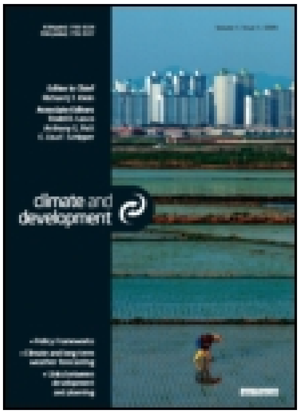

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climate and development

The implications of global climate change for fisheries management in the Caribbean

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Concerns about the socio-economic impacts of observed and projected climate change have been high on the research agendas of scientists for the last several decades. According to the Intergovernmental Panel on Climate Change, the recent observed warming is largely human induced, and the trend will continue well into the next century owing to 'thermal inertia', related to the concentration of greenhouse gases already emitted to the atmosphere. While there is a dearth of research on the effects of climate change on commercial and artisanal fisheries in the Caribbean, valuable insights can be gleaned from observations in other jurisdictions. This paper concludes that the consequences of climate change on Caribbean fisheries are likely to be mostly negative. Adverse impacts are expected to manifest themselves through habitat alteration and loss, reduced abundance and diversity, and shifts in distribution induced by changes in ocean currents. Stakeholders in the regional fishing industry might therefore wish to give greater credence to the challenges posed by climate change and climate variability than currently appears to be the case. Appropriate response strategies may not require radical changes in current approaches to management, but rather more effective implementation of existing and proposed arrangements.

Keywords: adaptation; Caribbean; climate change; fisheries; vulnerability

1. The global context

Global mean air temperatures have increased by approximately 0.7°C during the 100-year period 1906–2005. For the next two decades, a warming of about 0.2°C per decade is projected for a range of greenhouse gas (GHG) emission scenarios (IPCC, 2007). In addition, during the 20th century, global sea levels rose at a rate approximately 10 times faster than the average rate for the previous 3,000 years (IPCC, 2007). Outputs from a suite of climate models indicate that human-induced warming (approx. 0.1°C per decade) and incremental sea-level rise would continue for centuries due to inertia in the climate system, even if GHG concentrations were to be stabilized at year 2000 levels (IPCC, 2007).

Stakeholders in the fisheries sector should equally be concerned about the post-1900 increases in frequency, intensity and persistence of warm (El Niño) phases of the El Niño Southern Oscillation (ENSO), as well as an observed trend of increasing sea-surface temperatures. Before the end of the current century, mean global sea-surface temperatures are expected to be approximately 1.0–2.0°C higher than the 1990 mean (IPCC, 2001). In the specific case of the tropical oceans, temperatures are projected to be 2°C by the 2050s and 3°C higher by the 2080s, relative to the same 1990 baseline (Lal et al., 2002). The link between ocean warming, El Niño occurrences and coral bleaching is now well established, and there is considerable observational evidence to show that the most intense bleaching events since 1900 have all occurred in those years

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when the El Niño signal has been strongest (Glynn, 1984; Goreau et al., 2000; McWilliams et al., 2005; Oxenford et al., 2008; Clark et al., 2009).

Ever since publication of the First Assessment Report of the Intergovernmental Panel on Climate Change in 1990, a large volume of literature has emerged on the observed and projected impacts of climate change and climate variability on terrestrial and marine habitats, and their associated assemblages of flora and fauna. The literature provides an abundance of evidence of a wide spectrum of responses from the species to the community level in all latitudes, and documents observed as well as projected climate change impacts on all socio-economic sectors, including fisheries (IPCC, 1990, 2001, 2007; Walther et al., 2002; Edwards and Richardson, 2004; Winder and Schindler, 2004; Garpe et al., 2006). Regrettably, focused investigations on the impacts of climate change and climate variability on Caribbean fisheries has lagged considerably behind the work conducted in other regions. However, notwithstanding the dearth of region-specific research, there is both an opportunity and a need for Caribbean fisheries stakeholders to build upon the existing global knowledge base, as they become increasingly confronted with the inevitability of designing mitigation and adaptation strategies to global climate change.

2. Linking climate change and fisheries: What do we know?

While there is a need for considerably more research especially at the species level, there already exists a good generic understanding of the *potential* impacts of climate change and climate variability on key factors and processes that influence recruitment, abundance, migration, and the spatial and temporal distribution of many fish stocks. For instance, the consequences of GHG emissions on the seasonality and intensity coastal upwelling and the implications for fish and other marine organisms have occupied the attention of scientists for many decades (Bakun, 1990; Wiafe et al., 2008). This is well demonstrated in the case of the California Current, where both intensification of upwelling and seasonality changes in the phenomenon have been documented (Diffenbaugh et al., 2004). The impact of CO_2-induced warming is equally well documented for the upwelling region of the Gulf of Guinea, where zooplankton biomass decreased by approximately 6.33 ml per 1,000 m^3 $year^{-1}$ between 1969 and 1992, in phase with sea-surface warming (Wiafe et al., 2008). Coincidentally, *Calanoides carinatus*, a crustacean whose appearance is observed only in the major upwelling season (July–September) and known to be highly sensitive to temperatures $>23°C$, also decreased in abundance (Wiafe et al., 2008). Similar observations have been noted at various other upwelling locations including South Africa (Schumann, 1999), Northwest Africa (McGregor et al., 2007), Chile (Arcos et al., 2001; Escribano and Schneider, 2007) and India (Krishna, 2008).

Climate change is also projected to have indirect effects on the fisheries sector through changes in phenology, including alteration of length and timing of spawning seasons, higher mortality, increased larval swimming speed, higher mortality and reduced larval duration (Walther et al., 2002; Munday et al., 2008; Lett et al., 2010). It has also been suggested that the variation in responses to warming by species appears to be affecting relationships at different trophic levels and altering '…the synchrony of timing between primary, secondary and tertiary production' (Edwards and Richardson, 2004, p. 106). Moreover, there is increasing support for the view that alteration in seasonal migration patterns of many pelagic species is a direct response to climate-induced changes in zooplankton productivity, and is likely to impact recruitment success (Clark, 2006; Mackenzie et al., 2007; Rijnsdorp et al., 2009).

Equally well documented is a noticeable poleward shift in the range of various marine species, in response to ocean warming both at surface and at depth (Fields et al., 1993; Sagarin et al., 1999; Rose, 2005). Murawski (1993) has shown that a number of pelagic species including Atlantic mackerel and Atlantic herring tend to migrate poleward by approximately 0.5–0.8° of latitude for every1°C increase in mean sea-surface temperature. Similarly, Perry et al. (2005) have demonstrated that almost two-thirds of exploited and non-exploited North Sea fishes have shifted either poleward or to greater depth as a response to elevated sea water temperature over the last 25–30 years. This is further supported by the findings of Field et al. (2006), who documented a significant increase in the number of tropical and sub-tropical species of planktonic foraminifera in the California Current, but a decline in abundance of temperate and sub-polar species during the 20th century. Barry et al. (1995) have also noted a northward shift in the range of eight 'southern' invertebrate fauna along the California coast between 1931 and 1994, when mean temperatures in the bay increased by 0.75°C. Cheung et al. (2009a, b) projected a major poleward redistribution of many species by more than 40 km per decade, and that developing countries in the Tropics will be the biggest losers. This latter finding is underscored by the recent work of Allison et al. (2009), who noted that economic losses in the fishing industry will be greatest in the most vulnerable least developed countries, where dependence on the industry is very high. These projections will certainly increase the discomfort of fisheries stakeholders in the Caribbean and elsewhere (see e.g. Daw et al., 2009; McConney et al., 2009; Badjeck et al., 2010), where the industry is already confronted by challenges such as weak management structures, overfishing, and habitat alteration and loss (McConney et al., 2009; FAO, 2010).

These findings corroborate the conclusions of Roemmich and McGowan (1995), who had earlier noted an 80 per cent decrease in macrozooplankton biomass off the coast of southern California since 1951. This was linked to ocean-surface warming which exceeded 1.5°C in some localities, reduced upwelling and a smaller volume of inorganic nutrients to support the zooplankton population. These changes correlate well with 20th century anthropogenic warming at depth, a trend not as consistently observed in the earlier part of the century (Barnett et al., 2005). Similar findings are documented for the northeast Atlantic where a decline in phytoplankton abundance has accompanied sea-surface warming, with the reverse occurring in cooler regions to the north (Richardson and Schoeman, 2004). It is projected that with the continued warming trend, the spatial distribution of primary and secondary pelagic production would be affected to the extent that it would have a significant impact on the re-distribution of Atlantic fish stocks (Rose, 2005; Alter et al., 2010; MacNeil et al., 2010).

The sensitivity of tuna stocks to temperature changes, especially during ENSO, and the spatial variation in catch has been studied in the Pacific, and Maldives in the Indian Ocean. In the Pacific, there is a tendency for both skipjack and yellow fin tuna to move eastward during the El Nino phase, resulting in a significantly reduced catch. This is associated with the zonal displacement of the Pacific 'warm pool' where these species are dominant (Lehodey et al., 2003; Brander, 2007; Miller, 2007). In the case of the Maldives, skipjack catches tend to decline in El Niño years, while the yellowfin harvest increases. Contrastingly, during La Niña years, skipjack catches increase, while there is a decrease in other tuna species (MOHA, 2001). Overall, the IPCC (2007) projects that climate change is likely to lead to migration and ultimately to the decline of these tuna stocks.

Research indicates that climate change will also lead to other more complex biological changes and responses in marine organisms, including fish. For example, it has been shown that patterns of larval transport and population dynamics are being affected by observed changes in ocean circulation. It is also suggested that climatic impacts on a few 'leverage species' could ultimately lead to far-reaching community-level changes (Harley et al., 2008; Munday et al., 2008). In addition, there is evidence which suggests that the development and survival of many fish species may be impacted more by changes in ocean chemistry (linked to climate change) than by elevated sea-surface temperatures per se. Moreover, these climate-induced changes are likely to be exacerbated by other well-documented anthropogenic stresses, including overfishing (IPCC, 2007; Harley et al., 2008).

3. What are the key climate change projections of relevance to the Caribbean fisheries sector?

Apart from the obvious implications of the global observations highlighted above, there are additional avenues via which climate change will impact on the Caribbean fisheries sector, directly and indirectly. The discussion that follows is not intended to be exhaustive; it merely seeks to highlight issues of relevance to the region's fisheries sector for which sound, scientific consensus is emerging. It is also anticipated that the analysis will contribute to the development of a clearer understanding of the range of climate-related risks to which the sector will be exposed.

Of critical significance is the fact that the pattern of observed temperature changes in the region is generally consistent with the global trend (IPCC, 2007; Hayes and Goreau, 2008; Jury and Winter, 2010). Regional temperatures increased in the 20th century with the 1990s being the warmest decade since 1900. Outputs from a suite of global climate models (GCMs) suggest that surface air temperatures in the Caribbean will continue to increase in the present century by between 0.5° and 1°C during the period 2010–2039, 0.8° and 2.5°C in the decades 2040–2069, and 0.94° and 4.8°C between 2070 and 2099. Recent climate model runs for the Eastern and Southern Caribbean show that a similar trend in sea-surface temperatures can also be expected.[1] This is shown in Figure 1, which is derived from the HADCM 3 and ECHAM4 GCM, downscaled to 25 km resolution using the PRECIS model. These results clearly suggest that sea-surface temperatures will not only increase during the summer (JJA), but also during the traditional 'cool' season (DJF). Of equal interest is the indication that both the diurnal and seasonal temperature ranges will also decrease. This has particularly severe implications for Caribbean corals which would, under such circumstances, be consistently exposed to even higher minimum and maximum temperatures than at present.

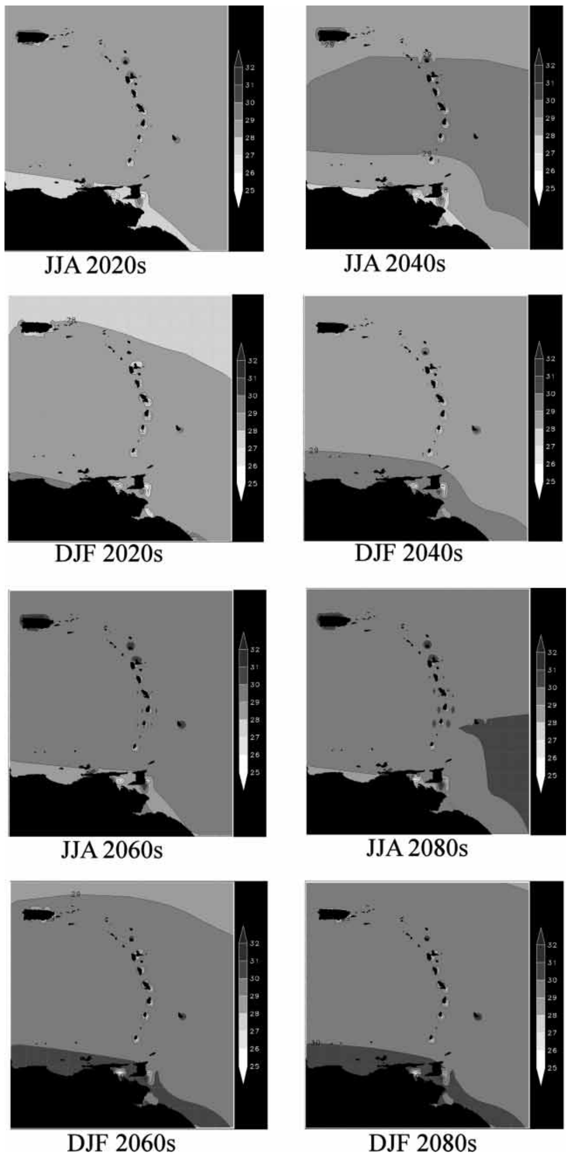

FIGURE 1 Projected decadal winter (DJF) and summer (JJA) sea surface temperatures for the Eastern Caribbean.

There is strong support from the observational records that elevated sea-surface temperatures are a primary cause of coral bleaching. The most severe episodes in the past have coincided with years when the El Niño signal was strongest, for instance in 1983, 1985, 1997/98, 2005/2006 (Glynn, 1984; Hoegh-Guldberg, 1999; Goreau et al., 2000; Alvarez-Filip et al., 2009). In the 1997/98 event, more than 95 per cent of Pacific corals were bleached, and approximately 25–30 per cent in the Caribbean. The most recent intense bleaching episode in the Caribbean occurred during the summer of 2005, when bleaching occurred in an area extending from Mexico in the north, to Tobago in the south. A detailed case study of the event at Barbados revealed that throughout the summer, sea-surface temperatures were consistently between 1° and 2°C above seasonal maxima, and all nearshore and offshore habitats were affected (Oxenford et al., 2008). The situation in Barbados was not unique to the Eastern Caribbean, since many other islands also reported significant bleaching. Certainly, fishers will find no comfort in these events, particularly since they are projected to become more frequent in the future.

Another emerging issue that could be potentially worrisome for fisheries stakeholders is the observed and projected change in the level of acidity of the world's oceans, associated with increasing anthropogenic emissions of CO_2. Research has shown that the world's oceans have become approximately 30 per cent more acidic (i.e. a reduction in pH from 8.2 to 8.1 units) since 1750 – the start of the Industrial Revolution (IPCC, 1990, 2001, 2007). Although the effects on marine organisms are not yet fully understood, ocean acidification is expected to be a limiting factor in the development of corals and other organisms, which use carbonate ions in sea water to build calcium carbonate shells and exoskeletons. With rising CO_2 emissions, more CO_2 is absorbed by the oceans, sea water becomes more acidic by stripping out carbonate ions, thus making it more difficult for organisms to form shells (Kleypas et al., 2006; Fabry et al., 2008; Talmage and Gobler, 2010). With global CO_2 emissions continuing to increase at a rapid rate, the threat to reef habitats and associated fauna, including fish assemblages, will become more pronounced (Cooley and Doney, 2009; Silverman et al., 2009). Since the reef fishery constitutes a vital component of small-scale activity, this sector of the industry is likely to be most affected. Notwithstanding the findings reported above, further research is needed to fully explore the relationship between ocean acidification and marine organisms including fish, as a few controlled laboratory studies (see, for instance, Iglesias-Rodriguez et al., 2008) appear to suggest that not all marine species may experience reduced rates of calcification.

While there is, as yet, no clear indication that tropical cyclones (hurricane) frequency will change, modelled data indicate that peak wind intensities are expected to increase by approximately 5–10 per cent by the 2050s (Emanuel, 2006; IPCC, 2007). Moreover, of those systems that reach hurricane status, a greater proportion appears to be attaining a status of category 3 and above than in prior decades. For instance, in the first seven years of the decade 2001–2010 eight category 5 hurricanes developed, compared with a total of 23 recorded between 1928 and 2000[2] (Table 1). Although it is still too early to suggest that this represents a trend, recent experience has shown that a number of these systems may be reaching high intensity over a

TABLE 1 Category 5 Atlantic Hurricanes, 2001–2007

Hurricane	Year	Maximum winds, km/hour (mph)
Isabel	2003	266 (165)
Ivan	2004	266 (165)
Emily	2005	290 (180)
Katrina	2005	282 (175)
Rita	2005	290 (180)
Wilma	2005	298 (185)
Dean	2007	266 (165)
Felix	2007	266 (165)

Source: NOAA hurricane database.

shorter duration than previously observed. This is exemplified by hurricanes Wilma (2005) and Gustav (2008), which moved from tropical depression status to category 5 and 4 hurricanes in less than 24 hours. However, if this becomes a trend, fishers will be faced with the prospect of having greatly reduced time frames for securing boats, gear and other equipment. Similarly, the expected increase in maximum wind speeds, combined with currently projected increments of sea-level rise for the region, would amplify storm surge effects, and accelerate coastal erosion and loss. This enhanced exposure would not only cause damage to equipment and gear, but would also place critical infrastructure such as wharves jetties and other fish landing at very high risk under this likely scenario. Thus, apart from having to adapt to altered conditions such as changes in fish stock distribution and abundance, stakeholders will also be confronted by the possibility of increased storminess at sea and on land, and higher risk to the safety of fishers as well as vessels. The resulting disruption to both sea- and shore-based operations would evidently have a negative impact on the livelihood of fishers themselves and other dependent stakeholders (Brander, 2007; Allison et al., 2009; Daw et al., 2009; McConney et al., 2009). For these reasons the call echoed by researchers including Mahon (2002), Garcia and Cochrane (2005), and more recently by Badjeck et al. (2010) for action to improve vessel quality and seaworthiness, safety equipment and the routine enforcement of safety protocols is not only timely but urgent.

4. Vulnerability of Caribbean small-scale fisheries to climate change

As elsewhere, the threat posed by climate change to the fishing industry in the Caribbean assumes an important economic and social dimension as well. Globally, the sector is critical to livelihoods in many ways, including its contribution to revenue earnings, nutrition and food security, employment generation and poverty reduction (Andrew et al., 2007; Conservation International, 2008; Badjeck et al., 2010; FAO, 2010; Garcia and Rosenberg, 2010; Rice and Garcia, 2011). Within the CARICOM region, the sector employs just under 200,000 persons, earns between US$5,000 million and US$6,000 million in foreign exchange, and accounts for approximately 10 per cent of the region's protein intake (Caribbean News Now, 2011). It has been estimated that for the year 2000, the annual net benefits to the Caribbean provided by coral reefs through fisheries amounted to some US$300 million (Burke and Maidens, 2004). For the Montego Bay Marine Park, Jamaica, the net present value of the reefs associated with fishing was calculated to vary between US$1.7 million to US$7.5 million as far back as 1995 (Gustavson, 1998). In the both the Cayman Islands and the Turks and Caicos, revenues from fisheries earned around US$3.7 million (Carleton and Lawrence, 2005). For the Caribbean as a whole, it is estimated that dive tourism based on coral reefs earned around US$2.1 billion in 2000 (Burke and Maidens, 2004). Coral reefs are also estimated to have contributed US$43.5 million to Tobago's economy in 2006, or 15 per cent of GDP (Burke et al., 2008).

There is universal agreement that the vulnerability of any sector to climate change is a function of (a) the degree of exposure to the threat; (b) the sector's sensitivity to the risk; and (c) the capacity of the sector to cope with or adapt to the threat (IPCC, 2001, 2007; FAO, 2005). Any objective assessment of small-scale fisheries in the Caribbean's would conclude that exposure and sensitivity to the climate change threat are *high*, while adaptive capacity is *low* (see e.g. FAO, 2005; IPCC, 2007; Salas et al., 2007). Most of the region's fishing facilities tend to congregate in low-lying vulnerable coastal areas. These serve not only as the residential locations of the fishing communities, but also as the 'haul up' sites for vessels, gear and other equipments. These sites are also frequently used for boat building and repair. The *exposure* of the sector to the adverse consequences of climate change would therefore be heightened by factors including sea-level rise and an increase in the intensity of hurricanes and storm surge, as projected (Anthes et al., 2006; Emanuel, 2006; Mimura et al., 2007; Knutson et al., 2010). Some critical fish habitats show high *sensitivity* to climate variables, and consequently are expected to be less resilient in a warmer world. This is demonstrated by the widespread bleaching of coral reefs due to higher sea-surface temperatures, and increasing salinization of mangrove nurseries as a result of sea-level rise (Mimura et al., 2007; Munday et al., 2008; Badjeck et al., 2010). These and other factors will almost certainly combine to increase the overall vulnerability of the sector.

The ability of Caribbean fishing communities to cope effectively with these changes, that is, their *adaptive capacity*, is arguably low, and for a variety of reasons. For instance, in many artisanal communities there is heavy dependence on fishing as the only source of employment, income generation and livelihood support, so that fishers have traditionally not diversified beyond this activity. Any necessity to explore other options in the future is likely to be dislocating for stakeholders, and may require some investment in 'retooling' of skills. Further, most small-scale fishers have little or no access to financial resources or insurance on favourable terms – requirements that are essential if the sector is to be able to rebound in the aftermath of extreme events, which are projected to become more frequent and/or intense in the future. Equally, while the sector has demonstrated considerable resilience to climate variability in the past, factors such as lack of consistent governmental and institutional support, weak fisher folk organizations and consequently low bargaining power will further compromise adaptation capacity in the future.

While the list of factors presented above is not exhaustive, it provides a reasonable indication of the issues confronting the fisheries sector in the Caribbean. Since it is widely anticipated that climate change will amplify these challenges, appropriate and timely interventions will be required in order to minimize the adverse effects on stakeholders. Some possible approaches are offered for consideration in the ensuing section of this article.

5. How might the Caribbean fisheries sector respond to climate change?

Like other sectors, the fishing industry in the Caribbean, in particular its small-scale sector, is already experiencing some of the negative impacts of anthropogenic climate change. Since elimination of the source of the problem is practically unachievable, adaptation is the only option. Given the range of impacts and challenges posed by global climate change, any meaningful response will inevitably require a suite of practical measures aimed, inter alia, at building resilience in the sector, exploiting available opportunities and minimizing the economic and social dislocation of fishers. At the very minimum, the design of an adaptation package should reflect the status of the science, it should be flexible in order to benefit from new research findings, it should exploit the rich knowledge base of key actors, that is, the fishers, while at the same time being cost effective, and socially and culturally acceptable to stakeholders.

It should be emphasized from the outset that adaptation must be regarded as a long-term *process*, not a short-term project. It should also be stressed that the process does not necessarily imply the abandonment of existing management practices and the implementation of new, high-cost strategies. While some new initiatives may be required, stakeholders may wish to begin the process by simply strengthening existing management structures and *mainstreaming* 'adaptation thinking' into these arrangements. Fortunately for the Caribbean, there is already a basic platform (e.g. legislation, advisory committees, a regional coordinating mechanism) in place which can be adjusted, as required, to accommodate sound adaptation practice.

First, there should be an ongoing commitment to implement those actions that will improve the resilience and therefore the sustainability of the sector (see for instance IPCC, 2007). Building resilience in the sector must focus on the implementation of efficacious actions that seek not only to improve the quality of the aquatic and coastal ecosystems, but also on those human systems (e.g. governance arrangements and legislation) that are vital to sustaining regional fisheries. In this regard the strategy should be guided by pragmatism, so that the initial emphasis should be on activities over which countries have some control and which, if efficiently and promptly implemented, will have short- as well as longer-term adaptation benefits. Thus, while the region can do little to reverse the trend of global GHG emissions and higher sea water temperatures, actions can be taken to improve the resilience of habitats and targeted species to the adverse effects of climate change. Such actions would include (i) strict enforcement of existing marine pollution control protocols and abatement of contamination from land-based sources; (ii) reactivation and expansion of habitat protection and restoration programmes; and (iii) control of non-sustainable practices such as overharvesting, and the use of inappropriate harvesting methods.

The benefits of applying good governance and *co-management* principles in the small-scale fisheries sector have been widely discussed in the literature (Pomeroy and Berkes, 1997; McConney et al., 2003). Governance and co-management systems that are based, inter alia, on an understanding of ecosystem health and thresholds, partnership, inclusiveness, equity and sustainable livelihoods should also be regarded as vital elements of climate change adaptation planning. These and other appropriate strategies such as leveraging the benefits of networks, through, for example, the strengthening of cooperatives, facilitation of access to financial and other resources and the timely sharing of information, can enhance the resilience of fisheries stakeholders to some of the adverse impacts of climate change.

As part of the adjustment to changing conditions, stakeholders may also wish to consider whether opportunities exist for targeting currently unexploited species, in a sustainable manner. Evidently, acceptance of 'new' or 'non-traditional' species will be affected by factors such as consumer perception, culture and taste, but such impediments may be overcome with the implementation of aggressive, innovative marketing programmes, education and outreach. The harvesting of non-exploited species, if found to be feasible, would not only diversify the options available to fishers for maintaining their livelihood, but might simultaneously alleviate the pressure on heavily exploited stocks, if only in the short and medium term. This would also make a positive contribution to the building of resilience into the sector. Agencies such as the Caribbean Regional Fisheries Mechanism and the Organization of Eastern Caribbean States (OECS) Fisheries Unit, whose missions already embody notions of adaptation, diversification and resilience building (though not explicitly defined in these terms), can play lead roles in such initiatives, in collaboration with other key stakeholders.

Since it is likely that climate change will impact negatively on the future availability of stocks, an overriding direct concern for fishers is the extent to which alternative forms of employment (seasonal or otherwise) can be pursued as an adaptation option. As suggested by Clark (2006) and Badjeck et al. (2010) the pursuit of alternatives would help to compensate for expected reductions in revenues and livelihood support caused by climate change. However, it would require the intervention and assistance of Government and the Private sector, working in close collaboration with the fishing community and affiliates. In this regard, organizations such as fisheries cooperatives could play a significant role in assisting with the creation and sourcing of opportunities, as well as the 'retooling' of fishers with new skills.

Notwithstanding the above, the reality is that although local adaptation strategies will help to cushion some present and future effects of climate change, global anthropogenic GHG emissions must be abated and stabilized urgently. There is a positive correlation between GHG forcing of the atmosphere and the severity of the impacts. The efficacy of adaptation also diminishes as the severity of impacts increase

(IPCC, 2001, 2007; Nurse and Moore, 2007). It is therefore regrettable that stakeholders in the fisheries sector have not engaged in the global debate with the same vigour as interest groups in other sectors. Since the adverse effects of climate change are expected to be greatest on low-lying small islands (Nurse and Sem, 2001; Mimura et al., 2007), the fisheries constituency must invest in its own self-interest and join the global lobby for steep emission reductions and swift implementation of agreed protocols.

The international community is currently negotiating successor arrangements to the Kyoto Protocol, with a view to reaching agreement at the 17th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), scheduled for Durban, South Africa in December 2011. Fisheries stakeholders should immediately seize the opportunity to have an effective voice at the remaining preparatory meetings and at the final decision-making forum. At the same time, the Caribbean fisheries sector must seek to equip itself to access the various climate change adaptation facilities that currently exist. *The Climate Change Adaptation Fund*, established under the Kyoto Protocol, should be a prime target. The fund was created specifically to assist vulnerable countries and communities to adapt to the adverse effects of climate change, provided that certain eligibility criteria are met. The Special Climate Change Fund is another source of financing that was also established under the UNFCCC. It can be accessed to provide funding for capacity building, technology transfer and other adaptation activities of direct interest to the fisheries sector. Stakeholders in the sector should therefore seize every opportunity to insert themselves strategically into the various processes that determine national and regional priorities for funding, under these mechanisms.

Ongoing, focused research should also constitute a vital component of the adaptation package. While it is possible to learn and apply the lessons from observations and research conducted elsewhere, more effective adaptation programmes can be designed if there is robust, region-specific information available. In this context, key research questions such as the sample listed below, readily come to mind:

- How will changing temperature, wind, salinity and circulation regimes affect the spatial and temporal abundance and migration patterns of commercially important species?
- What is the level of understanding of the population dynamics and seasonal availability of non-exploited species? What is the *harvesting threshold* beyond which these stocks might crash?
- Will there be a market for 'new' or non-traditional species? And what would be required to ensure the sustainability of that market?
- How do predators and prey respond under different climate change scenarios? (i.e. what is their sensitivity to *various increments* of warming, acidification, sea-level rise, etc.)? What is their 'natural' adaptive capacity?
- Will climate change alter the values of parameters commonly applied in fisheries management models to estimate optimal production, yield and levels of stock?
- What is the economic value of critical ecosystems such as corals, mangroves and segrasses to the region? How might climate change alter their productivity, and what would be the projected cost to the fisheries sector?
- Will there be a need to modify existing fisheries regulations and practices (e.g. extend/reduce closed seasons; issuance of permits for various fisheries), and introduce new technologies?

Full or even partial answers to these and other questions would provide valuable guidance on key issues including the optimization of catch effort, the relative vulnerability of various fisheries, the structuring of bilateral and other fishing agreements with neighbouring and extra-regional states, and types of behavioural changes that may be required of stakeholders in the interest of minimizing livelihood dislocation as a result of climate change. Such information could also be used effectively for purposes of stakeholder training and awareness. Failure to explore these issues may result in lost opportunities, that would further undermine the adaptive capacity of regional fisheries,

6. Conclusion

The observations presented above should provide a compelling reason for stakeholders in the Caribbean to accelerate the process of 'mainstreaming' climate change considerations into ongoing fisheries management programmes. While climate change may be regarded simply as an 'additional stressor', the difference is that it is one which the most vulnerable countries and communities have not invited upon themselves, and which they are poorly equipped to solve. Global and regional climate change assessments indicate that some of the Caribbean's most important economic and social sectors, including fisheries, are already being adversely impacted by climate change. Based on the current trend of increasing global GHG emissions and robust climate model projections, practically all sectors are likely to be severely affected in the future. Hence, comprehensive climate change adaptation planning for fisheries must be embarked upon with greater urgency than currently appears to be the case.

It is noteworthy that the *Strategic Plan for the Caribbean Regional Fisheries Mechanism* (CARICOM Fisheries Unit, 2002) makes absolutely no mention of 'climate change' or 'climate variability' as possible threats to the future of the fishing industry in the region. At best, this must be considered an unfortunate oversight given that the theme of the strategic plan is 'Towards sustainable development of fisheries for the people of the Caribbean'. The plan makes no contact with the impressive body of literature on the subject of climate change and fisheries that emerged in the decades 1980–2000, prior to its publication.[3] Certainly it is to be anticipated that this omission will be remedied in future iterations of the plan.

On a more positive note, there are a few initiatives underway that can make a valuable contribution to the field, two of which stand out on account of their focus and scope. The EU-funded initiative titled 'Future of Reefs in a Changing Climate' (FORCE), 2010–2014, is a collaborative effort involving 18 academic and research institutions mainly from the Wider Caribbean Region, Europe, North America and Australia. A major component will focus on the impacts of climate change, overfishing, pollution and weak governance on the health status of Caribbean reefs and the design of a suite of management strategies to respond to these threats.[4] The Caribbean Large Marine Ecosystem (CLME) project, which commenced in 2009, is a four-year GEF-funded initiative whose main goal is the 'sustainable management of the shared living marine resources of the Caribbean and adjacent areas through an integrated management approach that will meet WSSD targets for sustainable fisheries'.[5] These complementary exercises have an opportunity to fill some of the important knowledge gaps identified in Section 5 of this article, and since the projects are ongoing, regional fisheries stakeholders should seek to influence the types of products that are still to be delivered.

The solution to the climate change challenge is a global one, and the basis of that solution will likely emanate largely from outside the fisheries constituency. Yet, industry stakeholders in the Caribbean need to become more actively engaged in the global and regional debate, which hopefully will provide the consensus for a solution that is lasting and equitable. Only then are the legitimate concerns of the fisheries constituency likely to be fully ventilated, and access to available adaptation funding and other resources maximized. Such action must be regarded as a priority, if the Caribbean fisheries sector is to properly equip itself to adapt to the adverse consequences of a changing climate, with which it will be confronted for the foreseeable future.

Notes

1. This work focuses on the Eastern and Southern Caribbean, and is being conducted by the Climate Modeling Studies Group at the Cave Hill campus of the University of the West Indies in Barbados. Similar modelling experiments are ongoing at the Mona campus in Jamaica, where the focus is on the Northern and Western Caribbean.
2. Since official hurricane records have been kept, no category 5 systems have been identified prior to 1928.
3. Included in this list of publications are the IPCC's First, Second and Third Assessment Reports, which consistently reviewed and evaluated the nature of the climate change threat to the development of global fisheries.
4. More information can be found at www.force-project.eu.
5. See www.clme.iwlearn.org, for more information on the CLME.

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