# Adaptation of Fisheries and Fishing Communities to the Impacts of Climate Change in the CARICOM Region

## Issues paper

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**CONTENTS**

1 Introduction ........ 1
2 Climate change impacts ........ 2
2.1 CARICOM fisheries ........ 2
2.2 Caveats ........ 2
2.3 Anticipated climatic changes of importance to fisheries ........ 4
2.4 National climate change issues for fisheries ........ 4
2.5 Review of impacts ........ 5
2.5.1 The current status of fishery resources in CARICOM countries ........ 6
2.5.2 Impacts of climate change on fishery habitat ........ 7
2.5.3 Direct impacts of climate change on fishery stocks ........ 10
2.5.4 Impacts on fish stock availability ........ 13
2.5.5 Impacts on the harvesting sector ........ 14
2.5.6 Impacts on fishing communities and shore-based facilities ........ 16
2.5.7 Aquaculture ........ 17
2.5.8 Linkages with other sectors ........ 17
3 Adaptation ........ 17
3.1 Adaptation to impacts of climate change on fishery habitat ........ 18
3.2 Adaptation to direct impacts of climate change on fishery stocks ........ 18
3.3 Adaptation to impacts on fish stock availability ........ 18
3.4 Adaptation to impacts on the harvesting sector ........ 19
3.4.1 Deterioration of weather conditions ........ 19
3.4.2 Tropical storms and hurricanes ........ 19
3.5 Adaptation to impacts on fishing communities and shore-based facilities ........ 20
3.6 Aquaculture ........ 20
3.7 Linkages with other sectors ........ 20
3.8 Data and research needs to effectively assess the impact of climate variability and change of fisheries and fish stocks ........ 21
4 Inputs to effect decision-making and planning for the fisheries sector ........ 22
4.1 Policy ........ 22
4.2 Planning ........ 23
4.3 National and regional institutional capacity ........ 24
4.3.1 Capacity to monitor impact of climate change ........ 24
4.3.2 Capacity to integrate climate change issues in sustainable fisheries management ........ 25
4.3.3 Capacity building for climate change and fisheries under MACC ........ 26
4.4 Public education and primary stakeholder awareness ........ 27
5 References ........ 27

## SUMMARY

The Caribbean Planning for Adaptation to Global Climate Change (CPACC) Project (1997 - 2001) proivided support to CARICOM countries in preparing to cope with the adverse effects of global climate change on coastal areas through vulnerability assessment, adaptation planning and capacity building. CPACC is followed by the current project, Mainstreaming Adaptation to Climate Change (MACC) that is continuing to build capacity in the CARICOM Small Island Developing States and Low-Lying States to develop adaptation strategies and measures for the integration of adaptation into the general planning process of the countries.

With respect to fisheries, the MACC Project will assist the countries of the region in identifying and formulating measures that would enable the fisheries sector to develop appropriate adaptation measures to address impacts on fishing communities, fisheries resources, and associated ecosystems. The overall objective of the fisheries sub-component is to strengthen the capability of the national fisheries administrations and fisher organizations to anticipate and minimize negative impacts of climate change and sea level rise on the fisheries sector in the CARICOM region.

This paper is a compilation of information on impacts of climate change on Caribbean fisheries and adaptation approaches to these impacts. It also incorporates discussions and recommendations from the "Consultation on Adaptation of Fisheries and Fishing Communities to the Impacts of Climate Change in the CARICOM Region", held in Tobago, April 14-15, 2002.

Clearly, here is the potential for climate change to have a wide range of substantial impacts on fisheries in CARICOM countries. These include impacts on: habitats, the resources, harvesting patterns, shore facilities, aquaculture and fishing communities. Adaptations include habitat conservation, upgrading of vessels and facilities, relocation of facilities. However, underlying these is the needs for integration of climate change issues into fisheries planning. Given that fisheries planning should involve consultation with stakeholders, there will be the need for increased awareness among stakeholders regarding the possible climate change impacts and adaptations.

Increased capacity for dealing with climate change impacts is highly coincident with the broader needs of countries regarding improved fisheries management. These include improved fisheries data and information systems, approaches to interacting with stakeholders and capacity to carry out research, and/or to collaborate with regional and international institutions in pursuing research objectives.

# 1 INTRODUCTION

The four-year Caribbean Planning for Adaptation to Global Climate Change (CPACC) Project commenced in 1997 with the establishment of the project offices in Barbados and effectively ended on December 31, 2001. CPACC was the first major initiative in the Caribbean Region designed to support countries in preparing to cope with the adverse effects of global climate change on coastal areas through vulnerability assessment, adaptation planning and capacity building.

The current project, Mainstreaming Adaptation to Climate Change (MACC) is being designed to consolidate and build on the foundation of CPACC by continuing to build capacity in the CARICOM Small Island Developing States and Low-Lying States to develop Stage II adaptation strategies and measures for the integration of adaptation into the general planning process of the countries. One of the four components of this project is focused on mainstreaming of climate change concerns into planning and practices of highly vulnerable sectors including fisheries, tourism, agriculture and water.

With respect to fisheries, the MACC Project will assist the countries of the region in identifying and formulating measures that would enable the fisheries sector to develop appropriate adaptation measures to address impacts on fishing communities, fisheries resources, and associated ecosystems such as coral reefs. The outcome will be a regional fisheries sector plan that takes into account the impact of climate change. The project will finance the required stakeholder consultations, consultancies and training to undertake any assessment and support the drafting of the plan.

The overall objective of the fisheries sub-component is to strengthen the capability of the national fisheries administrations and fisher organizations to anticipate and minimize negative impacts of climate change and sea level rise on the fisheries sector in the CARICOM region.

In this context, the specific objectives for the work envisioned in this preparatory exercise are:

- Identify and characterize the direct and indirect ecological, social and economic impacts of climate change and sea level rise on fisheries resources, associated ecosystems, fishing communities and aquaculture in the region;
- Identify the adaptation strategies and measures that could be pursued to mitigate negative impacts and prepare fishers and fishing communities to adjust, including research, capacity building, education and awareness building;
- Identify measures to strengthen human resources and the capacity of the national fisheries departments for analysis and planning for adaptation to climate change;
- Identify, major issues and constraints which need to be addressed to integrate climate change adaptation practices and measures into the planning and management process in the fisheries and aquaculture sectors.

The purpose of the present paper is to compile available information on impacts of climate change on Caribbean fisheries and adaptation approaches to these impacts. A draft of the paper was discussed at the "Consultation on Adaptation of Fisheries and Fishing Communities to the Impacts of Climate Change in the CARICOM Region", held in Tobago, April 14-15, 2002 (CCCC 2020) (herein referred to as the Climate Change and Fisheries Workshop 2002). The ideas and amendments that were provided by participants have been incorporated into this version.

# 2 CLIMATE CHANGE IMPACTS

## 2.1 CARICOM fisheries

The fisheries of CARICOM countries are based on a wide variety of demersal and pelagic resources (Mahon 2002, (Haughton and Singh-Renton 2001). The problems and potential impacts of climate change differ among these fisheries (Mahon and Joseph 1997, (Murray *et al.* 2002). The fishery sectors of CARICOM countries comprise the biophysical production system for all the different types of fishery resources, the harvesting subsector, and consumers of fishery products, including exporters and the tourism industry. An overview of the interrelationships among climate change and the components of these sectors is provided in Figure 1. These relationships are biological, sociological and economic.

## 2.2 Caveats

A variety of methods would be required to assess the impacts via the numerous relationships in Figure 1. In most instances there is inadequate knowledge or insufficient data for quantitative assessment of the impacts. This is particularly so in the case of the impacts of climate on the fish stocks through biological interactions. Therefore, assessment of the impacts is at present limited to an elaboration of the current knowledge on the possible effects through the various pathways, and inference regarding the probable impacts in the case of CARICOM countries. The review of climate change impacts on fisheries by (Everett *et al.* 1996) provides a guide to the types of issues that should be considered.

A more quantitative approach may be possible regarding the assessment of the effects of climate on the harvesting sector. There are some empirical data that can be used for those assessments, but they will depend to a large extent on expert opinion.

Throughout the discussion of possible impacts, it will become apparent that a full quantitative assessment of the impact of climate change on the fishery sectors of CARICOM countries would require a substantial long-term research initiative. Even then, past experience has shown that the predictive power of relationships between environment and fisheries is characterized by a high degree of uncertainty (Glantz 1990, Frank *et al.* 1990). Therefore, the potential returns on investment in research to characterize these relationships and/or to model fishery resources should be carefully evaluated. Alternatives should be considered to modelling approaches for assessing impacts and advising on adaptations. A precautionary approach to managing the various components of the fishery sector may be the most feasible route, until better information become available.

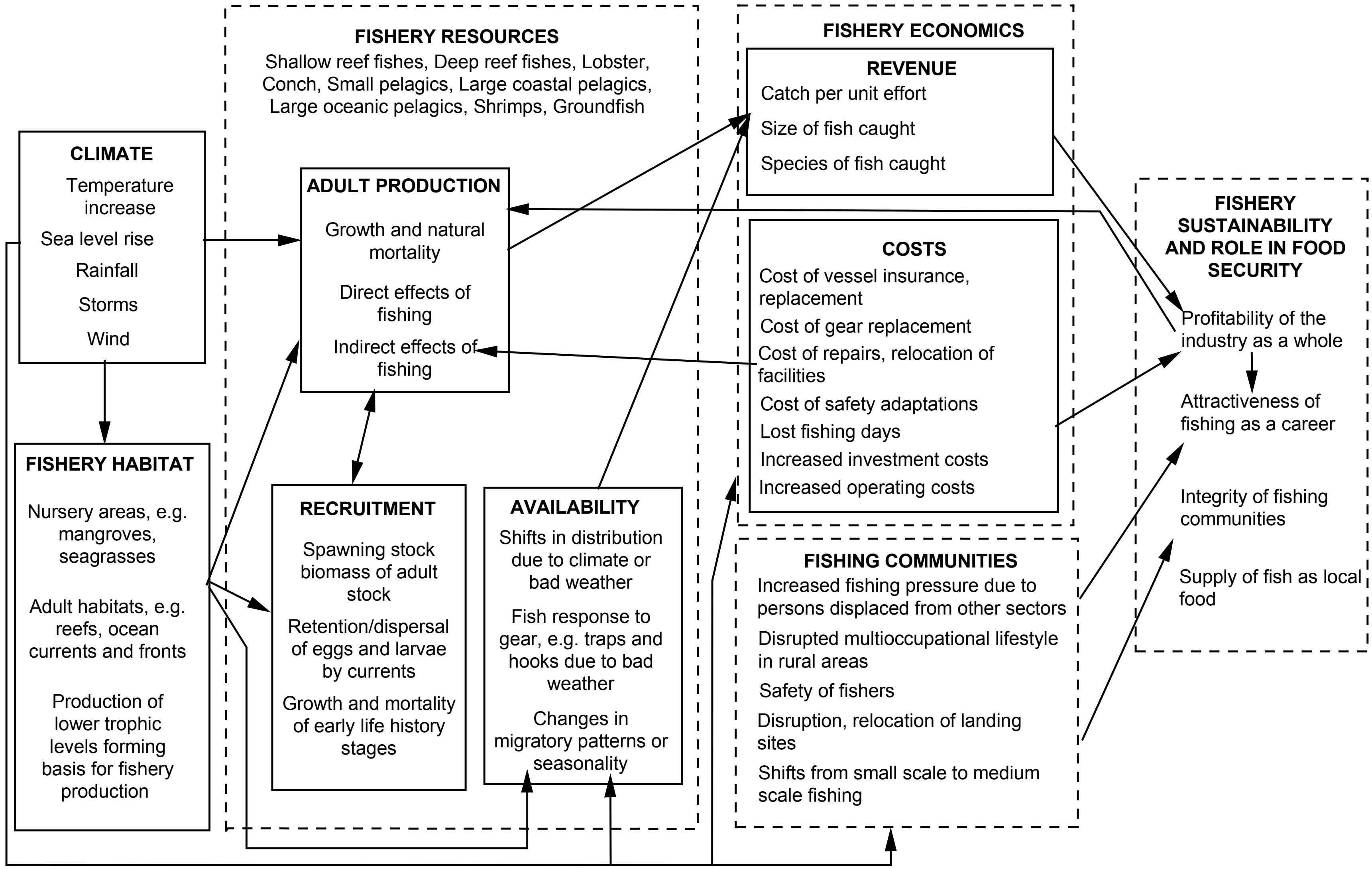


**Figure 1. A general framework for assessment of the impacts of climate change on the fisheries of CARICOM countries (adapted from Mahon and Joseph 1997)**

## 2.3 Anticipated climatic changes of importance to fisheries

There is considerable uncertainty regarding the extent to which climate change will take place a regional and subregional levels. The review for Latin America provided by (Canziani *et al.* 1998) provides little specific information on the Caribbean region itself. In reviewing the information for small island states, (Nurse et al. 2001) note the following for Caribbean islands:

- Temperature can be expected to increase;
- Mean rainfall is projected to decrease marginally.
- An intensification of the seasonally cycle is expected to lead to increase flooding in the wet season and increased drought conditions in the dry season.
- Amplification of the seasonal cycle may include surface winds, which may in turn result in changes in sea surface currents at various scales, and in sea surface conditions.
- Increased rainfall variability in the Caribbean may be associated with and increase in frequency of ENSO events in the Pacific.
- Information on possible changes in hurricane frequency is inconclusive, although for the Caribbean, association of increased hurricane activity with increased sea surface temperature suggests that hurricane frequency could increase.
- Similarly, there are indications that a doubling of $CO_2$ could lead to intensification of hurricanes by 10-20%.
- Global sea level rise of about 5 mm per year is projected for the next 100 years but will vary considerably from region to region.

However, CARICOM countries are distributed throughout the Wider Caribbean region, some on mainland South America and one in Central America. Thus there will be variation among countries in the effects of climate change.

## 2.4 National climate change issues for fisheries

As part of CPACC Component 4 – "Formulation of a Policy Framework for Integrated (Adaptation) Planning and Management" -- most CARICOM countries prepared national papers on climate change issues: Antigua and Barbuda (James), Bahamas (BEST 2001), Belize (Usher 2000), Barbados (Anon 2002), Dominica (CARIBISS), Grenada (Anon 2001a), Guyana (Khan 2001), Jamaica (Mahlung 2001), (St. Kitts and Nevis (Anon 2001b), St. Lucia (d'Auvergne 2001), St. Vincent and the Grenadines (Anon 2001c). The recommended format for these papers is shown in Table 1.

**Table 1. Format for country national papers on climate change issues**

| **Introduction** | **Key Issues with Respect to Climate Change** |
|---|---|
| • Physical Characteristics | • Ranking of Issues by Magnitude & Significance |
| • Regional/Local Climatology and Related Phenomena | • Institutional and Legal Arrangements for Responding to Issues |
| • Important Ecological/Biological Attributes | • Key Legislation Relating to Coastal Management |
|   • Mangroves | • Non-government Agencies |
|   • Coral Reefs and Sea Grass Beds | • International Agreements Relating to Marine Management |

- Beaches
- Biodiversity
- Hydrology and Water Resources
- Socio-Economic Characteristics
- Other Factors/Phenomena

**Impacts of Potential Climate Changes and Sea-Level Rise**

- Agriculture
- Fresh Water Resources
- Human Settlement
- Human Health
- Coastal Zone
- Tourism
- Fisheries
- Biodiversity
- Major Implications For Impacts

- Other Issues

**Towards an Adaptation Policy**

- Adaptation Options
- Policy Considerations

**Summary and Conclusions**

A review of these papers revealed a highly variable degree of attention to fisheries, and a variety of ranking for fisheries issues based on expected magnitude of impacts and the relative significance of the fisheries sector. In many cases the primary concern was with the impacts of climate change on marine habitats with the resulting impacts on fisheries being of secondary concern. This is not unexpected given the importance of marine habitats for tourism and biodiversity as well as for fisheries.

**Table 2. Ranking of the magnitude and significance of climate change impacts on fisheries and marine ecosystems by CPACC participating countries in their issues papers**

| Country | Magnitude | Significance of sector |
|---|---|---|
| **Fisheries** | | |
| Antigua and Barbuda | High | Medium |
| Belize[1] | Medium | High |
| Dominica | Medium | Low |
| Grenada[2] | Medium | Medium |
| | | |
| **Related sectors** | | |
| Antigua and Barbuda – Coastal zone | High | High |
| Dominica – Coastal and marine resources | High | High |
| Grenada -- Marine Ecosystems | Low | Low |

## 2.5 Review of impacts

The following review incorporates the impacts and issues raised by the country papers, but also seeks to explore these beyond the level of detail generally provided in these papers by referring to the literature. This is done with reference to the general framework provided in

[1] Not explicitly included in the paper, but inferred by this author form indications in the text

[2] Includes agriculture and fisheries

Figure 1. Whereas, the conclusion by Nurse *et al.* (2001) that impacts on fisheries resources of Caribbean SIDS will probably be relatively minor may be valid, there are other possible social and economic impacts that go beyond the resources and that should be given careful consideration.

2.5.1 The current status of fishery resources in CARICOM countries

The most difficult aspect of detecting climate induced changes in exploited stocks will be distinguishing them from changes resulting from exploitation and environmental degradation. Virtually all the significant exploitable fishery resources in the waters of CARICOM countries are exploited, and may in several cases be overexploited. Thus there will have been, and almost certainly still are, trends of declining abundance in most stocks. These declining trends may continue, or if management efforts are successful, there may be trends associated with recovery in various stocks as they rebuild towards target levels. These changes may be in abundance, in the size of individuals caught, and in the case of multispecies fisheries, such as the pot fishery for reef fishes, in the species composition of the catch..

There are few acceptable estimates of the current status of the reef related demersal (fishes, lobster, conch) or coastal pelagic fishery resources in CARICOM countries. Landings over the past few years have been estimated in most countries from the data collection systems implemented with assistance from the CARICOM Fisheries Resource Assessment and Management Program (CFRAMP). However, even rough estimates of potential yield for the various resource types are lacking in many countries, but are available for some (Neilson et al 199, Singh Renton and Neilson 1993).

Uncertainty regarding the current status or trends for most reef related demersal fishery resources in CARICOM countries makes it difficult to establish a baseline against which to evaluate possible changes in fishery resources due to climate change, even by monitoring.

For the large pelagic fish species that are managed under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT) the situation is quite different. These resources are shared by many countries in the Caribbean and throughout the Atlantic Ocean. Their status depends on the collective impact of all the countries fishing for them, and their management, including assessment must be carried out collectively by those countries. ICCAT assessments of the major species (e.g. yellowfin tuna, skipjack tuna, swordfish) indicate that most are at, or near, full exploitation. Any assessment of the impact of climate change on those resources, would require the input of ICCAT data and the participation of scientists from several countries.

For other large pelagic species, such as dolphinfish, *Scomberomorus* spp. and blackfin tuna, that are important to small-scale fisheries in the Caribbean, but not to commercial tuna fleets, there are no data with which to assess the resources, or climate change impacts on them (Mahon 1996a, FAO 2002).

Regarding the shrimp resources of the continental shelf off the north coast of South America, generally referred to as the Guianas-Brazil region, there has been a considerable amount of effort on monitoring and assessing the fishery and environmental effects of yields. Therefore, there may be some basis for assessing impacts of climate change on these resources. In contrast, the associated demersal and coastal pelagic resources are little known and are in a similar situation to the reef resources.

### 2.5.2 Impacts of climate change on fishery habitat

The impacts of the above climatic changes on fishery habitats cannot be readily quantified (Vicente *et al*. 1993, Nurse *et al*. 2001, McClean *et al*. 2001). There are also generally substantial other anthropogenic impacts from which it will be difficult to distinguish those that are due to climate change (Bossi and Cintron 1990, Ginsburg 1994, Dubinsky and Stambler 1996). Indeed, there may be synergistic effects of anthropogenic and climate change that will make prediction of climate change impacts extremely difficult (Kinsey and Buddemeier 1996).

#### *2.5.2.1 Mangroves*

Mangrove systems are important habitats for fisheries in Caribbean countries (Appeldoorn et al 1987, Dennis 1992, Boulon 1992, Alleng 1993). They provide spawning areas for several species of reef fishes, and nursery habitats for reef fishes and lobsters. Adults of several fish species are also harvested in mangrove lagoons (e.g. tarpon, snook, yellowtail snapper, mullet).

Mangroves are expected to respond to rising sea level by retreating shoreward (Snedaker 1993, Vicente *et al.* 1993). The topography of the shoreline will play a major role in determining whether there is habitat gain or loss due to sea level rise. Changes in freshwater inputs are more likely to result in impacts on mangroves. In addition, projected droughts may result in loss of mangrove habitats (Hamilton and Snedaker 1984).

Storms may damage mangroves severely, as was the case for Hurricane Gilbert in Jamaica (Bacon 1989) and Hurricane Andrew in Florida (Swiadek 1997). Mangrove stands reach maturity in about 25 years, therefore, since the average inter-hurricane period for most locations in the Caribbean is less than 25 years, their biomass is generally considered to be limited by hurricanes, (Lugo and Snedaker 1974).

#### *2.5.2.2 Seagrasses*

Seagrass beds are also of considerable importance to fisheries. They serve as nursery areas for many species of fishes, lobsters and conch (Appeldoorn *et al* 1987). They are also the primary habitat from which adult conch are harvested. Except in areas that are already temperature stressed, such as shallow enclosed bays or areas with thermal effluents, the predicted rise in sea temperature is not expected to impair the physiological functioning of seagrasses (Vicente *et al*. 1993).

Damage to seagrass beds in Jamaica by Hurricane Gilbert appeared to be relatively minor. In the case of beds of turtle grass (*Thalassia*) the most extensively distributed species, damage was largely confined to removal of the blades above the substrate. Regrowth from the rhizomes was expected to be quite rapid. Limited erosion damage to the rhizomes was observed around the edges of *Thalassia* beds, and in “blowouts”, sandy areas that occur in the middle of most *Thalassia* beds.

#### *2.5.2.3 Coral reefs*

Coral reefs provide the habitat for the wide variety of reef fishes that are exploited. Spiny lobsters are also caught on coral reefs. The coral reef habitats in which fisheries operate vary widely in structure and community composition. They include fringing reefs, patch reefs and barrier reefs in shallow water near islands; live hard and soft coral communities of medium depths (30-100 m); and deep reefs on the slopes of shelves and adjacent banks.

Reviews of the probable impacts of climate change on coral reefs appear to have focused mainly on shallow near shore reefs (Wilkinson and Buddemeier 1994, Wilkinson 1996). These publications conclude that in most areas reef corals and other reef associated species would be expected to adapt to predicted increases in temperature and sea level. However, as pointed out by Vicente *et al* (1993) the health of a coral reef system may be impacted by a wide variety of physical and biological factors.

Although the predicted increase in sea temperature would not be expected to impair the functioning of corals and other reef organisms, increased frequency of extreme high temperature events may increase the incidence of coral bleaching (expulsion of zooxanthellae) that can lead to the death of the colony (Atwood *et al*. 1992, Glynn 1996). The long term effects of coral bleaching are not clear. Fitt *et al*. (1993) report some recovery of bleached corals within a year. However, Reaka-Kudla *et al.* (1996) suggest that synergistic effects of temperature and UV may eliminate certain species of corals resulting in shifts in community structure towards more temperature resistant species. In their review of the effects of ultraviolet radiation on corals and other coral reef organisms, Shick *et al*. (1996) did not find much information that was useful in making long-term predictions regarding the health of coral reefs.

In the Caribbean, reef degradation has been linked to the interactions among reef dwelling herbivores and algae, that may overgrow corals. The combined reduction of herbivorous fishes, and the die-off of the black sea urchin, *Diadema antillarum,* in the early 1980s is believed to have impacts on coral reefs in many areas of the Caribbean (Steneck 1993, Vicente 1993). These include increased algal growth, overgrowth of corals and ultimately coral mortality. These conditions point to complex interspecific interactions that may have extensive effects on reef building corals, but may be impossible to predict from simple relationships between climate and biota.

Hurricanes can cause extensive damage to coral reefs (Stoddart 1985, Harmelin-Vivien 1994), for example as described for Hurricane Gilbert in Jamaica (Bacon 1989), and for Hurricanes David, Frederic and Hugo in the US Virgin Islands (Rogers et al 1988, Rogers 1992). Hurricanes reduce the physical complexity of coral refs and the abundance of living corals (Stenneck 1993). These effects are greatest at shallow depths, where wave action is greatest. However, shallow corals are adapted to wave action and hurricanes can cause considerable damage in deeper water where corals seldom experience wave action under normal conditions (Harmelin-Vivien and Laboute 1986).

The long-term role of hurricane damage in determining reef structure has only recently begun to become apparent. For Jamaica, Woodley (1992) has suggested that the classic descriptions of coral reef structure in Jamaica (these have been used throughout the Caribbean) may have been developed after an unusually long hurricane-free period. Thus given that hurricanes are an integral component of the ecosystem, with an average inter-hurricane period of 6.5 years, the average condition of Caribbean reefs in areas exposed to hurricanes may be quite different from these descriptions. The relative proportions of branching corals, particularly *Acropora* spp., may be much lower than those described, and the proportions of massive corals (e.g. *Diploria* or *Montastrea*), that can withstand hurricanes, may be much higher.

As Kjerve (et al. 1986) point out, our perception of the ability of coral reefs to withstand hurricane damage may depend largely on how long it has been since the previous hurricane. Alternation between coral communities dominated by branching corals and those dominated by massive corals may be a normal long-term condition for coral reefs in the Caribbean.

The implications of hurricane induced shifts in coral reef structure for shallow reef fish fisheries is by no means clear. There are no studies that have directly addressed the relative carrying capacity, or reef fish species composition of these different types of coral reefs. Some inference may be possible from a review of the many studies on reef fish assemblages on various types of coral reefs. However such a review would need to take many other factors into account as well, such as latitude, and anthropogenic effects. One relevant conclusion from reef fish studies is that, all else being equal, reef fish abundance and diversity tends to be positively related to three dimensional structure and complexity. Clearly, hurricanes reduce this. However, these studies have focused on entire reef fish assemblages. It is not clear that the relationship would apply for the exploitable species of the assemblage, and thus translate into comparable changes in fishery yields.

#### *2.5.2.4 Oceanic features*

Climate change may have a wide range of possible effects on ocean currents and processes that can affect fish resources (Everett 1996). Ocean fronts and eddies, that are determined by large scale and mesoscale current patterns, are the habitat and migratory pathways of oceanic pelagic fishes (Parin 1968, Olson and Podesta 1987). Changes in the location and/or strength of these oceanic features may affect the abundance of these fishes. However, changes in availability to the local fishing fleet are more likely to occur than are large scale changes in abundance. Possible changes in ocean currents and in pelagic fish availability are discussed in a subsequent section.

Ocean currents are also related to upwelling that result in nutrient enrichment leading to enhanced primary and secondary production that may support fish stocks. Changes to upwelling areas associated with the Canary and Benguela Current systems off Africa are expected to result from climate change (). In the Caribbean, upwelling areas off the Guianas-Brazil Shelf, downstream of island passages, and off Venezuela are known to influence fishery production and may also be affected by climate change.

#### *2.5.2.5 River inputs*

Climate change in the basins of the large South American Rivers, notably the Amazon and Orinoco Rivers, will affect the volume and seasonality of their discharges in ways that are difficult to predict (Muller Karger 1993). These river inputs contribute considerably to the offshore marine production systems of the Caribbean. The influence of the Orinoco plume extends across the entire eastern Caribbean up to Puerto Rico. The dispersal of these discharges will in turn be affected by winds and currents. Similar issues have been raised with regard to impacts on fisheries production systems of increased runoff from rivers in boreal Asia, where it is postulated that the effects may be beneficial (Lal *et al.*2001), and in the Gulf of Mexico (Cohen *et al.* 2001).

As noted by Muller Karger (1993), the Orinoco River discharge can be advected to the east of the Lesser Antilles by eddies, during periods when the westerly winds are relaxed. These conditions may become more frequent during the latter half of the year if there is intensification of the typical seasonal pattern of winds.

Recently, a fish kill that affected several countries in the south-eastern Caribbean was linked to increased water temperatures and the transport of a pathogen thought to be in the Orinoco discharge.

#### *2.5.2.6 Freshwaters and Wetlands*

In addition to the marine habitats, there is also a variety of freshwater habitats and coastal and estuarine wetlands that may sustain fisheries. Freshwater habitats include fluvial systems and standing waters. Fluvial systems range from small fast flowing streams that support subsistence fisheries for species such as mountain mullet and crayfishes (e.g. *Macrobrachium* spp., (Hunte and Mahon 1983) to large slow-moving rivers that support substantial fisheries. Standing waters include small lakes and ponds, as well as many coastal ponds associated with large rivers, e.g. Black and Cabarita R. morasses in Jamaica, Biggi Pan in Suriname, coastal marshes in Guyana (Mahon 1990, Sir William Halcrow and Partners Ltd. 1998). Rainfall variation will affect the availability of water to these systems, e.g. (Mol *et al.* 2000), and sea level rise may result in salt water intrusion to the low-lying coastal habitats that completely changes the fishery production system.

Typically, Caribbean fisheries managers and developers have paid little attention to the fisheries in these habitats. Because of their widely distributed, small-scale, often subsistence nature, these fisheries will be among the most difficult to assess and manage. Furthermore, their perceived low importance relative to marine fisheries has contributed to the lack of attention paid them, and thus low availability of information about them. Therefore, addressing these fisheries in any comprehensive manner in a programme to mainstream climate change into fisheries management and development will require a substantial reorientation of the present focus of fisheries departments in the relevant CARICOM countries. It will also require that there be a considerable effort expended on acquiring information about these fisheries that would be required to assess the possible impacts of climate change upon them.

### 2.5.3 <u>Direct impacts of climate change on fishery stocks</u>

The biological data from which to predict the impact of climate change on the variety demersal and pelagic resources, each with different bionomic characteristics, life history and habitat requirements, do not exist. Furthermore, as will become evident below, the resources that would be required to carry out such a study for even one of the fishery types would probably be prohibitive. Therefore, the most appropriate response to the threat of climate induced changes in fishery resource biomass or production, may be the establishment of monitoring systems that can detect gross trends in the fisheries, and unpredictable departures from these trends that may be attributable to climatic change, or anthropogenic effects.

The data collection systems established by the CARICOM Fisheries Resource Assessment and Management Program (CFRAMP) can provide data of the sort that would be required for monitoring gross trends. The continued refinement and operation of these systems will greatly facilitate the evaluation of changes in the fisheries.

Despite the above caveats, it is still considered useful to review the possible qualitative changes that could result in the future from the anticipated climatic changes. These are treated under three headings below. Regardless to the biological mechanism, increased variability in climate, either on an interannual basis or by amplification of the seasonal cycle can be expected to result in increased variability in exploitable biomass in fisheries. This may require new approaches to harvesting that are either precautionary of based on risk assessments such as was proposed for flyingfish (Oxenford *et al*. 1993)

#### *2.5.3.1 Impacts on stock distribution*

Climate change is expected to cause shifts in distribution of species at the extremes of their distributional ranges. For most species exploited by Caribbean fisheries the range extremes occur to the north and south of the region. Therefore, in general, distribution shifts are not expected to extensively affect Caribbean fisheries resources for most countries, as may be the case in other regions (Cohen *et al.* 2001). However, there would need to be a species by species examination of ranges in order to determine potential specific local impacts of range shifts.

#### *2.5.3.2 Impacts on recruitment*

Depending on the type of life history, variability in recruitment may result in variations in adult stock and vice versa. The latter relationship between stock and recruitment is sometimes used in predicting responses of stocks to exploitation or other perturbations, but not known for any fishery resource exploited in CARICOM countries. In some areas where stock-recruitment relationships are better known than in the Caribbean, recruitment variability appears to be linked to climate variability, and climate change is expected to affect recruitment, in some cases positively, in others negatively (Pittock et al. 2001).

Most fishery resources of importance to CARICOM countries have early life history (ELH) stages (eggs and larvae) that drift in the plankton (e.g. most reef fishes, lobster, conch, all pelagic fishes). Once the young leave the plankton, some use coastal habitats such as mangrove ponds, and seagrass beds as juveniles, before they move on to their adult habitats, and are recruited into the fishable stock. Thus any impacts on the habitats in which they spend their early life history may affect the numbers and sizes of recruits that survive to enter the fishery.

Possible impacts on coastal habitats have been dealt with above. However, there is another aspect to early life history that must be considered: possible change in small and medium scale coastal circulation. It is becoming increasingly apparent that planktonic ELH stages of reef organisms are retained largely in the vicinity of their parent populations and recruit to nearby habitats (Boehlert 1996). Near shore circulation probably has a significant effect on the proportion of ELH stages that are dispersed away from the reef area in which they originate (possibly off the island shelf), and thence on recruitment. The strength and direction of wind was correlated with nearshore currents and with abundance of ELH stages of coral reef fishes on the west coast of Barbados (Cowen and Castro 1994, Sponaugle and Cowan 1996). Any changes in coastal circulation, either wind driven, or due to changes in large scale ocean currents impacting on shelf topography may affect recruitment. Increases in advective processes are likely to lead to reduced recruitment.

Finally, due to a lack of knowledge and data, the impact of changes in climate, directly through temperature and indirectly through habitat modification, on the food chain leading up to the ELH stages cannot be predicted. However, temperature is known to play a key role in the initiation of spawning behaviour, such as the formation of aggregations, in some species. Indeed the effect of changes in water temperature on the entire marine production system is illustrated by the response of the eastern tropical Pacific during ENSO events.

Possible impacts of hurricanes on recruitment would be highly speculative. Large numbers of juvenile conch were washed up on shore in seaweed in Antigua after Hurricane Luis (Mahon and Joseph 1997). These were observed to survive for several days. Since the nursery habitats for juvenile conch are mainly inshore, it is possible that such mortality could have a significant impact on subsequent recruitment to the fishery. Getting the seaweed with the juvenile conch back into the water as soon as possible after the storm would be a way of reducing the mortality of the stranded juvenile conch.

Reef fishes have their main spawning peak in February-April (Munro *et al.* 1973). Most species would have settled by the beginning of the hurricane season. Therefore, storms are not likely to affect recruitment of reef fishes by advecting large numbers of planktonic ELH stages away from suitable habitats. However, the possible effects on newly settled juveniles are unknown.

The planktonic period of spiny lobsters is long (about 6 months) relative to that of reef fishes. Peak larval settlement of lobsters takes place during the hurricane season. Therefore, it is possible that advection of water masses by storms could affect the settlement of lobster larvae and subsequent recruitment.

#### *2.5.3.3 Impacts on adult biomass and production*

Much of the discussion regarding the effects of climate change on fishery resources has been in relation to the effects of temperature on growth and mortality (e.g. Regier and Holmes 1990). Increased temperature is likely to result in increased growth and mortality of most fishery resources. The extent of these changes could be explored by comparing growth and mortality data for the major species at localities within their ranges with different mean temperatures. For reef species the data for such a comparison is probably only available for species such as spiny lobster, conch, a few common reef fishes such a red hind or coney and the most common deep slope snapper species.

As previously discussed, many large pelagic species migrate throughout the Caribbean region and beyond, into the Atlantic Ocean. They are therefore likely to be able to compensate for climate change by adjusting their migratory routes and distribution patterns. The impact of climate change on availability of these species in the waters of CARICOM countries is likely to be of greater concern than its impact on their overall biomass and production.

Ecosystem models may also be useful in predicting the response of fishery resource populations to climate change (DeAngelis and Cushman 1990). There are few such models of Caribbean fishery ecosystems. A variety of ECOPATH models have been constructed for Caribbean ecosystems, including reef ecosystems in the Florida Keys, USVI and off Venezuela (Mendoza 1993, Opitz, 1996 Venier and Pauly 1996), coastal lagoon systems in the Gulf of Mexico (Chavez *et al*. 1993, Abarca-Arenas and Valero-Pacheco 1993, De la Cruz-Aguero 1993), and the Campeche Bank (Vega-Cendejas *et al* 1993. Recent extensions of ECOPATH models to ECOSIM and ECOSPACE may allow for spatial simulation of climate effects.

No information could be found regarding the impact of hurricanes and storms on the biomass and production of lobsters or conch. Regarding reef fishes, hurricanes do not appear to result in direct mortality of adult fishes. They do appear to affect the distribution of adults, which move into the least damaged areas, and juveniles, which also redistribute, and may not settle in damaged areas (Lassig 1983, Walsh 1983, Bouchon *et al* . 1981, Letoureur *et al*. 1993). In Reunion Island, SW Indian Ocean, low diversity and abundance of reef fishes were found on two near shore reef flat areas immediately after a hurricane (Letoureur *et al*. 1993). Both abundance and diversity increased over the following 18 months. This was interpreted as a recovery. There was less increase at the locality which had been most degraded by human impacts prior to the hurricane. Heavy siltation of the reef flat by runoff from the land was considered to have affected the populations.

2.5.4 Impacts on fish stock availability

Availability may be defined as the proportion of the resource that is vulnerable to the fishing gear or method. Availability may change independently of the abundance of the resource. Climate and weather may affect availability by affecting the distribution of the resource, or the way they interact with the fishing gear.

In the eastern Caribbean, from November through May, and particularly in February to April, the sea is reported to "roll" or "surge" intermittently. The effect of these surges is to stir up the sea in shallow areas down to depths of 20-30 m. At these times, fishes are reported to leave the affected areas and to move to deeper water. Trap catches are reduced. At the same time, the surges are reported to cause lobsters to leave their hiding places and move about, thus increasing their vulnerability to traps. From June through October, the opposite is the case. The sea is calm except for storm events, catches of fishes are high and those of lobster are low, relative to the period during which the surges take place.

Conch also follow the seasonal pattern described above. During the period of surges, they tend to bury themselves in the sand, and thus cannot be found by divers.

Deep reef fishes are apparently not affected by the surges. No information was offered by those interviewed regarding seasonal changes in availability of these species. Some of these deep reef species, notably the groupers, are known to form large aggregations for spawning. These aggregations form at very predictable times and locations that are well known to fishers, who exploit them. Some shallow water species also form spawning aggregations.

In conclusion, it appears that weather has considerable influence on the availability of the major demersal resources of coralline shelves. Thus, changes in the weather, particularly in the seasonal cycle as suggested by Galegos *et al*. (1993) and Gray (1993) is likely to affect availability of these resources to fishers.

The availability of large pelagic fishes, both coastal and oceanic, is highly seasonal in the eastern Caribbean (Mahon and Mahon 1987, Mahon *et al*. 1990, Mahon 1990b, Mahon 1996a). Most of the available information for these species in CARICOM countries is from the southern Lesser Antilles where there are well established fisheries for them.

The preceding discussion on availability of large pelagic fishes is highly speculative and serves mainly to illustrate the linkages with and potential impacts of climatic changes in the central tropical Atlantic and drainage basins in the north of the South American continent.

The passage of storms and hurricanes also appears to affect the availability of the demersal resources. In Antigua, Hurricane Luis was followed by a large increase in lobster catches. Increased vulnerability of lobsters to fishing due to storms could result in stock depletion leading to recruitment overfishing and stock decline (Mahon and Joseph, 1997).

The passage of storms and hurricanes results in decreased availability of conch, which bury themselves in the sand when sea conditions are rough. An increased frequency of storms may result in extended periods when conch are not available for harvest.

Reef fishes also reportedly show a response in availability due to storms. Immediately before storms their availability is low, but when fishers are able to return to fishing after storms, there can be short periods in which catches are higher than usual.

### 2.5.5 Impacts on the harvesting sector

Economic effects of the harvesting sector can be placed in two categories: those that affect revenues, and those that affect fishing costs. There are also potential impacts on fishers and fishing communities that may affect the viability of fisheries and their contribution to food security.

#### *2.5.5.1 Impacts on revenues*

Climatic change may affect revenues from fishing indirectly through stock abundance and stock availability as discussed above. Both stock abundance and availability affect the catch per unit effort and thus, for constant prices, the revenues from that effort.

If climatic change affects the amount of effort that can be expended each year, the total annual revenue per vessel, and for the industry overall will be changed proportionally. Fishing activities by all sizes of vessels may be curtailed by adverse weather conditions. In the eastern Caribbean islands, these are most likely to occur in the first two to three months of the year, when high winds are frequently sustained for one to three week periods, during which fishing activity may be reduced. Fishing activity is also curtailed by the passage of storms during the hurricane season (July to October).

Thus, climatic change could affect the amount of fishing that can take place during two periods of the year. If there is an intensification of the seasonal cycle of winds, then there would be an increase in the number of days during which vessels would be forced to stay in port during the first part of each year (windy season). Similarly, an increase in the frequency of storms during the hurricane season would increase the number of days on which vessels cannot go to sea to fish.

Given estimates of the probable increases in average wind speeds in the windy season, and in the frequency of storms, it would be possible to estimate the marginal increase in non-fishing days due to both causes. This would require a quantitative survey of fishing vessel captains to determine their response to weather conditions in general, and to the small vessel weather advisories issued by the Meteorological Services.

Mahon and Joseph (1997) outlined approaches to estimating the impacts of weather changes on fishing effort. For the windy season, the frequency distribution of daily wind speed in recent years incremented by the predicted increase in wind speed could be used to indicate the number of days during which wind speed would exceed a threshold above which vessels do not fish. The thresholds could be determined by interviews with fishers using the Beaufort scale to translate sea conditions into wind speed. Different threshold values may be required for vessels of different sizes.

A more precise approach would be consideration of the frequency and duration of wind events above the various thresholds, since sea conditions take several days to build and subside.

It would require the analysis of daily wind speeds for a number of years to determine the average frequency and duration of wind events in the period of concern. It would then be possible to predict changes in these due to an increase in average wind speed. The most technically sophisticated, and correct approach to these predictions would involve time-series analysis of past wind data and forecasting of future conditions. Given the uncertainty regarding the predicted changes in wind speed, the simplest of the three approaches may be adequate at first.

A similar approach could be taken to estimate the increase in the number of days during which vessels cannot fish during the hurricane season. In this case, data would be required on the proportion of past Atlantic tropical depressions, waves, storms and hurricanes (systems) that passed sufficiently close to CARICOM countries for associated winds to have resulted in sea conditions that exceeded any of the vessel thresholds. From those data it would be possible to estimate the proportional impact of any projected increase in the numbers of Atlantic systems.

Any climatic change that reduces the number of days on which vessels can fish, and thus the total effort expended in fishing will bring about a short-term reduction in catch per vessel and overall catch. For those resources that are overexploited, this reduction in fishing effort may lead to stock recovery in the longer-term, and thence to increased catch per unit effort and increased total landings, even from lower effort.

The theoretical basis for the stock response to reduced effort described above is well documented in the fisheries literature (e.g. Hilborn and Walters 1992). Briefly, as total effort increases, total catch, and thence revenue, increases to a maximum (the maximum sustainable yield, MSY) and then decreases as the resource becomes overexploited. If total effort is less than that producing MSY a reduction in effort will result in a reduction in catch. If it is greater than the effort which produces MSY, reduced effort will result in an increase in total catch.

Any possible benefits from stock recovery due to reduction in effort from to climate change impacts, may be negated by dislocation of workers from other sectors into the fishing industry. This response to Hurricane Luis was observed in Antigua and Barbuda. After the hurricane many individuals who became unemployed due to closure of hotels and businesses, sought short-term employment in fishing. Most of this short-term effort was probably directed at the already overexploited nearshore areas. Thus the short-term response to hurricanes may result in further overexploitation of nearshore resources.

#### *2.5.5.2 Impacts on costs*

The costs of many inputs into fishing could be affected by intensification of the seasonal cycle and by any increase in the frequency of storms. Worse weather conditions in the windy season will increase costs by: increasing travelling times to fishing grounds, increasing fuel costs due to rough seas, increasing labour costs due to the working conditions, increasing maintenance costs due to damage of the vessel, equipment and fishing gear. Destruction of fish traps during the windy season is one of the main costs caused by weather.

Storm and hurricane damage has a major impact on the fishing industry. Substantial losses were sustained by the fishing industry of Antigua and Barbuda as a result of Hurricane Luis. About 16% of the fleet was either destroyed or lost, and a further 18% was damaged. Assuming that the damaged vessels could not fish for some time, this represents a loss in fishing capacity of about one third following Hurricane Luis, at a time when food would be scarce.

In September 1989, Hurricane Hugo also caused considerable damage to the fishing industry of Antigua and Barbuda, although less than that caused by Luis. Total damages were assessed at US$1.15 M. This included: replacement of 28 boats that were lost (2 sloops and 26 open boats); repair of 36 that were damaged and, replacement of traps (FAO 1989). The fishing industries of several neighbouring islands also suffered substantial losses.

Few other quantitative reports of hurricane impacts on fishery sectors in Caribbean islands could be found. Hurricane Gilbert resulted in the loss of 90% of traps in Jamaica, and also in considerable damage to boats and infrastructure (Aiken *et al*.1992). Hurricane Mitch caused considerable damage to vessels and gear on the Pedro Cays south of Jamaica in 1998.

##### *2.5.5.3 Loss in national revenue from the fishing industry due to a hurricane*

In addition to the cost of replacement and repair to fishing vessels and gear caused by a hurricane there is a loss of revenue due to disruption of the fishing industry. The Fisheries Division and FAO together estimated a recovery period of about 6 months for Hurricane Luis. The estimated schedule of recovery as a percentage loss of landings is as follows: 80% loss in month one; 60% in month 2, 40% in month 3; 20% in month 4; 10% in month 5; and full recovery in month 6.

The above schedule would result in an overall loss of 24.2% of the revenues from fishing in the 12 month period following the hurricane. The timing of the hurricane and its magnitude would cause this estimate to vary.

##### *2.5.5.4 Impacts on shore-based harvesting – beach seining*

Beach seining is a harvesting methods that is carried out from shore. It depends on appropriate beach and near shore bottom conditions for its success. If there is significant erosion of beaches due to seas level rise, suitable sites for beach seining may be eliminated. This tope of fishery is one that is carried out primarily for local consumption and is thus an important component of the food security aspect of fisheries.

#### 2.5.6 Impacts on fishing communities and shore-based facilities

The complexity of inter-relationships among members of resource dependent communities may result in unpredictable responses to changes in resource availability, as these changes relate not only to the harvesting of the resources but also to the entire supply chain from fisher to consumer (Scott *et al.* 2001).

The fisheries in CARICOM countries are predominantly small scale and operate from undeveloped landing sites, mainly beaches where vessels can be hauled up, but also mangrove creeks and shallow back-reef lagoons where boats can be tied or moored safely within easy reach of shore. Erosion of beaches and/or loss of habitats that eliminate landing sites or make them less functional would affect adjacent communities.

In general, fishing communities, or communities with a significant component of fishing, occupy low-lying coastal lands. Thus they will be exposed to most of the variety of disruptive impacts that can be identified for human settlements in the coastal zone.

Fishing facilities may be among the most vulnerable of those found in coastal communities. These vary widely in degree of development from minimal (e.g. a few storage lockers and a covered area for working on gear) to extensive (e.g. small complexes with jetties, cold storage offices, retail areas, boatyards)

A particular type of fishing community that should be given special consideration is fishing camps on low lying cays that may be submerged by sea level rise. Examples of these occur in Jamaica (Morant and Pedro Cays ), Belize, Bahamas, St. Vincent and the Grenadines. They form a base for fishers that sell their catch to carrier vessels. These bases reduce the cost to small-scale fishers of accessing resources that are remote from established communities. They are essential if small-scale fishers are to be involved in harvesting the resource. The alternative would be to harvest the resource with larger vessels that can make trips of several days and store fish on ice.

#### 2.5.7 Aquaculture

Aquaculture enterprises are likely to be very vulnerable to impacts of climate change. Aquaculture activities on shore are usually in low-lying coastal areas. These are likely to be inundated as sea level rises. They are also likely to be threatened by any loss of protection to the coast such as by degradation of mangroves, seagrasses and coral reefs. Similarly, aquaculture enterprises in cages and pens in sheltered coastal habitats, are likely to be affected. Inshore areas that are sheltered by mangroves and reefs may lose their shelter, and thus their suitability as mariculture sites.

#### 2.5.8 Linkages with other sectors

Fisheries and other sectors are linked in a number of ways. In particular, there are linkages with tourism, through:

- A common dependence on marine habitats;
- Dependence on tourism for a market for fishery products;
- Competition for scarce coastal land space (hotels, marinas and landing sites);
- Conflicts in marine space use (recreational and commercial fisheries);
- Incompatibility in fishery management objectives (reef fisheries versus snorkel and SCUBA uses).

Fishing effort may be closely linked with the national unemployment rate, such that as the rate increases, unemployed persons turn to fishing as a means of short-term support. This is particularly prevalent in small-scale fisheries where the costs of entry into the fishery may be relatively low, e.g. by spearfishing, diving for lobster and conch, or setting a few traps near shore. Near shore resources are usually most impacted.

## 3 ADAPTATION

The literature and the CARICOM country issue papers include a wide range of possible adaptation measures for the climate change impacts on fisheries that have been identified in the preceding section. Others were suggested at the Climate Change and Fisheries Workshop (CCCC 2002). These are treated below using the same organisational structure as the section on impacts. At the end of the section, research and data needs for adapting to climate change are considered.

In preparing CARICOM countries to deal with impacts of climate change on fisheries, the aim must be to develop the capacity to deal with change rather than to attempt to determine 'up front' all the adaptations that might be required. Therefore, information provided in this section is intended to be indicative of the types of adaptation that could be required, rather than comprehensive.

### 3.1 Adaptation to impacts of climate change on fishery habitat

The effects of climate change on marine ecosystems cannot easily be controlled by engineering measures. The greater the quantity of coastal habitats that are important for fisheries, (mangroves, seagrasses and reefs) the less likely it will be that climate change will reduce these habitats below critical levels for fisheries. Furthermore, the better the condition of these habitats, the more resilient they will be. Therefore, a general strategy to conserve these habitats both in quantity and in quality would be an appropriate precautionary adaptation to the effects of climate change. Where these habitats have been destroyed, this may include restoration which, in many cases will provide other benefits such as shoreline protection (reefs and mangroves) and hurricane harbours (mangroves).

In order to address the changes that are likely to take place in the coastal zone, and ultimately to affect fisheries, a Coastal Zone Management Plan should be formulated. It should include the .measures that needed to adequately deal with the effects of climate change on coastal habitats.

### 3.2 Adaptation to direct impacts of climate change on fishery stocks

Adaptation to changes in stock distribution, recruitment levels and variability and adult biomass and production can only be achieved by adjusting fishing effort to levels that are consistent with the yield levels that can be sustained by the changed populations. This can be attempted by conventional assessment and management measures, adaptive management or co-management approaches. As will be discussed in the section on policy and planning below, which of these approaches to use is a strategic decision that must be made at the national level before the details of the approach can be developed. Different approaches may be required for different fisheries. These decisions are central to ongoing fisheries management and development in CARICOM countries.

### 3.3 Adaptation to impacts on fish stock availability

Where climate change results in reduced availability of the resource to fishing vessels and gear (but not changed abundance) it may be possible for the industry to adapt by adopting vessels and gears that can pursue the resource in its new habitat. This may require larger vessels for longer trips and investment in gear development. It may also take vessels into the waters of other countries, thus necessitating fishing agreements and entry into collaborative management as required by the UN Fish Stocks Agreement (United Nations 1995).

## 3.4 Adaptation to impacts on the harvesting sector

### 3.4.1 Deterioration of weather conditions

Apart from tropical storms, which are extreme events, there is the expectation of increased winds, and thus of generally worse sea conditions for boating. These effects will be best addressed by a program to increase seaworthiness of and safety aboard fishing vessels. Given the high proportion of small vessels in the fleets of CARICOM countries, it would be advisable to encourage fishers and boat owners to invest in larger vessels with the fullest range of safety equipment feasible for the size of boat. The latter adaptation will be to some extent autonomous, but will require support from Government agencies

### 3.4.2 Tropical storms and hurricanes

The arguments presented above for habitat restoration and conservation apply also to the effects of storms.

The effects of storm conditions on fishing vessels can be adapted to by:

- Provision of mooring sites for large vessels, particularly in protected areas afforded by mangroves;
- Provision of facilities for removal of vessels of all sizes from the sea to sites above the reach of the storm surge, and provision of the means to secure them against wind damage.

Gear loss will be minimized if vessels are sufficiently large and safe to retrieve gear when storm conditions are imminent, and if there are adequate facilities for storing or securing them ashore.

The impact of trap loss on fish and lobster resources through ghost fishing can be reduced by the introduction of biodegradable escape panels that open after about a week, allowing the animals to escape from the trap.

The effects of storm conditions on fishery shore infrastructure would be best adapted to during the design and construction of new facilities. However, existing facilities can be upgraded as per recommendations for human settlements and habitation..

Given that marine habitat destruction would likely result from climate change, the demersal resources that are dependent on near shore habitat such as coral reefs, seagrass beds, and mangroves would be most affected. In countries where these resources are the mainstay of the fishing industry, this possible impact may points to the need for the commercial exploitation of the pelagic resources in order to sustain a satisfactory level of fish landings, and to maintain the economic viability of the industry.

Given the seasonal nature of the pelagic resources, it will be necessary to use multipurpose vessels that can fish for demersal fishes in the off season. A development approach promoting cautious investment in vessels of the size that would be capable of harvesting large pelagics, would be consistent with the need for larger vessels for safe harvesting of demersal resources. However, it is necessary to bear in mind that these vessels will result in additional pressure on demersal resources in the off season. Therefore, the strategy should be for them to replace existing small vessels, rather than to add to the fleet.

Other adaptations to possible climate impacts on the harvesting sector, primarily due to hurricanes and seasonal weather conditions, are also consistent with development changes, such as larger boats, that would enhance productivity, product quality and safety.

### 3.5 Adaptation to impacts on fishing communities and shore-based facilities

Erosion of beaches at landing sites where vessels are typically hauled out can be addressed through beach stabilisation and renourishment works but these are costly. Haul-out ramps for small boats can be constructed. Where there is loss of beach and/or protective structures, construction of small harbours pr breakwaters can be considered. However, the high cost of these usually means that only a few can be built and may be accompanied by centralisation of fisheries, either planned or in reaction to conditions. This may disrupt small communities as well as increase costs of operation through the need to travel to the landing site.

Whereas, rebuilding or relocating existing facilities in response to actual or potential climate change impacts may be prohibitively pensive, new ones should be located and designed with these impacts in mind. Upgrading of landing sites is an ongoing process in most CARICOM countries. This provides the opportunity to incorporate adaptation to climate change. However, in order for this to take place the following are needed:

- Awareness on the part of the developer regarding climate change impacts and adaptive design options;
- Information on what the impacts of climate change are likely to be on a site specific basis.

It is assumed that the adaptations that will be developed for human settlement will address most of the concerns for fishing communities. However, particularly in areas where they are already being marginalized by tourism development, fishing communities may not get the priority attention that they need. Fishing facilities may be among the most vulnerable of those found in coastal communities.

### 3.6 Aquaculture

There will be impacts on both land based aquaculture and mariculture. Land-based aquaculture usually takes place in low lying coastal areas that will be among the first to be inundated by rising sea level. Mariculture usually takes place in shallow coastal marine habitats such as mangrove lagoons, back-reef lagoons, semi-enclosed bays, etc. These habitats are all threatened by climate change.

### 3.7 Linkages with other sectors

Adaptation should be integrated across sectors to minimise duplication of effort. Similarly, there will be the opportunity for integration of research activities that address the effects of climate change. As previously indicated there are considerable linkages among sectors regarding impacts, therefore, there will be opportunities for collaborative adaptation activities that might not be economically feasible if pursued from a single-sector approach.

### 3.8 Data and research needs to effectively assess the impact of climate variability and change of fisheries and fish stocks

It is clear that there is the potential for the predicted climate change scenario to affect the fishery sectors of CARICOM countries through a complex set of direct and indirect mechanisms, including effects on habitat, exploited populations, their prey, and by no means least the harvesting sector and fishing communities. It is not possible to provide quantitative predictions of these impacts.

The data required for comprehensive modelling of these relationships are not available, and unless key relationships can be identified, collection of the broad spectrum of data that would be needed may not be feasible. Therefore, the most appropriate approach to assessing climate impacts may be to monitor changes in the fisheries. How this should be approached is, at this stage, more a strategic issue than a technical one, and is addressed in the following section.

Monitoring for changes in critical habitats is an issue with wider relevance than fisheries, e.g. for tourism, biodiversity, coastal protection, and should be treated as part of a broader plan. However, there will be the need to ensure that fisheries consideration are fully address in those broader plans and provisions must be made for the necessary fisheries inputs.

It may be possible to identify certain research activities that can, with existing data, provide valuable information on the probable responses of Caribbean fisheries to climate change. There are databases that have climate information that could be useful in exploring fisheries-climate relationships (e.g. at NOAA NODC and NCDC). However, these data have seldom been used for Caribbean fisheries and are not routinely accessible by national Fisheries Divisions. Consequently, data on fish distribution and abundance and data on climatic variables seldom been brought together to address fisheries questions. Some examples of the types of studies that could be informative and that might be possible with existing data are:

- The relationships between present distributions of fishery resources and temperature (e.g. Murawski 1993);
- The relationships between seasonal availability of migratory species and the seasonal climate cycle (e.g. Mahon 1990);
- The effects of the seasonal cycle on spawning, including aggregation, of fishery resources (e.g. Sadovy 1996);
- Relationships of early life history, particularly planktonic stages, to meso-scale and local-scale circulation (e.g. Cowen and Castro 1994, Sponaugle and Cowen 1996);
- Effects of large scale climate phenomena, such as the North Atlantic Oscillation and ENSO on Caribbean fishery resources (e.g. Mahon 1990, Norton 1998).

Focussed research initiatives on these and other topics could provide valuable information for planning for adaptation to climate change.

At the Climate Change and Fisheries Workshop (CCCC 2002), participants offered a wide range of ideas regarding research that would serve to inform adaptation to climate change and also to enhance ongoing efforts to improve fisheries management. These included research into: planning and process at national regional and international levels, the social and economic bases of fisheries, use of local knowledge, and basic biological processes. The need to support and enhance basic data collection systems for fisheries catch and effort was emphasised. This can be seen as both a research need and a capacity building need.

# 4 INPUTS TO EFFECT DECISION-MAKING AND PLANNING FOR THE FISHERIES SECTOR

## 4.1 Policy

Climate change issues should be fully integrated into regional and national decision-making and planning for the fisheries sector. Thus far they have received little consideration. To achieve this integration, there will be the need for specific attention to the relationship between these issues and ongoing fisheries management. At its Heads of Government meeting in February 2002, CARICOM approved the establishment of the Caribbean Regional Fisheries Mechanism (CRFM) to address fisheries issues at the regional level. The structure and function of the CRFM are described in the report of the Working Group that was formed to develop the CRFM (CFU 2000). Since the CRFM will be the primary coordination mechanism for fisheries in CARICOM countries, mainstreaming climate change issues in fisheries for CARICOM countries will require close collaboration between the CCCC and the CRFM. The relative roles of these two CARICOM institutions must be clearly defined at the outset, as must the roles of national fisheries administrations. To this end, the Climate Change and Fisheries Workshop 2002 recommended that the CRFM Working Group be mandated to integrate climate change issue into the Strategic Plan that is currently being developed for the CFRM.

Many of the challenges to be addressed in mainstreaming climate change issues in fisheries for CARICOM countries will be the same as those that are currently being faced in establishing systems for sustainable fisheries management in these countries. These are well documented in numerous publications (Chakalall *et al*. 1998, CFRAMP 2000, Murray 2000, McConney 2000, Haughton and Singh-Renton 2001). However, policy adaptations beyond those already identified may be required to address climate change issues. Some policy and other areas that may require special attention are listed below. These should be considered in the light of global awareness and trends in fisheries management outlined subsequently:

- The specific inclusion of climate change issues in fisheries planning, possibly through risk evaluation and risk criteria;
- The need for greater attention to application of the precautionary approach owing to uncertainty associated with climate change;
- Increasing involvement of stakeholders as partners through information and liaison;
- Critical fisheries habitat policy, such as a 'no net loss' or restoration;
- Greater attention to the use of ecosystem indicators that may relate to climate.

Globally, attitudes and approaches towards fisheries management and development are in a state of flux. This situation has come about as a result of the growing acceptance that conventional fisheries management has failed to prevent overexploitation of the world's major fisheries and that new thinking and urgent action are required. Some major issues for these fisheries are:

- Inadequacy of population models to provide a basis for management;

- Massive overcapitalisation of large-scale commercial fleets;
- Illegal, unregulated and unreported (IUU) fishing;
- Major losses due to bycatch;
- Failure to recognise key ecosystem linkages.

At the same time, the inappropriateness of conventional management for small-scale fisheries has become increasingly clear (Berkes *et al.* 2001).

The way ahead is not as clear as are the problems. The "Code of Conduct for Responsible Fisheries" is one attempt to address this situation (FAO 1995). For small-scale fisheries, it is becoming accepted that there will need to be increased reliance on:

- Co-management and other participatory approaches;
- Capacity building for fisherfolk institutions to take part in co-management;
- Traditional and local ecological (and other) knowledge (TEK, LEK);
- Commonsense, indicator-based control systems that include ecosystem considerations;
- Application of the precautionary principle in the absence of technically derived targets and limits;
- Development of Sustainable Development Reference Systems (SDRSs) based on a wide range of indicators (Garcia and.Staples 2000), possibly leading to systems of management rules based to greater extent upon consensus among participants than on technically derived targets (Caddy and Mahon. 1995, Caddy 1998)

These new ideas and approaches are evolving and will take some time to be tested and if workable, established in CARICOM countries. It is into this scenario of innovation and change that climate change issues must be integrated. This integration must be consistent with and promote improved fisheries management.

## 4.2 Planning

There are ongoing initiatives in support of management and development planning at the national level in CARICOM countries. In most countries, the legislation requires that there be a plan. However, only a few countries have an institutionalised planning process that follows a regular cycle (e.g. (McConney and Mahon 1998, Fisheries Division 2001). In order that climate change issues can be addressed in fisheries planning, there will need to be substantial attention to strengthening the planning process in most countries.

The possible impacts of climate change on shore-based fishing facilities at landing sites, aquaculture and fishing communities, means that planning adaptation to climate change impacts on fisheries must include interaction with the national Physical Planning process. This is necessary so that matters such as land-use, location of facilities and site specific measures such a setbacks and erosion protection structures are properly addressed in planning at the national level.

As with many other aspects of fisheries management and development, climate change adaptation may often take the form of discrete, project type activities. For this type of activity there will be the need for attention to the development of use of project planning and management tools (e.g. LFA).

## 4.3 National and regional institutional capacity

### 4.3.1 Capacity to monitor impact of climate change

Assessment of the national and regional institutional capacity to systematically collect and analyse data to monitor the ecological and socio-economic impact of climate change on the fisheries sector would be best based on a strategic assessment of the type and level of assessment that would be sustainable for Caribbean fisheries.

A full, quantitative monitoring system for impacts of climate change on Caribbean fisheries would require that there be systems to determine the current and future states of indicator variables for all the fisheries sector components outlined in Figure 1. These would include habitats, resource populations, sector level economics, fishing unit level economics, landing sites, and communities. This assumes that relevant climatic and oceanographic variables are already being adequately monitored. This level of monitoring is probably not achievable, even with the full attention of all institutions, or sustainable. There is a parallel here between the issue of the appropriateness of conventional science-based fisheries assessment used for large fisheries in developed countries (Berkes *et al*. 2001) and the appropriateness of related approaches for monitoring climate change impacts.

An alternative, towards the other end of the scale, would be a monitoring system that relies upon participatory feedback from a cross-section of aware resource users. Such a system would still require a considerable amount of capacity to acquire, record and analyse and interpret information. It would also require that stakeholders be well informed of the potential impacts of climate change so that they be effective partners in monitoring.

At present, even simple ongoing systems for acquiring information on landing sites, resources, fishing activities, etc. are not established in many CARICOM countries. Berkes *et al.* (2001, Chapter 4 Fishery Information) provides some examples of simple ongoing systems. For example, the proposed system for acquiring and recording information on landing sites if implemented, could be adapted to include information on the incidence of erosion, wave damage, flooding, or other problems that could be climate change related.

Similarly, systems for acquiring TEK and LEK could be adapted to include information on changes in resources, such as timing of reproduction, migration, etc. Data collection systems that are oriented towards this type of data have been proposed for both Suriname and Jamaica (Mahon 2001a, 2001b).

Clearly, there is the underlying need to have basic information on the catch and fishing effort for major fisheries. This information is necessary for management decision-making as well as for planning development. CFRAMP has invested several years of effort into establishing fishery data collection systems in participating countries. The continued support and enhancement of these will be a cornerstone to any initiative aimed at developing capacity to monitor and respond to impact of climate change on fisheries. Continuing attention to updating, revising and refining these systems is required until they become sustainable.

### 4.3.2 Capacity to integrate climate change issues in sustainable fisheries management

#### *4.3.2.1 National level*

In CARICOM countries, fisheries are administered by Fisheries Divisions or Departments that are often in Ministries of Agriculture. The most recent comprehensive evaluation of CARICOM fisheries divisions was conducted in 1991 as a baseline for assessing the impact of CARICOM Fishery Resources Assessment and Management Programme (CFRAMP)(Mahon and Boyce 1992). A post-assessment of fisheries divisions would provide an indication of the extent of capacity change that can be achieved with a decade of capacity building costing about US$ 20M. This could inform planning for what might be achievable by MACC.

It is frequently said that fisheries are undervalued and under-budgeted in most CARICOM countries. Despite CFRAMP's achievements in many areas relating to management planning, data collection, resource assessment, training and community participation, most Chief Fisheries Officers consider their divisions to be inadequately staffed and funded to address their mandate. This chronic situation raises several questions.

- Are fisheries under-funded by national governments in relation to other productive sectors?
- Does the information on the value of fisheries exist to support a case for increased funding?
- What are appropriate levels of national and regional funding for fisheries management in relation to the value of fisheries sectors?

Answers to these questions are needed to allow fisheries divisions enter a mode of strategic planning based on feasible levels of resources. Without them, fisheries management is likely to continue on an ad hoc path, driven by crisis management and donor funding availability. It is worth noting that CFRAMP did initiate human resource development planning for fisheries divisions. An approach was developed in a workshop, but the outputs were not pursued due to lack of funding.

In the above circumstances, CARICOM fisheries divisions will be slow to pursue the fisheries management innovations and changes described in the previous sections. To do so, will require a shift in perspective from the conventional one of fisheries manager as technocrat to the merging one of fisheries manager as facilitator. New skills will be required in fisheries divisions that seek to move in this direction. These will include participatory methodology, planning and project implementation.

Attempts to integrate climate change issues into fisheries management that foster these changes in national fisheries divisions will contribute broadly to achievement of sustainable utilisation of fishery resources in CARICOM countries.

#### *4.3.2.2 Regional level*

At the regional level, the CRFM is yet to become operational. However, in developing the CRFM, climate change issues did not emerge as a priority area, and no provisions were made for addressing these issues within the proposed structure. Incorporation of climate change information and issues into the ongoing work of the CRFM should be possible if provisions can be made for any additional data management and analysis requirements. As stated above, the relative roles and responsibilities of the CCCC and the CRFM in integrating climate change into fisheries need to be specified.

There is some technical capacity for fisheries related climate change research in tertiary educational institutions (University of the West Indies, the University of Guyana, the University College of Belize) and national or regional research institutions that serve the region (Caribbean Meteorological Institute (CARMETI), Caribbean Environmental Health Institute (CEHI), Institute of Marine Affairs of Trinidad (IMA), Caribbean Fisheries Training and Development Institute (CFTDI), and the Jamaica Maritime Institute (JMI)). However, research institutions are generally weak in the area of oceanography, most effort having been expended on the study of near shore habitats such as reefs, and mangroves. This situation was flagged by a review of oceanographic capacity at UWI in 1990, and recommendations made for strengthening that capacity in the areas of biological, physical and chemical oceanography. The recommendations were not implemented.

Regional (CANARI, CCA CaMMP) and national NGOs (particularly fisherfolk organisations) can also play a role in dissemination of information and facilitating stakeholder participation. These institutions are already usually fully engaged. Therefore, there would be the need for reorientation, or expansion of capacity to incorporate climate change issues.

#### 4.3.3 Capacity building for climate change and fisheries under MACC

The Climate Change and Fisheries Workshop (CCCC 2002) articulated the following approach to capacity building.

Building capacity to deal with the impacts of climate change on fisheries and aquaculture is a long-term ongoing process. To begin this process the following is proposed:

- Capacity building is a holistic process that address the roles and capacity of all stakeholders, regional and national government, NGO and private sector.
- The effective delivery of capacity building programmes must be informed by a comprehensive capacity building strategy that incorporates the necessary components such as assessment of existing capacities, identification of capacity building needs, development of strategy, implementation strategy, assessment and evaluation.
- In order to build capacity there is the need to identify where stakeholders need to go and what they need to do to get there.

The development of the broader CARICOM fisheries picture is an ongoing process that is being carried forward by the CRFM

- MACC can further and strengthen this ongoing process by assisting in the development of a strategic approach to integrating climate change issues into all aspects of CRFM planning
- It can further assist by developing a long-term capacity building program for prudent fisheries management modalities that incorporate climate change adaptations

In doing this it should be noted that there is considerable communality of data and other requirements between climate change issues and ongoing fisheries management as well as between fisheries management and other sectors related to sustainable livelihoods for coastal and marine systems

Recognising that climate change will increase uncertainty in marine resource management systems, and that adaptation is likely to involve two routes:

- Quantification and modeling of risk and uncertainty;
- Precautionary approaches to management;

MACC can further contribute through focused demonstration activities that build capacity to pursue either or both of the adaptation approaches for priority resources.

The Climate Change and Fisheries Workshop (CCCC 2002) recommended that scholarships be established to support fisheries officers to undertake M.Sc. research on the linkage between GCC and fisheries. This is expected to contribute to the mainstreaming of GCC into the broader fisheries management decision-making framework.

### 4.4 Public education and primary stakeholder awareness

Public education and primary stakeholder awareness are two levels of information generation and dissemination that should be given a high priority. The former is more general and aims at schools and the general public. The latter is more specifically targeted at the information that primary stakeholders need to know to participate in adaptation.

If, as suggested in the previous section, future fisheries management involves a considerably greater degree of stakeholder participation than is currently the case, then the education and awareness components of fisheries and climate change will have to assume a much more prominent role.

It should be noted that the primary stakeholders include Government Departments. Therefore, any initiative aimed at education should have a major component aimed at these departments. The Climate Change and Fisheries Workshop (CCCC 2002) recommended that National Advisory Committees on Climate Change be established, as this would go a long way to promoting information exchange among relevant Government departments. Additionally, existing committees such as Fisheries Advisory Committees (FACs) could be good avenues through which to increase awareness of climate change issues.

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