggested impacts of climate change out of the realm of speculation and into that of probability underscores the need for a fully integrated approach to vulnerability assessment. The interaction of various biophysical attributes such as size, elevation and relative isolation, with the islands' socio-economic and socio-cultural character ultimately determines vulnerability. Further, since some eastern Caribbean islands are prone to periodic non-climate-related hazards such as earthquakes and volcanic eruptions, the overall vulnerability cannot be accurately evaluated in isolation of these threats (Watson et al. 1997).

It is also important to take into consideration the value of non-marketed goods and services such as subsistence assets, community structure, traditional skills, and knowledge provided by the fisheries sector, and which would also be at risk from climate change. In the eastern Caribbean islands these assets are just as important as marketed goods and services. Determining the cost of change to the society in general as some values are eroded in the face of altered traditional practices, a consequence of altered ecosystems on which livelihoods are dependent, will be difficult, but may have far reaching implications.

Policymakers in the eastern Caribbean islands will, as in the rest of the world community, have to decide to what extent they want to take precautionary measures by enhancing the resilience of their more vulnerable systems by means of adaptation. The uncertainty in the magnitude of climate change impacts does not mean that SIDS cannot better position themselves to cope with the broad range of possible climate changes or to protect against possible future outcomes (IPCC 1996b). Delaying such measures may leave a nation poorly prepared to deal with adverse changes and may increase the possibility of irreversible or very costly consequences. A proactive approach to securing change in the industry will obviously be less costly than attempting to address change after it has taken place. Economic and social consequences must inform developments on the refocusing of the sector if the sustainability of livelihoods of fishers is to be guaranteed.

The challenge of addressing climate change raises an important issue of equity, namely the extent to which the impacts of climate change or mitigation policies create or exacerbate inequities both within and across nations and regions" (IPCC, 2001b). As a guiding principle, policies and development programmes which seek to use resources in a sustainable manner, and which can respond effectively to changing conditions such as climate change, would be beneficial to the eastern Caribbean islands even if climate change did not occur. As part of the "urgent requirement" (McConney 2000) of an integrated ocean policy, sectoral policies and programmes need to be implemented for the fisheries sector without hesitation if it is to survive the onslaught of global climate change.

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