

# **An Assessment of Potential Impacts of Climate Change and Climate Variability on Small-scale Fisheries in the Eastern Caribbean**

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## **ABSTRACT**

Small-scale fisheries can play an important role with respect to key development issues such as poverty alleviation, food security and pro-poor growth especially in small island developing states (SIDS). The ecosystems in which fisheries operate are very vulnerable to several factors including climate change and climate variability. This paper focuses on potential impacts of climate change and climate variability on small scale fisheries in the Eastern Caribbean.

In response to a demand for more information on the likely impacts of climate change on small-scale fisheries particularly the livelihoods of Fishers the perceptions of fishers were assessed in three selected Eastern Caribbean island countries: Antigua and Barbuda, Barbados, and St. Kitts and Nevis. Rising sea surface temperatures, variable currents and rising fuel cost were among the main factors that affected the fisheries. The perceptions of fishers based on observations at sea were compared to available scientific information on climate change and climate variability.

Fishermen throughout the Eastern Caribbean have various perceptions of climate change and climate variability. They have also identified climate and other factors that impact fisheries. Based on the findings, suggestions were made of coping strategies that facilitate adaptation of small scale fisheries to climate change and climate variability. Possible areas for further research were also suggested. It is anticipated that these can assist in shaping future climate change adaptation strategies and project ideas for fisheries in the Caribbean

**KEY WORDS:** Small-scale fisheries, impacts, climate change, perceptions, fishers

## **Impactos Potenciales del Cambio Climático y Variabilidad Climática en Pesca de Pequeña Escala en el Caribe Oriental**

La pesca a pequeña escala puede jugar un rol importante con respecto a aspectos de desarrollo claves tales como alivio de pobreza, seguridad alimenticia y crecimiento pro-pobreza especialmente en pequeñas islas estados en vías de desarrollo (SIDS). Los ecosistemas dentro de los cuales opera la pesca son muy vulnerables ante ciertos factores incluyendo cambio climático y variabilidad climática. Este escrito se enfoca en los impactos potenciales del cambio de clima y la variabilidad climática en la pesca a pequeña escala en el Caribe Oriental. La investigación se hizo en respuesta a la demanda de pescadores para mayor información sobre posibles impactos del cambio de clima en la pesca de pequeña escala, y particularmente en su sustento. Las preocupaciones de los pescadores y sus estrategias para sobrellevar estos cambios fueron investigados en tres islas estados seleccionadas del Caribe Oriental: Antigua y Barbuda, Barbados, y San Cristóbal y Nevis. Incremento de la temperatura de la superficie marina y corrientes continuamente variables se encuentran dentro de los principales factores que afectan la pesca. Las percepciones de los pescadores basados en sus observaciones en alta mar fueron comparados con información científica disponible sobre cambio climático y variabilidad climática. Los pescadores del Caribe Oriental tienen diversas percepciones del cambio y variabilidad climática, y como estos impactan la pesca. Se identificaron estrategias para facilitar la adaptación de la pesca de pequeña escala frente a los cambios y variabilidad climáticas. Se sugirieron posibles áreas para investigaciones futuras. Se anticipa que estos resultados puedan ayudar a formar las estrategias de adaptación de cambio de clima y estimular ideas nuevas para proyectos de pesca en el Caribe.

**PALABRAS CLAVES:** Pesca a pequeña escala, cambio climático, variabilidad climática, Caribe Oriental, pescadores

## **Impacts Potentiels de Changement Climatique et de Variabilité de Climat sur la Pêche de Petite Taille dans les Caraïbes Orientales**

La pêche de petite taille peut jouer un rôle important en ce qui concerne les issues principales de développement telles que l'atténuation de la misère, la sécurité de nourriture et la croissance pro-pauvre particulièrement dans les petits états en voie de développement d'île (SIDS). Les écosystèmes dans lesquels la pêche fonctionne sont très vulnérables à plusieurs facteurs comprenant le changement climatique et la variabilité de climat. Ce document se concentre sur les impacts potentiels du changement climatique et de la variabilité de climat sur la pêche à échelle réduite dans les Caraïbes orientales. La recherche a été faite en réponse à une demande des pêcheurs pour plus d'information sur les impacts probables du changement climatique sur la pêche de petite taille, et en particulier à leurs vies. Les soucis et les stratégies de faire face du pêcheur que des gens ont été étudiés dans trois ont choisi les pays orientaux d'île des Caraïbes : L'Antigua et le Barbuda, les Barbade, et la rue Kitts et Nevis. Les températures de surface de élévation de mer et les courants de plus en plus variables étaient parmi les facteurs principaux qui ont affecté la pêche. Les perceptions des pêcheurs basés sur leurs observations en mer ont été comparées à l'information scientifique disponible sur le changement climatique et la variabilité de climat. Les pêcheurs dans les Caraïbes orientales ont des perceptions diverses de changement climatique et de variabilité, et comment ceux-ci effectuent sur la pêche. Des stratégies de faire face qui facilitent l'adaptation de la pêche de petite taille au changement climatique et à la variabilité de climat ont été identifiées. Des secteurs possibles pour davantage de recherche ont été suggérés. On le prévoit que ces résultats peuvent aider à former de futures stratégies d'adaptation de changement climatique et stimuler de nouvelles idées pour des projets de pêche dans les Caraïbes.

## INTRODUCTION

There is a paucity of shared scientific information on the likely impacts of climate change on fisheries in the Eastern Caribbean. Within the region, fishers generally hear of climate change impacting the natural environment but little about how it may impact the livelihoods associated with small-scale fisheries. These include the actual fishing activity, fish processing, trade, and fisheries technical support services. Although some climate change research by universities, intergovernmental organizations, and non-governmental organizations is in progress, there has not been much aimed specifically at small-scale fisheries (SSF) in the Caribbean. The Cuban Institute of Meteorology (INSMET) in collaboration with the University of the West Indies (UWI Cave Hill and Mona campuses) is producing downscaled climate models for the Caribbean Community Climate Change Centre (CCCCC). Scientists and students at the Discovery Bay Marine Laboratory (UWI, Jamaica) and the Centre for Resource Management and Environmental Studies (CERMES) have conducted extensive marine research including climate and fisheries studies. The fisheries sector has particular significance for small island states since fish is one of the world's most widely traded foodstuffs and a key source of export earnings for many poorer countries (APO 2008). Fishers are particularly vulnerable to the direct and indirect impacts of predicted climatic changes, including changes in physical environments and ecosystems, fish stocks, infrastructure, fishing operations, and livelihoods (FAO 2008). Additionally, fishing households in general, and poor fishers in small-scale fisheries in particular have a high occupational risk in that they are prone to very high levels of vulnerability closely related to their activity (fishing) and associated livelihoods (Béné 2006).

Both at the local and global levels, fisheries play important roles as food provider and income generator with some 42 million people working directly in the sector, the great majority in developing countries (APO 2008). When those who work in associated processing, marketing, distribution and supply industries are considered the sector supports several hundred million livelihoods (APO 2008). Local supplies of fish can be highly unpredictable given the nature of the resource.

Caribbean fishers have observed changes within their natural work environment, some of which may be due to impacts from climate change and climate variability. The central theme of this research paper is to: assess the potential impacts of climate change and/or climate variability on small-scale fisheries in the Eastern Caribbean. It also provides additions to the information pool on sectoral climate change impact studies (Fisheries Sector). This information will be important to increasing awareness among the stakeholders, especially those involved in the primary (harvesting) stage of the industry.

The paper focuses on the perceptions of fishers in the Eastern Caribbean, particularly fishermen, in relation to

how they see climate change/ climate variability affecting their fishing activities and consequently their livelihoods. Efforts were made to relate perceptions of fishers based on observations at sea to available (published) scientific information on climate change and climate variability.

A simple research framework is used to show the vulnerability of small-scale fisheries. It revolves around driving forces which produce impacts which calls for adaptation and/ or mitigation. Whether these processes occur, monitoring and evaluation are critical for understanding trends in space and time. While this paper provides a generalised overview of perceived climate change impacts on small-scale fisheries, it serves as a basis for identifying possible future climate change adaptation strategies and project ideas for fisheries in the Caribbean in light of the international requirements of countries under the United Nations Framework Convention on Climate Change (UNFCCC). It is also an opportunity to integrate SSF into the work being done at the University of the West Indies (UWI), Caribbean Community Climate Change Centre (CCCCC), Caribbean Natural Resources Institute (CANARI), and other regional organizations, both in terms of doing research on impacts, but ultimately also in civil society mobilization for adaptation. It is also proposed that appropriate information will be made available for dissemination throughout the region.

## METHODS

In recognition of the need for more information on the likely impacts of climate change on small-scale fisheries particularly the livelihoods of Fishers, several research methods were utilised to achieve the stated objectives. However, the following two major categories may be distinguished: a literature search and the use of informal interviews among fishers. Where available, landing data for the selected countries was analysed to identify possible trends. The interviews included fishers whose livelihoods are hinged directly on harvesting of fish. Interviews were done individually or in groups of three to six fishers. The setting was generally a well relaxed atmosphere so that fishermen can share freely and honestly. Where possible, fisheries historical data were related to climate change events. The results from the interviews when compared with findings from the literature review show some commonalities. Although the study area was confined to the following Eastern Caribbean countries: Antigua and Barbuda, Barbados, and St. Kitts and Nevis, it is assumed that the general trends extend throughout the entire Caribbean region based on similarities in fishing methods and the scale of operations. Even within the Eastern Caribbean, there may be distinct diversities between the fisheries of the islands in the north and those in the south.

Primary data was collected mainly through interviews with fishers in the selected countries. Settings for interviews were generally informal and occurred at landing sites or in homes. A total of 111 fishers were interviewed at

their convenience (Antigua – 18 (8), Barbados – 16 (9), Barbuda – 16 (8), Nevis – 12(5), St. Kitts – 13 (6). Time limitation for primary data collection also posed a constraint to use available fishers. The fishers who were interviewed may not be the best and in a group, true perceptions may not always be revealed. In some cases, inexperienced fishers have given abnormal responses when compared with others in the group. Secondary data was retrieved mainly from the FAO database, in order to ensure consistency of data source with the assumption that there is some commonality with data collection and analysis.

Fishers were interviewed in various settings with a view of getting their perceptions of how climate change may impact their livelihoods especially fishing activities. Although there were organised groups at fish landing sites, fishers were interviewed randomly. It was evident that fishers with more (>10 years) fishing experience could better compare present conditions with those of the past. Additionally, increased success of this process was due mainly to the guidance of Fisheries Officers from each island.

The field survey was designed to get fishers' perceptions of climate change and the impact(s) of this change on fisheries. While individual fishers were randomly interviewed, where practicable the main landing sites were targeted in each country. Interviews were either with individuals or groups. However, there were several (individual) interviews which did not cover the full range of themes but were still considered in the final analysis. In addition, information was also gathered from a few selected Fisheries Officers who have considerable fishing (sea) experience and knowledge of fishing activities and can even be considered as fishers. Conclusions were based on the dominant responses from the interviews. However, lone responses were not neglected as these could also corroborate with the scientific literature.

A literature search was used to source any initial data from relevant studies on climate change and fisheries. Base reference (historic) data on fisheries and climate events within the Caribbean were also important sources of information. The information from the literature search was useful in the assessment of changes over a specific time period, whether for climatic conditions or fisheries-related human activity.

Most of the secondary data was collected from published sources the majority of which were originally derived from the Fisheries Divisions within the specific countries. Available information for large pelagic fish species in CARICOM countries, mainly from the south-eastern Caribbean where there are well established fisheries for pelagics show that the availability of large pelagic fishes, both coastal and oceanic, is highly seasonal (Mahon 2002). Additional information, for example, reports on catch and effort produced by the Fisheries Division also substantiated this point. The FAO database provided the most comprehensive set of data on fish

landings. Tabular or graphical data for individual species or specific time periods were also derived from various websites and workshop or conference reports. However, there were various gaps within the data for fisheries of the Eastern Caribbean.

Since the study is limited to the perceptions of fishers especially in relation to fishing activities, potential impacts of climate change and climate variability on many other aspects of the fisheries sector may have been neglected. Even among the fishermen, different fishing methods (diving, trapping, trolling, etc.) may be under-represented as there is a general research bias towards pelagic fisheries. The impacts of any change in climate parameters may be different for pelagic and demersal fish species. The study also tends to be general rather than specific given the timeframe and the demanded scope of research work. It should also be considered that not all perceptions are close to the facts. Thus further studies may be necessary to test the various conclusions derived from this study.

Other limitations include the level of acceptability of conclusions of this study. It is recognised that models used in the prediction of climate trends have associated uncertainties. In addition, the lack of adequate time series fisheries data is a major factor. Trends are more easily recognised over long periods but most records for the Eastern Caribbean (fisheries and climate change) fall within the last 50 years. The recent 50 year period of climate records may be less reliable compared to century or longer time-scale records (Sharp 2003).

## RESULTS

Some of the characteristics for small-scale fisheries within the selected countries are outlined in Table 1. Small-scale fisheries are scattered around the seashores of the islands, especially within sheltered bays near settlements or areas of economic activity. Their development may be hampered by inadequate infrastructure. They are generally exposed to natural calamities like floods, inundation, sea erosion and storms. However, small-scale fisheries in the Caribbean are exploited under some sort of open access regime thus the fishers show high geographic mobility and may migrate over considerable distances and operate from different landing sites.

While Table 2 presents a summary of the main results of the study it also provides general answers to the following questions:

- i) What do fishers consider to be the main features of climate change and variability? Major elements stressed include global warming as experienced by rising air and sea temperatures, more variable rainfall amounts, patterns and distribution of rainfall distribution and increased frequency and severity of tropical storms.
- ii) What do fishers perceive as the likely impacts of climate change and/or climate variability on small-scale fisheries at selected sites in the

Eastern Caribbean? The main perceptions are that there is a general decline in fish catch while the cost of fishing continues to rise as a result of increasing fuel prices. Natural fisheries habitats such as coral reefs and mangroves are also affected.

- iii) Based on the perceptions of fishers, does scientific evidence support or refute the climate change and variability impacts on small-scale fisheries? Some of the perceptions are corroborated by facts. However, it is still not clear what proportion of impacts may be attributed directly to climate change.
- iv) How can fishers cope with changes resulting from likely climate change impacts? There are wide variations in responses. Shifting to other areas of economic activity, the use of improved technology and fishing methods, more integrated management of fishing operations and abandoning fishing are some of the proposed solutions.
- v) What future research is needed on issues related to the impacts of climate change and variability on small-scale fisheries in the Eastern Caribbean? Several areas were suggested including: seasonal and local variations of currents around the Caribbean, the influence of local habitat on different fish species, possible relationships between climate change and the migratory patterns of fish and bird species throughout the Caribbean region, implications of possible impacts of climate change on marine invasive species, climate change and the occurrence of ciguatera in the north-eastern Caribbean, the relationship, if any, existing between sea level rise and fishing activity and possible linkages between changes in sea water colour and climate change.

**Table 1.** General Characteristics of Selected Eastern Caribbean Countries

Country	Location	Representative Characteristics
Antigua and Barbuda	North	Well developed demersal fishery (mainly reef fish, lobster and conch); Pelagic fisheries undeveloped.
Barbados	South	Well developed pelagic fisheries (longliners and ice-boats); Demersal fishery is minor in importance.
St. Kitts and Nevis	North	Expanding pelagic fishery (both coastal and offshore). Important demersal fisheries exist (mainly finfish and lobster with some conchs as well).

## DISCUSSIONS

Generally, fishermen perceive that global warming is occurring and has caused increased melting of polar ice sheets. Stronger and more frequent storms, effects of ground swells and impacts on the amount of fish being caught are also linked to climate change.

According to the IPCC Fourth Assessment Report, the observed averaged temperatures for all small-island regions are showing consistent warming trends over the 1901 to 2004 period (IPCC 2007b). For the Caribbean region, analyses show warming ranging from 0 to 0.5°C per decade for the 1971 to 2004 period. It is projected that atmosphere and ocean temperatures will continue to rise through to the next century. Temperature and other variations resulting from climate change will have a strong impact on fisheries. Since most marine species used for human consumption are poikilothermic, any changes in habitat temperatures can significantly influence their metabolism, growth rate, productivity, seasonal reproduction, and susceptibility to diseases and toxins (APO 2008). Research has shown that while fish may take refuge from rough conditions through minor changes in distribution, most fish species have a fairly narrow range of optimum temperatures related both to the species basic metabolism and the availability of food organisms that have their own optimum temperature ranges (NOAA n.d.). Researchers believe this decline in zooplankton may be the result of increased warming of the surface layer that reduces the nutrient enrichment of this layer by reducing upwelling from below the thermocline (NOAA a n.d.). While species, particularly those with shorter life spans, will change the timing of their life cycle, some plankton species will bloom earlier, resulting in mismatches between the early life stages of fish and their prey, and therefore cause declines in abundance (FAO n.d.). Studies have also shown that there is a similar decline in the abundance of seabirds which rely upon the fish as prey and this overall decline of fish species correlated to the decline in zooplankton abundance, as shown in Figure 1 (NOAA a n.d.). The different fish species will vary in their abundance based on their optimum temperature ranges. Increased temperatures will not only affect the productivity of some marine areas but will also have a negative impact on associated marine ecosystems such as coral reefs (Murray 2005, Van der Meerin, S. 1998). It is widely recognised that extensive coral bleaching occurred in the Eastern Caribbean over the last 25 years (Donner, *et al.* 2007, Everett 2007). However, there are significant local and regional variations in the scale and type of threats to coral reefs especially in small-island situations. It is difficult to measure direct impacts of climate change as against other elements such as misuse or overuse of coral reefs or other habitats. Ocean acidification on the marine biosphere can add stress to coral reefs as progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms and their dependent species (IPCC

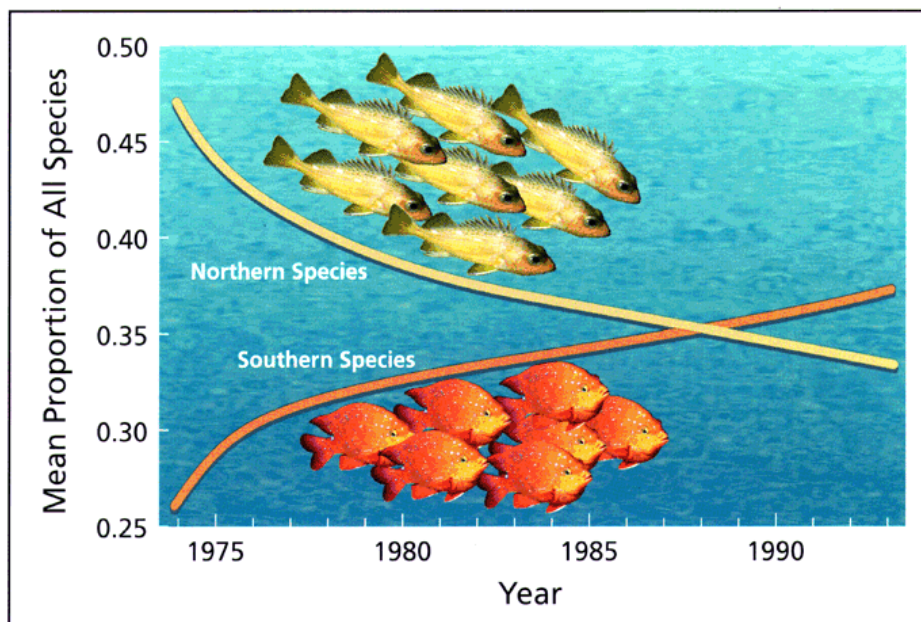
2007b). Air temperatures are projected to continue to rise further as depicted in Table 3.

**Table 2.** Perceptions of Fishermen

Characteristic Feature related to Fisheries or Climate Change	Conclusions / Perceptions of Fishermen
Understanding of Climate Change	Generally, it is perceived that there is global warming causing melting of polar ice sheets. Stronger and more frequent storms, effects of ground swells and impacts on the amount of fish being caught are also linked to climate change.
Fishing Distance/Depth/ Time	Varies from country to country, depending on type of fishing, size and type of fishing vessel used and the general bathymetric conditions around the islands.
Fishing Activities	The type and extent of fishing activities vary from island to island. Trap fishing and different types and techniques of net and line fishing are common. Depending on the area, focus is on catching fin fish, lobster or conch.
Characteristic of Sea (Surface) Temperature	Few fishermen quoted specific sea surface temperatures but the majority believe that there is a general increase in SST. Increasing temperatures are perceived as causing a general decrease in fish catch.
Effects of Rain/Rainy Season	Some fishermen believe that there is a tendency to catch more fish during the rainy season. This is mainly attributed to more nutrients reaching the sea as well as mixing of fresh water.
Effects of tropical storms/ hurricanes	Tropical storms are recognised as being destructive to fishing vessels, fishing gear and the physical environment in which fish survive. However, most fishermen take necessary precautions to weather the effects of storms.
Observance of Currents/ Upwelling currents and winter swells	There is a general perception that currents are getting stronger. Winter swells or ground swells are perceived to be more unpredictable and therefore may occur any time of the year.
Moon Phases and Fishing	Some fishermen, using hook and lines/trolling, believe in fishing according to moon phases. Other fishing methods in most cases occur independently of moon phases
Observed Water Colour	Fishermen perceive that sea water colour varies throughout the region from clear or light blue to green or even brown. They believe that more fish is caught in the clear or blue water. Some relate the water colour to nutrients, volcanic activity or even dust from the Sahara.
Migratory Sea Birds	While different species of migratory seabirds are observed, there is no real recognition of changes in populations and migration patterns.
General Marine life around Island	Many fishermen are unable to comment on general marine life. Divers, however recognise a general decline in the condition of coral reefs and sea grass in particular.
Sea Level Rise	Surprisingly, sea level rise is not considered a major issue. Most fishermen perceive that it will not have much effect on fishing activities.
Economics of Fishing	The cost of fuel, ice and bait seems to be the main elements for a fishing trip. This cost varies from island to island based on the type of fishing, distance of operation and the local price of fuel and engine oil. The price of fish also varies from country to country.
Fish Landings	In the south-Eastern Caribbean, the landings tend to be species specific and generally include more pelagic species while there is more 'mixed fish' in the northern Eastern Caribbean with a higher percentage of demersals. In general, it is perceived by fishermen that there is a recognisable decline in fish landings.

**Table 3.** Projected increase in air temperature (°C) and change in precipitation (%) in the Caribbean, relative to the 1961–1990 period. *Source:* (Mimura, *et al.* 2007)

Period	2010 - 2039	2040 - 2069	2070 - 2099
Temperature Increase (°C)	0.48 - 1.06	0.79 - 2.45	0.94 - 4.1
Precipitation Change (%)	-14.2 to +13.7	-36.3 to +34.2	-49.3 to +28.9



**Figure 1.** Reduced Abundance of Zooplankton and Temperate Fish during Two Decades of Warming

Most fishing vessels in the Eastern Caribbean are not equipped to measure sea surface temperatures. However, while a few fishers quoted specific sea surface temperatures the majority believe that there is a general increase in SST contributing to a general decrease in fish catch. According to Figure 1, the catch may be dominated by species that can tolerate much higher temperature ranges. Fishers have also reported seeing new or unaccustomed species in their catch. This could also be a result of changes in temperature ranges thus varying the (thermal) tolerance levels of the different fish species.

Precipitation patterns are also changing in the Caribbean. The maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing (Mimura *et al.* 2007). As illustrated in Table 3, it is anticipated that precipitation will become more variable (extreme dryness to extreme wetness). Fishermen tend to believe that more fish is caught during rainy periods. There is an association between rains, the transport of sediments in rivers and the supply of nutrients as a source of food for fish. This applies mainly to 'surface' fishing. The influence of the Orinoco plume across the entire Eastern Caribbean is affected mainly by winds and currents and increased precipitation, in addition to intensification of the typical seasonal pattern of winds could lead to the Orinoco River discharge reaching east of the Eastern Caribbean during periods when the westerly winds are relaxed (Mahon 2002). A fish kill that affected several countries in the south-eastern Caribbean was also

linked to increased water temperatures and the transport of a pathogen thought to be in the Orinoco discharge (Mahon 2002).

The movement and amount of particles within the sea or ocean depends on the supply of sediments and the operation of currents within the water column. Fishers noted that currents are generally getting stronger and surges which usually occur between November and May are now more unpredictable. The presence or absence of sediments could influence water colour and could either have a positive effect on productivity depending on the type of species. Sediment supply may also be affected by volcanic activity within the Caribbean region and shifts in the pattern of winds that transport dust from the Sahara to the Caribbean.

Storm activity is also on the rise in the Caribbean. According to the IPCC First Assessment Report, except for two El Nino years (1997 and 2002), hurricane activity was greater from the 1930s to the 1960s, in comparison with the 1970s and 1980s and the first half of the 1990s. After 1995, all but two Atlantic hurricane seasons have been above normal relative to the 1981 - 2000 baselines. There was a generally below-normal hurricane season observed during the previous 25-year period, 1975 to 1994. The EC falls within the Main Development Region (MDR) for hurricanes where during 1949-2002 Tropical Systems accounted for 71% of the 53-year total activity measured, 55% of all hurricanes and 79% of all major hurricanes (Knutson 2006, Saunders and Rockett 2001). During that period there was a nine-fold drop in activity in MDR

between above- and below-normal seasons. Most fishers noted an increase in the frequency of storm or hurricane activity. Potential impact can include damage to both vessels and fishing gear as well as the physical environment. Upon notification of an approaching storm, fishermen would normally take necessary precautions by storing their vessels in a safe place on land. In most instances, fish traps, especially those set at a distance, would be left in the water. Based on the dominant type of fishing activity and the distance of operation, a country such as Antigua and Barbuda would suffer more loss to damage of fish traps from a hurricane than say St. Lucia or Barbados because of the nature of its fisheries.

It is anticipated that increased hurricane activity could cause widespread physical damage to habits such as coral reefs and mangroves areas. In addition, there could be considerable losses in incomes due to fewer fishing days when there are unfavorable weather conditions (Mahon 2002). Several fishermen have also recorded increased lobster catches following storm activity. Without knowing the full implications, this can be regarded as a positive effect of increased storm activity.

According to the IPCC Third Assessment Report, the projected globally averaged sea-level rise at the end of the 21st century (2090 to 2099), relative to 1980 to 1999 for the six SRES scenarios, ranges from 0.19 to 0.58 m (Mimura *et al.* 2007). Slight changes in sea level rise may not affect fishing activities but can have severe impacts on the natural environment associated with fishing. However, the Caribbean region experienced, on average, a mean relative sea-level rise (SLR) of 1 mm/yr during the 20th century (Mimura *et al.* 2007). It was also recognised that there were considerable regional variations in sea level observed in the records due to large-scale oceanographic phenomena such as El Niño coupled with volcanic and tectonic crustal motions of the Caribbean Basin rim, which affect the land levels on which tide gauges are located. Locally, difference in the response to tectonic movements have caused recent variations in sea level, such as on the west coast of Trinidad where there are indications that sea level in the north is rising at a rate of about 1 mm/yr, while in the south the rate is about 4 mm/year (Mimura *et al.* 2007).

The analysis of the perception of fishermen did not fully identify potential coping strategies and mitigation measures against impacts of climate change and climate variation on small-scale fisheries in the Eastern Caribbean. However, the findings support the following measures:

- i) The development of appropriate alternatives to present fishing gear and methods: There is a need to develop more innovative and cost effective technologies for fishing. This could involve not only changing fishing gear and methods as well as fishing for new species but also the expansion of fishing activities in time and space.
  - ii) Utilisation of the fisheries resources using an integrated management approach: Fishing as a livelihood should be developed in a broader environmental and socio-economic context. The fisheries resources should be managed based on the best available scientific information. This information should be shared among all resource users.
  - iii) Fishing activity should be treated as a business: Fishers need to plan adequately and prepare for climate change including climate variation. This will be more effective if there is mainstreaming of climate change into the entire fisheries sector.
- Most related studies for the region tend to be more qualitative in nature. The lack of specific information and data for this study has demonstrated a need for more specific/qualitative research on issues related to small-scale fisheries and climate change. These could include but not limited to the following:
- i) Seasonal and local variations of currents: Studies could be based on current movement within local areas around the Caribbean and the influence of currents on fishing activities of individual Caribbean countries.
  - ii) An analysis of the influence of local habitats on different fish species and how different fish species adapt to different temperature and depth regimes throughout the Caribbean region could prove beneficial to fishers.
  - iii) Migratory patterns of fish species: Climate change impact on fish migration throughout the Caribbean region needs to be investigated. Major controls specially temperature need to be determined.
  - iv) Migratory patterns of different bird species: Investigations into the impacts of climate change on bird migration throughout the Caribbean region and possible relationships with fishing activity could be a useful area of research. The major trends can be studied.
  - v) Climate change and marine invasive species: The appearance of new species of fish and their possible connection to climate change and/or climate variability may be useful for further studies. Invasive species could have serious implications for fish production throughout the Caribbean.
  - vi) Possible influences of climate change on ciguatera occurrence particularly in the north-eastern Caribbean needs to be examined. This could have real implications for the fisheries sector.
  - vii) Possible relationships between sea level rise and fishing activities.
  - viii) Changes in sea water colour and linkage to climate change: Studies of possible relationships

between water colour and fish productivity throughout the Caribbean could be undertaken.

While fishing activities occur within a natural physical environment, general research should be placed in the context of socio-ecological systems. This is necessary, considering the many complex relationships that exist between the different systems.

### CONCLUSIONS

Based on scientific evidence, we are certain that climate will continue to change and fisheries distributions and abundances within the Caribbean will continue to be impacted even though we are unsure of the extent of the influences due to our lack of adequate quantitative evidence. There are many interconnected environmental, social and economic factors that affect the fishing industry making it very difficult to pinpoint direct linkages between climate change and fisheries. The problem is exaggerated further when the dynamic nature of climate and elements such as the migratory nature of some fish species are considered. Although the study focuses on the Eastern Caribbean, fisheries and climate change should always be studied in a broader global context.

Fishers have recognised that they can and will cope using different strategies even considering the difficulties of predicting the nature and extent of the impacts of climate change.

Future research should focus on key ecosystem and other linkages we need to understand in order to wisely manage our fisheries. Several fisheries-related areas and possible relationships with long term changes and natural climate variability have been identified for further study. However, the results and implications of research must reach the primary stakeholders. Fishers must know and be aware of their environment.

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