Chapter 9: Climate change impacts, vulnerabilities and adaptations: Western Central Atlantic marine fisheries

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KEY MESSAGES

- Negative impacts from climate change that are already obvious in this region include coral bleaching, increasing frequency of high intensity storms and hurricanes, increased sea level, and sargassum influxes that are disrupting fishing operations, fish landings and fisher livelihoods.
- Because most species in the Western Central Atlantic are already at their maximum thermal tolerance and the Gulf of Mexico and Caribbean Sea are constrained by land barriers, there are expected to be few "winners" under future climate change with regard to the commercially important fishery species, which are expected to suffer population declines and reduced productivity in this region.
- Smaller catches can be expected to have significant socio-economic implications for those working in the harvest and post-harvest sectors. This will also have implications for national governments such as reduced domestic productivity in the fishing sector, food security and international trade and foreign currency earnings, especially for those countries with export-oriented fisheries.
- The fisheries sectors of the region's small island developing states are the most vulnerable to climate change.
- Fisher conflicts will increase as fish resources become scarcer. Conflicts will also arise between consumptive users and non-consumptive users within the fishery sector and between sectors.
- Fish resources in the region are typically shared by multiple nations and climate-induced changes to their distribution may require changes to multi-lateral or international agreements, whilst changes in genetic connectivity of stocks may impact the effectiveness of marine reserve networks in protecting source populations.
- Increasing sea surface temperatures in this region, in combination with increased nutrient loading, have implications for the safety of fish and shellfish consumption, given the expected increases in the occurrence of toxic algal blooms, ciguatera fish poisoning and the increasing prevalence of various shellfish diseases.
- Climate change stressors such as sea level rise and increased frequency of severe hurricanes in the region will continue to have significant negative impacts on the safety of fishers, fisheries infrastructure, boats and fishing equipment, and coastal fishing communities.
- Adaptation measures already being undertaken across the region include: development of mobile apps for tracking and early warning; investment in improved infrastructure and facilities; improving resilience of fisherfolk and aquaculturists, and mainstreaming climate change into fishery policy and planning.

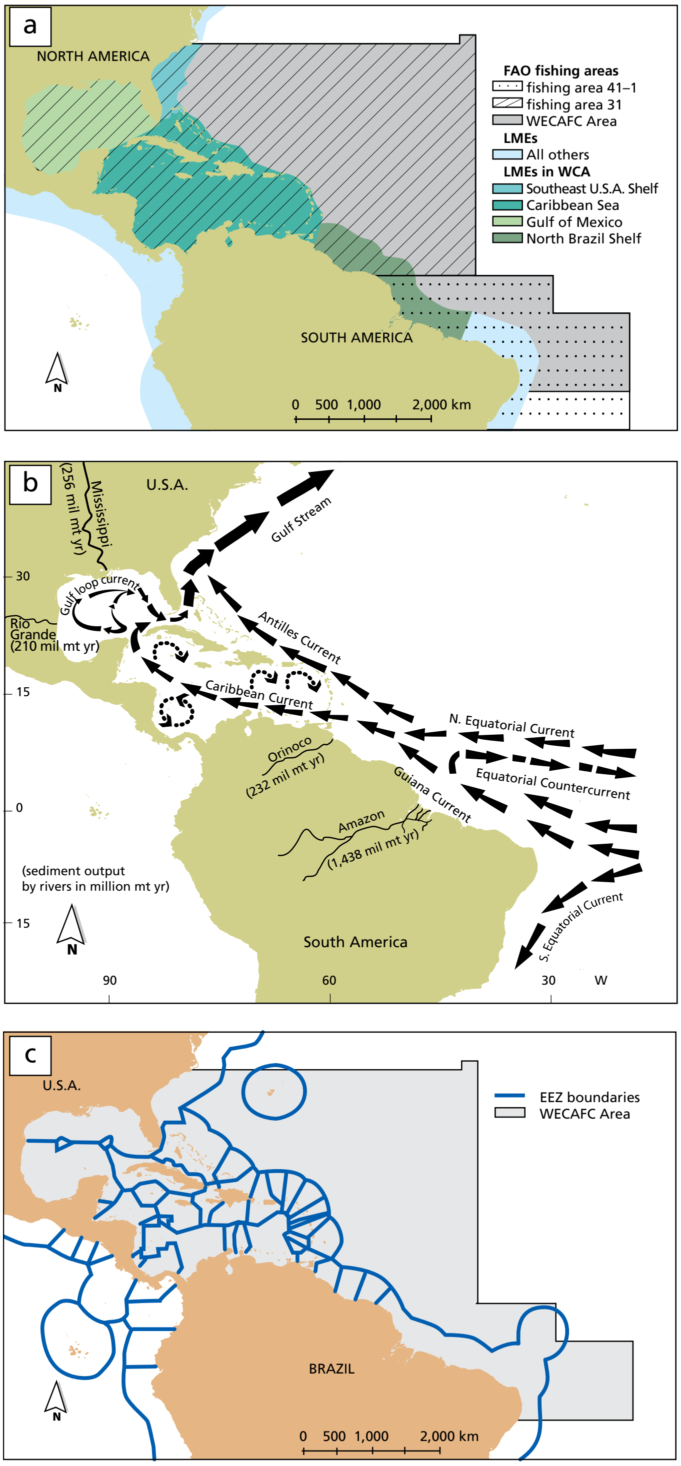
9.1 INTRODUCTION

9.1.1 The Western Central Atlantic region

The Western Central Atlantic (WCA) represents the area covered by the FAO Western Central Atlantic Fishery Commission (WECAFC), which includes FAO major fishing area 31 and the northern part of FAO major fishing area 41 (Figure 9.1). This area encompasses four distinctly different biogeographic regions considered as different large marine ecosystems (LMEs): the northeast coast of South America (North Brazil Shelf), Caribbean Sea, Gulf of Mexico (GOM) and the southeast shelf of the United States of America (SE USA), as well as a large area of open ocean linked by major ocean currents. It covers 14 644 544 km^2 of which 10.5 percent is continental and island shelf, incorporates two of the world's largest semi-enclosed seas, and is influenced by the discharge of some of the world's largest rivers (e.g. Amazon, Orinoco, Mississippi). The WCA includes the exclusive economic zones (EEZs) of 28 nation states and 16 territories belonging to the Netherlands, The United Kingdom of Great Britain and Northern Ireland, France and the United States of America, of which 29 are considered small island developing states (SIDS) and has five official languages, making it one of the most geopolitically complex and vulnerable regions of the world. It is also one of the most bio-diverse areas of the world's oceans, exhibiting a wide range of oceanographic and hydrographic features, a great diversity of tropical, subtropical, estuarine, coastal, shallow-shelf, deep-slope and oceanic habitats, including around eight percent of the world's coral reefs and six percent of the seamounts, and supports a wide diversity of commercially important fishery species (Table 9.1).

FIGURE 9.1

Maps of Western Central Atlantic region showing a) LME boundaries and FAO fishing areas, b) major surface currents, and c) EEZ boundaries[1]. Quantitative data are given in Table 9.1



[1] The designations employed and the presentation of material in the map(s) are for illustration only and do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers or boundaries.

TABLE 9.1

Summary of main oceanographic features and fisheries characteristics of the LMEs in the Western Central Atlantic

LME key oceanographic features[a]	Main target groups	Socio-economic importance of fisheries	Fisheries governance arrangments[e]
NORTH BRAZIL SHELF Area: 1 000 000 km^2, 47% shelf, 1.7% protected. Contains <0.1% world's coral reefs and seamounts. Tropical, very high annual primary production (>300 g C/m^2). Dominated by a branch of the South Equatorial Current, the North Brazil Current (NBC) flowing NW towards the Caribbean, and by nutrient rich, high sediment Amazon River discharge. 	Brazilian sardinella, penaeid shrimps (seabob, white, brown, pink), groundfishes (weakfishes, croakers, sea catfishes), deep slope (southern red snapper, spiny lobsters). 50% stocks overfished or collapsed[b]	Annual production (2014): 450 250 tonnes, worth USD1 041 million[b]. Includes five nations (Brazil, French Guyana, Suriname, Guyana, and the Bolivarian Republic of Venezuela). Significant dependence on fish protein throughout the region. Very important export-oriented shrimp fisheries. In Guyana the fishery sector is critical to the national economy (6% GDP) and social well-being with per capita fish consumption[c] at 30 kg/yr.	No regional fisheries management organisation (RFMO). Shared responsibility for assessment and management of shrimp and groundfish resources of the Guianas/ Brazil shelf is recognized under the Western Central Atlantic Fishery Commission and Caribbean Regional Fisheries Mechanism (WECAFC/CRFM). No shared fishery information system. National legislation and management plans for some key species across the different countries.
CARIBBEAN SEA Area: 3 200 000 km^2, 16% shelf, 3.9% protected. Contains 7.1% world's coral reefs including second largest barrier reef and 1.4% seamounts. Tropical, annual hurricanes, moderate annual primary production (150–300 g C/m^2). Influenced by nutrient-poor North Equatorial Current and seasonally by nutrient-enriched NBC forming the Caribbean Current flowing NW and into GOM. 	Reef fishes, conch, spiny lobster, coastal pelagics (sardines, pilchards, anchovies), oceanic pelagics (dolphinfish, wahoo, billfishes, tunas), deep slope finfishes (snappers, groupers). 58% stocks overfished or collapsed[b].	Annual production (2014): 440 250 tonnes, worth USD 986 million[b]. Includes 38 nation states and dependencies and has a current population around 84 million people. Many SIDS highly dependent on fish for food with annual individual per capita consumption rates[c] twice world average* (e.g. Antigua/ Barbuda 53 kg, Barbados 40 kg, Saint Kitts and Nevis 37 kg). Non-consumptive use of reef resources (SCUBA diving, ecotourism, education, research) economically important.	No overarching RFMO or shared fishery information system despite significant percentage of transboundary stocks. There is a Caribbean Community Common Fisheries Policy for insular Caribbean. The Central America Fisheries and Aquaculture Organization (OSPESCA) has a common fisheries and aquaculture policy for Central America. Regional Fishery Bodies (e.g. OSPESCA, WECAFC, and CRFM) have subregional management plans for some key species. Some tuna species under quota management by the International Commission for the Conservation of Atlantic Tunas (ICCAT). States have national legislation. Local co-management arrangements in place for a few fisheries.
GULF OF MEXICO Area: 1 500 000 km^2, 38% shelf, 1.6% protected. Contains 0.6% of world's coral reefs and <0.1% seamounts. Annual tropical storms, moderate annual primary production (150–300 g C/m^2). Characterized by estuaries, strongly influenced by 47 major rivers, the Loop Current and associated upwelling. Extensive deoxygenated dead zones develop in the summer in the northern gulf. 	Coastal pelagics (Gulf menhaden), penaeid shrimps (brown, white), groundfishes (croakers and weakfishes), shellfishes (blue crab, American cupped oyster, octopus). 60% stocks overfished or collapsed[b].	Annual production (2014): 1 391 990 tonnes, worth USD 3 628 million[b]. Includes two nations (United States of America, Mexico). Coastal population around 55 million people. Very important contributor to United States of America fishery production[d] (25% of United States of America commercial fishery landings, 40% marine recreational fishing effort, 78% of shrimp landings, 62% of oyster landings).	Mexican national government shares fishery management responsibility with government of local states and municipalities. United States of America Gulf States have management plans for many key species through the Gulf of Mexico Fishery Management Council and some joint plans with the South Atlantic Fishery Management Council (SAFMC). State and federal regulations may differ. Regional partner organizations involved in fisheries governance including the Gulf States Marine Fisheries Commission and National Oceanic and Atmospheric Administration (NOAA).
SOUTHEAST UNITED STATES OF AMERICA SHELF Area: 300 000 km^2, 48% shelf, 2.4% protected. Contains 0.3% of world's coral reefs. Subtropical-temperate, moderate annual primary production (150–300 g C m^2). Characterised by estuaries, extensive coastal marshes, bays and barrier islands. Influenced by warm north-flowing Gulf Stream. 	Shellfishes (blue crab, American cupped oyster, quahog clam), jellyfishes, oceanic pelagics (wahoo, dolphinfish, billfishes). 56% stocks overfished or collapsed[b].	Annual production (2014): 106 000 tonnes, worth USD 423 million[b]. Includes single nation (United States of America). Around 96 million residents with coastal population growing at 2% per year. Oceanic pelagics and spiny lobster highly valued for recreational fishing.	The SAFMC is responsible for the conservation and management of fish stocks in this LME in collaboration with the National Marine Fisheries Service Southeast Fisheries Centre, NOAA playing a regional role and also guiding fishery adaptation through its 2015 Fisheries Climate Science Strategy. State and Federal regulations may differ.

Data sources: [a] www:seaaroundus.org, Sherman and Hempel (2009); [b] www:seaaroundus.org 2014 data; [c] FAOSTAT 2013 data; [d] Ward (ed., 2017); [e] Singh-Renton and McIvor (2015), Ward (ed., 2017).

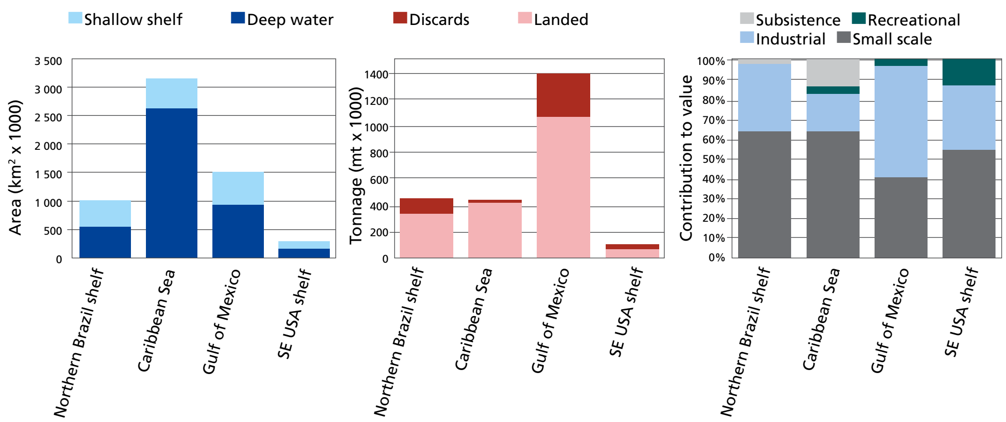
*Note that these figures are apparent consumption by the local population and do not include tourist visitors which may be significant in some of these countries.

9.1.2 Main fisheries of the region

This heterogeneous region has a high reliance on marine capture fisheries and exhibits a wide range of fishery types from single to multispecies and from small-scale subsistence and small-scale commercial operations to large-scale semi-industrial and industrial fisheries to private recreational and sports-fishing charter operations (Figure 9.2; Table 9.1). Fishery production is also highly variable across the region with the GOM LME landing more than twice the tonnage of the Caribbean and North Brazil LMEs and more than 10-fold that of the SE USA LME (Figure 9.2). Small-scale fisheries (SSF) are important across the entire region and represent the most valuable sector across all LMEs except the GOM where industrial trawl and purse seine fleets predominate (Figure 9.2). The governance arrangements are also highly variable among fisheries and nation states, from unmanaged free-access (typical of SSF) to highly regulated (typical of the larger-scale fisheries, particularly in the United States of America; Table 9.1).

FIGURE 9.2

Comparison of the four LMEs found within the WCA, showing size, fishery production and relative economic value by sector. Fishery data are for 2014 and represent reconstructed estimates based on the FAO FishStatJ database



Data sourced from: www.seaaroundus.org.

The broad, multi-species groups of greatest importance to fisheries of the WCA are given in Table 9.1 by LME and are considered separately in Section 9.3. These include coastal benthic and reef-associated species of which there are over 100 commercially important finfish species belonging to many different families such as snappers (Lujanidae), groupers and hinds (Serranidae), grunts (Haemulidae), squirrelfishes, (Holocentridae), parrotfishes (Scaridae), surgeonfishes (Acanthuridae), triggerfishes (Balistidae) and wrasses (Labridae) *inter alia*. This group also contains the high-value shellfishes such as queen conch (*Strombus gigas*), spiny lobster (*Panulirus argus*), American cupped oyster (*Crassostrea virginica*), quahog clam (*Mercenaria mercenaria*), blue crab (*Callinectes sapidus*) and octopuses (common, *Octopus vulgaris;* red, *O. maya*). The coastal schooling pelagic finfish group includes many species of sardines and pilchards (Clupeidae) (e.g. Gulf menhaden, *Brevoortia patronus*; Brazilian sardinella, *Sardinella brasiliensis*), anchovies (Engraulidae) and jacks (Carangidae). The benthic continental shelf shrimp and groundfish group contains the penaeid shrimps (e.g. various pink and brown species, *Farfantepenaeus* spp.; white shrimps, *Litopenaeus* spp.; seabob, *Xyphopenaeus kroyeri*), weakfishes (e.g. *Cynoscion* spp.; bangamary, *Macrodon ancylodon*), croakers (e.g. corvina, *Micropogonias furnieri*) and sea catfishes (Ariidae). Another commercially important group is the deep-slope benthic finfishes including deepwater grouper species (e.g. misty, *Epinephelus mystacinus*; red, *E. morio*), deepwater snappers (e.g. southern red, *Lutjanus purpureus*; queen, *Etelis oculatus*; vermilion, *Rhomboplites aurorubens*) and greater amberjack (*Seriola dumerili*). Also important is the highly migratory oceanic pelagic finfish group including the common dolphinfish (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), mackerels (*Scomberomorus* spp.), small tunas (e.g. skipjack, *Katsuwomis pelamis*, blackfin, *Thunnus atlanticus*), large tunas (e.g. yellowfin, *Thunnus albacares*; bigeye, *T. obesus*; albacore, *T. alalunga*), and billfishes such as blue marlin (*Makaira nigricans*), white marlin (*Kajikia albidus*), Atlantic sailfish (*Istiophorus albicans*) and swordfish (*Xiphias gladius*).

9.2 IMPACTS OF CLIMATE CHANGE ON THE MARINE ENVIRONMENT

The climate change stressors on the marine environment of greatest significance to fisheries in the WCA are increasing sea surface temperature (SST), ocean acidification (OA), sea level rise (SLR) and increased frequency of extreme weather events (e.g. storms, hurricanes, precipitation anomalies). The projections published in the most recent assessment (AR5 2013 to 2014) of the Intergovernmental Panel on Climate Change (IPCC) are considered here, together with global climate change models downscaled to smaller regional scales where available.

9.2.1 Physical and chemical

Sea surface temperature

With respect to the WCA, air temperatures could rise between 0.5 °C to 0.9 °C by 2100 for the lowest carbon emissions scenario (representative concentration pathway – RCP2.6) and in excess of 4 °C under RCP8.5. This will ultimately cause SSTs to rise considerably, but the increases are likely to be variable across the region. For example, SST increases to date have shown considerable disparity across the WCA, influenced by major sea surface currents. The North Brazil Shelf is considered among the slow to moderate warming LMEs of the world with a 0.38 °C increase in SST over the period 1957 to 2012, whilst the Caribbean and GOM are among the slow warming LMEs with increases of 0.15 °C and 0.16 °C respectively, and the SE USA shelf LME has actually cooled by 0.28 °C over the same period (Belkin, 2016). Regional downscaling of global models indicates that the present spatial heterogeneity of SST in the Caribbean basin will change during this century from a seasonal warm pool that expands out from the Western Caribbean each spring/summer and retracts each fall/winter, to be replaced by two warm pools centred over the Western and Eastern Caribbean that will merge, blanketing the entire region (Nurse and Charlery, 2016). As a result, the small annual range in SST, characteristic of this area, will continue to decrease from a current average of 3.3 °C to just 2.3 °C by the end of the century, such that seasonal “warm” and “cool”periods will become less differentiated over the coming decades.

Increasing SSTs over most of the region will mean stronger ocean temperature stratification and reduced oxygen content in the upper layers. Concomitantly, increasing air temperatures have promoted a poleward shift in the large-scale atmospheric Hadley circulation that dominates the tropics and has resulted in a northward shift of the intertropical convergence zone and weakening of the trade winds that drive surface circulation and upwelling in this region (Taylor *et al.*, 2012). A shallowing of the oxygen minimum layer (representing a hypoxic habitat boundary for high oxygen demand species) has already been observed in the tropical Atlantic (Stramma *et al.*, 2012), diminished upwelling and increased stratification have been recorded in the southern Caribbean off the Bolivarian Republic of Venezuela (Taylor *et al.*, 2012) and seasonal dead zones (lacking sufficient oxygen) in the northern GOM are continuing to expand every summer (Helleman and Rabalais, 2009). In addition, the Atlantic meridional overturning circulation (AMOC), a branch of the global thermohaline circulation is predicted to slow down under future climate change. This will further affect the North Brazil Current, the dominant feature of the North Brazil LME and responsible for bringing episodic nutrient-enriched, lower salinity, South Atlantic water (and pelagic sargassum seaweed) into the Caribbean, because it is strongly linked to the AMOC and to surface winds (Rühs *et al.*, 2015). This change in the North Brazil Current is expected to affect the strength of the Caribbean Current, and will result in a decrease in the strength of the Yucatan and Loop currents in the Gulf of Mexico (Ward and Tunnell, 2017) and a weakening of the Gulf Stream. The latter has already been implicated in the slight decrease in the SST recorded for the SE USA shelf (Phillips and Perez-Ramirez, eds., 2017).

Ocean acidification
In the WCA, a recorded decrease in the pH of the open sea has followed the global trend and has been accompanied by a sustained decrease in the aragonite saturation state (Ωar) (albeit seasonally and spatially variable as influenced by SST and salinity) from an annual mean value of Ωar 4.05 to 3.39 in just 11 years (1996 to 2006; Gledhill *et al.*, 2008). With increases in mean atmospheric pCO_2 to 450 µatm, the Ωar values in this region are expected to reach 3.0–3.5, whilst pCO_2 reaching 550 µatm will reduce Ωar to <3.0, a value associated with net erosion of coral reef framework (Gledhill *et al.*, 2008).

Sea level rise
Over the last six decades the mean SLR of 1.8±0.1 mm/yr recorded for the wider Caribbean region has tracked the global mean value (Palanisamy *et al.*, 2012). However, the annual rate of SLR has increased significantly in this century and for the WCA region mean sea level is projected to increase by between 0.35 to 0.65 m (depending on which emissions scenario is followed) by the end of this century (2081 to 2100) relative to the period 1986 to 2005 (Church *et al.*, 2013). The multiple factors affecting local SLR vary across the WCA (e.g. the Mississippi delta in the GOM is experiencing relative SLR three times greater than world average) and the coastal impact of increases in mean sea level also varies regionally with tidal range and frequency of storm surges (SS; Losada *et al.*, 2013). This implies that the Caribbean and GOM, both of which experience micro-tides and increasing SS, will be most affected, whilst the North Brazil LME with its macro-tides and lower storm frequency will be least affected. Comparing the decades of 1950 to 1960 and 1998 to 2008, SLR has already led to a significant increase (20 percent to 60 percent) in the frequency of sea level extremes across the Caribbean, whilst there has been little to no change along the North Brazil Shelf (Church *et al.*, 2013; Losada *et al.*, 2013).

Extreme weather events
The IPCC AR5 recognizes that unusual extreme weather events have been affecting the WCA (especially the Caribbean, GOM and SE USA) region over the last few decades (Magrin *et al.*, 2014). There is also evidence that more tropical storms in the Atlantic are developing into dangerous category four and five hurricanes (Murakami, Mizuta and Shindo, 2012). Projections indicate that further enhanced hurricane intensity is likely in this region under climate change with continued increases in SSTs, although the current understanding of tropical cyclone generation and frequency is still limited.

9.2.2 Biological and ecological

Increasing SSTs, OA, SLR and extreme weather events driven by climate change have already had significant impacts on essential coastal habitats and the wider ocean ecosystem of the WCA, and have certainly exacerbated the impacts of chronic anthropogenic stressors on marine communities such as overfishing and poor water quality linked to coastal development and agriculture (e.g. Jackson *et al.*, eds., 2014). In particular, coral reefs in this region have suffered large declines in live coral cover in recent decades due to high SST-induced mass coral bleaching events and associated mortality (especially in 1998, 2005 and 2010; Eakin *et al.*, 2010). Furthermore, such events are predicted to increase in frequency and even become annual events in this region by the mid-twenty-first century (van Hooidonk *et al.*, 2015). Contributing to the degradation of coral reefs is the increasing prevalence of coral diseases linked to increasing SSTs (Bruno and Selig, 2007), and larger more damaging storms in the Caribbean, GOM and SE USA (such as those experienced in 2005 and 2017). As a result there has been a significant loss of reef architectural complexity (Alvarez-Filip *et al.*, 2009), a loss of coral reef species (Newman *et al.*, 2015), changes in the dominant species assemblages and, in some cases, a complete phase shift to algal dominated reef communities (e.g. Hughes *et al.*, 2007) providing significantly altered ecosystem services. Many coral reefs in the region are already experiencing significant reductions in carbonate production rates with 37 percent of surveyed sites showing net erosion (see Melendez and Salisbury, 2017 and references therein).

Other tropical and subtropical essential habitats such as seagrasses, mangroves and estuarine salt marshes are also being impacted. Within the Caribbean and Gulf of Mexico basins in particular there have been significant declines in seagrasses (van Tussenbroek *et al.*, 2014; Ward and Tunnell, 2017), although much of it caused by chronic anthropogenic stressors other than climate change, such as coastal development and eutrophication (increased nutrient load). Likewise there have been substantial declines in mangroves across the WCA caused largely by coastal development (including aquaculture) and timber harvesting (Ward *et al.*, 2016). Under future climate change, mangroves in the WCA are expected to be most impacted in the Caribbean (especially the SIDS with significant coastal infrastructure development and limited coastal land for mangrove habitat to retreat inland) and GOM because of the micro-tidal regime and increasing storm intensity in these LMEs. In the SE USA there is some evidence that the distribution of mangrove habitat has already responded to increasing temperatures through a northerly extension along the southeast coast and this is expected to continue (Phillips and Perez-Ramirez, eds., 2017). Extensive mangroves along the coast of the North Brazil LME will be least affected given the macro-tidal regime and rarity of catastrophic storms here (Ward *et al.*, 2016).

Estuarine environments are being affected by changes in freshwater inflow and SLR and those with high nutrient loads, particularly in the GOM, have been further impacted by climate change associated increases in SST resulting in an increase in the size and extent of summer “dead zones” (seasonal hypoxia) where oxygen levels in the water column are too low to support most marine life (Phillips and Perez-Ramirez, eds., 2017; Tunnell, 2017). Seasonal hypoxia is expected to become more severe with increased rainfall and warmer water (Phillips and Perez-Ramirez, eds., 2017).

Increasing levels of eutrophication and increasing SST together also enhance the blooming of pelagic (floating) algae, resulting in more frequent “green tides” and toxic algal blooms (Smetacek and Zingone, 2013). Such events are becoming more common in the WCA, and since 2011 the wider Caribbean region has been experiencing unprecedented influxes of pelagic sargassum (Franks, Johnson and Ko, 2016). These extraordinary sargassum blooms, entering the Caribbean Sea through the Lesser Antilles as large floating mats of algae, have resulted in mass coastal strandings throughout the region and significant damage to critical coastal habitats such as mass mortality of important seagrass beds and associated corals through shading, anoxia and excessive nutrient loading (van Tussenbroek *et al.*, 2017). Changes in biological productivity of any of the coastal habitats will have impacts on their ecosystem services and the trophic linkages among them, and will affect both the nearshore and the oceanic pelagic food chain such that impacts will not be limited to these coastal areas.

9.3 EFFECTS OF CLIMATE CHANGE ON FISHERY RESOURCES

The key climate change stressors will have numerous interrelated impacts on commercially important fishery species in the WCA, through 1) direct effects on their physiology and life processes (e.g. neurotransmission, respiration, growth and development rate, reproduction, longevity); and 2) indirect effects arising from significant impacts to essential habitats affecting nursery areas, living space, refuge and predator-prey relationships; and from physical and biological oceanographic changes affecting survival, dispersal and settlement of early life history stages, and migration and distribution ranges of adults, *inter alia*. Together these are expected to significantly affect the distribution, abundance, seasonality and fisheries production of the key fishery resources in the WCA (see Oxenford and Monnereau, 2017 for a detailed review of the literature). Although there is a relative dearth of studies on the impacts of climate change specifically on fishery species in the WCA (Oxenford and Monnereau, 2017), implications can be drawn from the literature covering similar species from outside the region and projections for climate change stressors within the WCA. Here we consider implications for the main fishery species groups important to the WCA (shown by LME in Table 9.1).

9.3.1 Coastal benthic and reef-associated species

The impact of climate change on this group (reef fishes, molluscs, spiny lobsters and crabs) although highly species-diverse, is almost undoubtedly the most serious of the commercially important fishery groups across the WCA. Their particular vulnerability arises from the fact that: 1) most species are highly reliant on critical coastal habitats (coral reefs, mangroves, estuaries) that are themselves already significantly degraded, not only from climate change stressors, but also from other anthropogenic activities (e.g. coastal development, sewage and agricultural runoff, over-harvesting); 2) they have biphasic life histories involving a pelagic early life stage and a requirement to settle in specific benthic nursery habitat for development into juvenile through to adult stages; and 3) many of these stocks in the WCA are already compromised by overfishing, significantly reducing their genetic biodiversity, productivity and hence resilience to further environmental changes.

Of particular concern are those species with an obligatory relationship to coral reefs, one of the most sensitive of all marine ecosystems to climate change and other anthropogenic stressors. Research to date has identified significant negative impacts on tropical reef fishes, conchs and spiny lobsters not only from loss of nursery and adult habitats, but also from increasing SST and OA (see Oxenford and Monnereau, 2017 for review).

Reproduction in reef fishes examined to date shows a high sensitivity to SST, with reduced pairing, lower fecundity and smaller eggs and larvae being produced, or even a complete cessation of spawning at climate change-relevant increases of 1.5°C to 3 °C (Pratchett, Wilson and Munday, 2015). Temperature is an important spawning cue, not only for reef fishes (e.g. Erisman and Asch, 2015) but for many other species in this group including conch (Aldana Aranda *et al.*, 2014) and spiny lobster (Phillips and Perez-Ramirez, eds., 2017). There is also evidence that pelagic larval duration (PLD) of many species will be shortened by small increases in temperature. As such, changes to SST will have far-reaching effects on the reproductive success of this commercially important group by affecting spawning behaviour (timing and/or location), the quality and quantity of reproductive output (eggs/larvae) and the PLD which will affect the dispersal, survival and settlement success of larvae as a result of potential mismatches with other environmental factors that ensure adequate food and return of post-larvae to suitable settlement habitat. Spiny lobsters with their uniquely long PLD (6 to 12 months) are particularly vulnerable (Phillips and Perez-Ramirez, eds., 2017). Unlike those of temperate and polar species, growth rates in adult tropical reef fishes have also been shown to slow down with marginal increases in SST (Munday *et al.*, 2008). Increasing SST has also been implicated in disease outbreaks in commercially important species in this group in the WCA, such as oysters in the GOM (Phillips and Perez-Ramirez, eds., 2017; Tunnell, 2017). Furthermore, the *Panulirus argus* Virus 1 (PaV1) which is usually lethal to juvenile Caribbean spiny lobsters is likely dispersed via pelagic larval stages, demonstrating how any climate-induced changes in the hydrology of the Caribbean Sea could significantly affect the spread of the disease (Kough *et al.*, 2015).

As OA increases, affecting the concentration of ions (especially H^+) in seawater, calcifying organisms will find it increasingly difficult to build calcareous skeletons and shells, although the impact on the region's important shellfish species (queen conch, spiny lobster, cupped oysters, quahog clams, penaeid shrimps) to near-future ocean pH levels is largely unknown. OA has also been shown to result in impairment of a diverse suite of sensory and behavioural abilities in reef fishes, especially the early life history stages which affect the ability to escape predation, habitat selection and timing of settlement to coral reef habitats (Devine, Munday and Jones, 2012).

Increased storminess, changes in precipitation and SLR in the WCA have already impacted other important species in this group. For example, many important oyster reefs in the GOM have been smothered by sediments as a result of hurricanes in recent years (Phillips and Perez-Ramirez, eds., 2017; Tunnell, 2017). Blue crabs, heavily reliant on healthy estuaries for reproduction, recruitment and survival, are particularly vulnerable to changing patterns of salinity linked to SLR and/or changes in precipitation patterns (Tunnell, 2017).

Reduced population sizes and productivity are expected across this multi-species group under near-future climate change, with significant impacts on production of SSFs across the region, particularly in the SIDS of the Caribbean LME where reef-associated species are often exclusively targeted (Table 9.1).

9.3.2 Coastal schooling pelagic species

Most of the coastal pelagic species (e.g. menhaden, sardinella, anchovies) are highly reliant on critical estuarine habitats (mangroves/saltmarshes) which, like coral reefs, are particularly sensitive to climate change, in particular SLR and storminess, and other anthropogenic stressors. Under increasing SSTs, coastal pelagic fishes, especially menhaden in the GOM, will be increasingly affected by the enlarging seasonal areas of hypoxia, resulting in direct mortality or sub-lethal effects such as reduced growth and impaired reproduction (Langseth *et al.*, 2014). Small schooling pelagics also typically have short life spans, meaning that response time of populations to climate change will be rapid. For example, menhaden population abundance in the GOM is highly sensitive to inter-annual changes in SST and salinity, which have resulted in significant impacts on fishery production in this region. Off the coast of the Bolivarian Republic of Venezuela, climate-induced reductions in seasonal coastal upwelling have been associated with a change in phytoplankton productivity and a coincident 87 percent drop in catches of planktivorous sardines at Margarita Island (Taylor *et al.*, 2012).

Localized (subregional) reductions and increased inter-annual variability in productivity of these coastal pelagic species are expected under near-future climate change across the WCA, significantly affecting fisheries production in GOM and North Brazil Shelf LMEs with large industrial fisheries for these species (Table 9.1).

9.3.3 Continental shelf shrimp and groundfish species

The penaeid shrimp and groundfish (e.g. weakfishes, croakers, sea catfish) species in this group mostly rely on estuarine nursery areas, and offshore deeper soft bottom areas as adults. The early life stages will therefore be particularly vulnerable to further degradation of estuarine habitats expected under climate change and continuing eutrophication (e.g. changes to salinity, increased hypoxia), although, the adult habitats will likely be less impacted by climate change and adults could probably move to deeper offshore soft-bottom habitats. This group also has biphasic life cycles and will therefore share the same potential threats posed to early life stages as all of the other fishery groups (i.e. shorter PLDs and changing currents impacting successful dispersal and delivery of new recruits to suitable estuarine settlement habitats and nursery grow-out areas for population replenishment) and the early life stages will also be vulnerable to the myriad of potential effects of elevated SST and OA, with the latter likely to impact shrimps in particular. Penaeid shrimps in the northern GOM where the development of seasonal hypoxic areas is particularly severe and increasing under climate change are expected to suffer significant impacts, since the adults will be unable to pass through the hypoxic zones to spawn in open water (Tunnell, 2017).

Declining productivity of shrimp and groundfish populations are expected in the WCA over the near- to medium-term with significant reductions in fisheries production in the North Brazil Shelf, continental countries of the Caribbean, and the GOM where these species are targeted by industrial fleets and SSFs (Table 9.1).

9.3.4 Deep slope species

The impacts of climate change on this group (e.g. snappers, groupers) in the WCA have received little to no specific attention, but, considering their biological characteristics (biphasic life history; use of shallow reefs and associated habitats as nursery areas; use of reef spawning aggregation sites) and current exploitation status, the impacts are likely to be similar to, or perhaps slightly less severe than, the coastal reef-associated species group. The fact that the species in this group tend to be longer lived than their shallower relatives, means however, that the impacts of climate change on stock biomass and abundance will likely be delayed, but any recovery will also take longer. Likely declines over the near- to medium-term will particularly affect the fisheries production of the GOM and North Brazil LMEs where these species are particularly important (Table 9.1).

9.3.5 Oceanic pelagic species

This group of highly migratory large pelagic species (billfishes, large tunas) and smaller more regionally migrating species (dolphinfish, wahoo, mackerels, small tunas) have also received little attention in this region, but will likely be less impacted by climate change, at least in the short-term, than the other four groups. This is largely because of their high mobility, lack of a biphasic life history, less vulnerable reproductive behaviour, and the fact that the open ocean is less impacted by other anthropogenic stressors than coastal habitats. Furthermore, the regionally migrating species are also generally not overexploited and therefore more resilient to future change.

Nonetheless, for many species, increases in SST will mean changes to their productivity and distribution as they move northwards and out of the WCA area to more favourable temperatures. For some species, such as bluefin tuna, this could mean abandoning their spawning area in the GOM (Muhling *et al.*, 2011).

As such, reductions in productivity of the oceanic pelagic species are expected over the medium- to long-term, affecting fisheries production across the WCA, but especially in the Caribbean and SE USA LMEs where ocean pelagic species are among the top species landed and also support significant recreational fleets (Table 9.1).

9.4 SOCIAL AND ECONOMIC IMPLICATIONS OF CLIMATE CHANGE

Despite some progress made in advancing climate change science in the WCA in recent years, there are very few impact studies focussed on social and economic implications for the fisheries sector. Furthermore, there have been no quantitative studies specifically related to impacts on changes in fisheries production, fish size or fish distribution for the region or the direct socio-economic consequences thereof. Here we consider food security, livelihoods, economic and fisheries management implications of climate change for the fisheries sector of the WCA. This is based on the observed and expected changes in fishery resources within this region (see Section 9.3), the heterogeneous nature of the region's fisheries (see Section 9.1) and the additional observed and expected direct impacts of climate change on the harvest and post-harvest sectors.

9.4.1 Food security

The fisheries sector of the WCA is important to food security with an annual harvest in excess of an estimated 2.3 million tonnes (2014 data, see Table 9.1). Fisheries are especially important to food security within the Caribbean and the North Brazil LME where: fish consumption (per capita supply) is well above the world average in many of the SIDS (Table 9.1); fish represents more than 20 percent of the animal protein consumed in Guyana and French Guiana (FAO, 2016a); subsistence fishing is still important; and SSF contribute more than 55 percent of total landings by weight and 60 percent by value (Figure 9.2). Personal income derived from the fisheries sector is also important in this region, in providing financial access to food.

Climate change is expected to negatively affect food security in the WCA by reducing species' productivity and availability and hence reducing fishery catch per unit effort (CPUE) and ultimately total landings in all of the main fishery species, but especially the reef-associated species group which supports mostly SSF. The coastal pelagic species will also be impacted in the short-term, but will have fewer implications for food security at the regional level given that most landings in this species group across the WCA are by industrial fleets and used for non-consumptive products (e.g. fish meal, fish oil). The impacts on food security are expected to be greatest in low-income fishing communities where subsistence fishing is still important (or where at least some of the commercial catch is always retained by the crew for personal consumption); where fish are generally consumed locally, or sold and used for income; and where populations are often already vulnerable and food insecure.

More intense and frequent extreme weather events are also expected to have negative impacts on food availability, accessibility, stability and utilization. The poor will face the greatest risk of food insecurity as a result of loss of assets (e.g. fishing boats, engines and gear) and lack of adequate insurance coverage. Increasing SSTs and extreme weather events such as hurricanes are expected to increase the geographic extent and occurrence of ciguatoxic reef fish (Tester *et al.*, 2010). As such, food security in the region is expected to be affected by increases in ciguatera fish poisoning in humans, which will affect trade in reef fishes and the health of local communities, since consumption of ciguatoxic fish can lead to gastrointestinal distress, severe neurological and cardiovascular symptoms that can persist for months or even years and, in rare cases, can result in death (Tester *et al.*, 2010).

Fisheries for high value species (e.g. snappers, groupers, shrimps, conchs, spiny lobsters, large tunas) in the North Brazil LME and the Caribbean (e.g. Guyana, Suriname, the Bahamas, Belize, Grenada, Jamaica) are often export-oriented and generate significant foreign earnings. As fisheries face increasing pressures from climate change impacts as well as other challenges, coupled with human population increases, it will become more critical for countries to consider their policy options regarding the relative advantages of trading fish internationally versus having fish available for the domestic food market.

9.4.2 Livelihoods

The fisheries sector of the WCA generates landings valued in excess of USD 6.1 billion annually (2014 data, see Table 9.1) and helps support the socio-economic viability of coastal communities across the entire region by providing direct employment, livelihood and benefits to thousands of people across 42 countries. Expected reductions in the productivity of the region's fishery resources (especially in the reef-associated group), increased inter-annual variation in availability (especially in the coastal pelagics group), and changes to their distribution (to cooler water) as a result of climate change (Section 9.3) means that fishers in the WCA are expected to face declining catches, lower CPUE, lower fishery-related income and increased levels of conflict. This would especially affect the large number of small-scale coastal fishers targeting benthic, reef-associated species in the region, as they would be forced to fish longer and may need to travel further and/or fish deeper, change their target to offshore pelagic species or find alternative employment outside the fishery sector to maintain their income. The implications include: reduced fisher safety (e.g. travelling further offshore, diving longer and deeper); the need to invest in training and new gear (e.g. mechanized reels, fish aggregating devices) and new and/or larger boats and engines; and increased levels of income uncertainty. This could in turn lead to more demands on government social security and unemployment benefits.

Climate change stressors such as SLR and increased severity of hurricanes in this region will continue to have significant negative impacts on: fisheries infrastructure (safe harbours, jetties, coastal markets, landing sites); gear (boats, fishing equipment); and coastal fishing communities (housing, facilities), especially in the micro-tidal, storm-prone Caribbean and GOM LMEs. For example, in 2017 alone, two of the strongest hurricanes ever recorded caused extensive damage to the fisheries sectors of several Eastern Caribbean SIDS[2] (Horsford, 2017). This will translate into significant economic losses especially for SSFs since most small-scale fishing enterprises, particularly in the Caribbean, are privately owned and currently have no access to affordable insurance. This was revealed by Tietze (forthcoming) who reported that 97 percent of fishers in the 11 Caribbean countries studied have no insurance for their boats or other assets, indicating high economic risk for a significant number of fishers in this region under future climate change. Fishers could very well be left without a safety net or access to financial resources to cope with an increasingly difficult economic situation. In other areas, such as the GOM and SE USA, where storms and hurricanes have severely disrupted or destroyed the infrastructure necessary to support fishing in the recent past, insurance is more readily available in the harvest and post-harvest sectors. However, although fishers in these areas are generally insured, the recovery is often a slow process, having to settle insurance claims before the repair and restart of fishing operations.

The ability of fisherfolk to cope with climate change depends on a variety of factors including the existing cultural and policy context, as well as socio-economic factors such as social cohesion, household composition, gender, age, and the availability and distribution of assets and economic alternatives. In the Caribbean area whilst men typically dominate the harvest sector, women play a critical role in the post-harvest sector in fish processing and trade and also in ancillary activities, such as financing (McConney, Nicholls and Simmons, 2013). As such, in this area as well as the North Brazil LME, women will be the most disadvantaged by the negative impacts of climate change in the post-harvest sector.

9.4.3 Economic

As fish resources in the WCA become less available and the CPUE decreases (resulting in lower profits), and more high intensity storms occur in the coming decades (resulting in higher risks), investments in the fisheries sector will become less attractive in this region (Monnereau and Oxenford, 2017). Climate change has the potential to impact the fisheries sector at the national level in the WCA through various pathways, for example, by alterations in revenues for governments as a result of changes in total fish production volumes available for the local and export markets; changes in the ability of nations to achieve food security; and the necessity to make changes to fisheries policies

[2] 10 Oct 2017. FAO assesses the impact of Hurricanes Irma and Maria on agriculture sector in Antigua and Barbuda, Dominica and St. Kitts and Nevis. http://www.fao.org/americas/noticias/ver/en/c/1043252/

and legislation. The impacts of these on economic development can be expected to differ by country, especially given the diversity of countries in this region (from some of the world's richest to poorest). For example, changes in availability of high-value species that support export-oriented fisheries will impact export trade volumes and national economies (especially in the SIDS). High value species that are not exported are generally sold directly to high-end markets such as hotels and restaurants supporting the local tourism industry. With the expected decline in availability of these resources, the tourism sector will have to look for alternatives, possibly driving up market prices of species consumed by the local population. Alternatively, more fish will have to be imported to satisfy tourist demand, in a region that is already importing most of the fish consumed. For example, the Caribbean region is currently a net importer of fish with an astounding USD 8.5 billion deficit between exports and imports of fish products to the region (FAO, 2016b). Decreases in foreign exchange for countries because of declining exports of high value fish species could thus have implications for a country's food import bill, an important issue especially for many SIDS with little available land for local food production. Processing plants relying on local fish resources will be affected by decreasing sales unless they invest in developing more value-added products, which will in turn have implications for local employment opportunities, particularly for women.

9.4.4 Fishery management

Fish resources in this region are typically transboundary and shared among multiple nations over short distances (especially in the North Brazil and Caribbean LMEs). Climate-induced changes to their distribution and abundance could therefore impact fisher access under current management arrangements, and may require changes to multi-lateral or international agreements and quotas. For example, changes in distribution of tunas and tuna-like species as a result of rising SSTs and changes to ocean circulation patterns, could lead to a need for renegotiating ICCAT quotas among member states (Mahon, 2002). On a smaller regional scale, change in the abundance and/or distribution of flyingfish (*Hirundichthys affinis*), a key fish species in the Eastern Caribbean, which may be occurring as a result of the climate change related influxes of sargassum to the area (Franks, Johnson and Ko, 2016), could affect the relevance of limit and target reference points agreed to in the recently adopted Eastern Caribbean sub-regional Flyingfish Management Plan. Likewise, the recent influxes of sargassum have raised concern about the large numbers of small juvenile dolphinfish that are now being caught by pelagic fleets in the Lesser Antilles, which has highlighted the need to agree upon and impose a minimum legal size for dolphinfish in this subregion (Monnereau and Oxenford, 2017).

Reduced availability of fishery resources will increase fisher competition resulting in increased levels of conflict and the likelihood of increased illegal, unreported and unregulated fishing, requiring management interventions and improved surveillance and cooperation between nations. There is also likely to be an increasing level of tension between different stakeholder groups using marine space and resources for different purposes. For example, climate change could exacerbate existing conflicts between extractive and non-extractive user groups requiring policy decisions on how resources are to be shared among groups and on new regulations to control access.

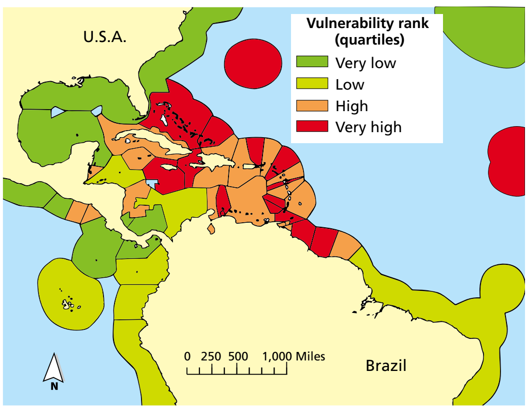
The effectiveness of management regulations such as closed areas and seasons, gear limitations, and minimum sizes may be affected by climate change impacts. For example, closed areas (fishery reserves, marine protected areas) may currently be protecting spawning stock biomass of important commercial species, or critical locations such as nursery grounds, fish spawning aggregation sites (SPAGS), regions that feature high species diversity or high rates of endemism, and areas that contain a variety of habitat types in close proximity to one another. However, under climate change, the locations and/or ecological health of these critical areas are likely to shift, highlighting the importance of integrating climate change projections with management measures. For example, the location of protected multispecies SPAGS located along the Mesoamerican barrier reef and other islands in the Caribbean might need to be revised (Erisman and Asch, 2015). Likewise, the timing of closed seasons implemented to protect the main spawning period for many other species throughout the WCA (e.g. conch, lobsters, groupers, snappers) are likely ultimately to need changing to match expected changes in their phenologies. Expected climate-induced changes in genetic connectivity of stocks, particularly the reef-associated group, could also impact the effectiveness of current marine reserve networks across the WCA in protecting source populations. This will need addressing to ensure their continued value in conservation of spawning stock biomass of commercially valuable species.

Climate change is expected to increasingly exacerbate the ongoing decline of fish resources in the region, caused largely by overfishing and degradation of the marine environment. With close to 60 percent of commercially important stocks already collapsed or overfished in the Caribbean, North Brazil and SE USA LMEs (Table 9.1), there is clearly a need for more effective and flexible fisheries management and fisheries policies in the region, that take climate change impacts into consideration.

9.5 VULNERABILITY AND OPPORTUNITIES FOR THE MAIN FISHERIES

The impact of climate change in the WCA is expected to be considerable because of its high level of exposure to climate change variables, the high economic dependence on the fisheries sector, and the low adaptive capacity of many of the countries in the region (Monnereau *et al.*, 2017). This is especially true for the Caribbean SIDS because of their specific characteristics such as small size, susceptibility to natural disasters, vulnerability to external shocks, concentration of population and infrastructure in the coastal zone, high dependence on limited resources including marine resources; fragile environments, and excessive dependence on international trade (Nurse *et al.*, 2014; Monnereau *et al.*, 2017). Monnereau *et al.* (2017) in their recent assessment of climate change vulnerability of the fisheries sector at the national level across 173 countries (based on 35 indicators including exposure, sensitivity and adaptive capacity) revealed that the fisheries sector in SIDS, especially within the Caribbean, and the North Brazil shelf area, is extremely vulnerable to climate change (Figure 9.3).

FIGURE 9.3
Vulnerability assessment of the fisheries sector to climate change for the Western Central Atlantic based on 35 indicators. Each country is delimited by its EEZ boundary. Colours represent relative vulnerability ranked across 173 countries



Data sourced from: Monnereau *et al.* (2017).

9.6 RESPONSES AND ADAPTATION OPTIONS

Responses and adaptation actions to moderate the actual and potential impacts of climate change, and to take advantage of new opportunities will need to be tailored to national contexts. With regard to the fishery sector, countries in this region are generally focussing on adaptation through reducing risks from climate change and natural hazards, and improving resilience of fisherfolk and aquaculturists (see detailed assessment of the wider Caribbean region by McConney *et al.*, 2015). Here we present some examples of national and local level adaptation measures that have been recommended or are already taking place in the region.

At the national level, adaptation activities within the framework of the international climate change regime (the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement) are set out in countries' five-year Nationally Determined Contributions (NDCs). Within the WCA 24 independent nations have submitted NDCs of which 14 (mostly the Caribbean SIDS) specifically mention the fisheries sector, but mostly only in the context of highlighting its vulnerability to climate change. Only two of these countries make specific reference to fisheries in terms of mitigation, although ten countries list some aspect of fisheries within their stated adaptation plans. Proposed actions include: general improvements in fishery habitats (through implementation of marine protected areas, rehabilitation of mangroves, seagrasses and coral reefs; improved environmental impact assessments; and integrated coastal zone management); paying greater attention to the role of fisheries in food security; implementing updated fishery legislation; and considering alternative livelihood opportunities. Only in a few cases are concrete and specific measures listed such as provision of affordable insurance schemes for fishers (in Dominica, and Antigua and Barbuda). In several NDCs the need for additional (international) financing is highlighted, as well as the need for technical support, including capacity building and technology transfer in order to carry out the mitigation and adaptation measures. Further, there is no specific mention of the fisheries sector in the nationally appropriate mitigation actions prepared and submitted to the UNFCCC by six of the developing nations within the WCA, nor in the very few national adaptation plans.

Factors that can influence the success of adaptation include raising awareness of climate change impacts on the fisheries sector and coastal communities, as well as awareness on possible adaptation measures for the fisheries sector. Better communication and information sharing on these issues can, and in some cases already has, fostered innovative solutions and development opportunities within the sector. Other factors affecting success include capacity building activities through training and education which empower local stakeholders and facilitate collective self-governing action (e.g. by fisherfolk organizations). Mainstreaming climate change adaptation (CCA) and disaster risk management (DRM) into new or improved fisheries legislation, policies and plans is also important (McConney *et al.*, 2015).

A select number of adaptation measures which are already taking place or currently being developed in the region are summarized here. These activities include anticipatory and reactive measures as well as private and public initiatives, and are grouped here under three broad categories.

9.6.1 Innovation and capacity building

- Development of innovative context-appropriate mobile applications designed to improve early warning and safety of small-scale fishers with regard to approaching storms and hurricanes *inter alia*, as well as improving responses to crisis (e.g. training in methods of recording of damage and losses post-disaster).
    - An example of this is the award-winning, open source "mFisheries" suite of applications, developed by The University of the West Indies in collaboration with the local fisher community, specifically for smartphone use by SSF in

Trinidad and Tobago[3]. This suite has now been tailored for Eastern Caribbean fishers under the climate change adaptation in the Eastern Caribbean Fisheries sector (CC4FISH) project, and Fisheries Early Warning and Emergency Response (FEWER) modules have recently been developed under the Pilot Programme for Climate Resilience (PPCR) project.

- Improvement in adaptive capacity and resilience of the fishery sector to climate change through improved safety, improved earnings and savings, and better access to assets insurance and social security.
  - There are many examples of successful hands-on training courses being provided to SSF across the WCA by various international and regional non-governmental organizations (e.g. FAO-WECAFC, CRFM), Caribbean Natural Resources Institute, Gulf and Caribbean Fisheries Institute, Caribbean Network of Fisherfolk Organisations). These have included sponsored courses in: improved safety-at-sea; design of safer fishing vessels; use of tracking devices; improved fish handling; value-added processing; and developing business skills (see McConney *et al.*, 2015; Monnereau and Oxenford, 2017).

9.6.2 Improving physical environment

- Investments in safer harbours and boat hauling sites as well as other climate-smart fisheries infrastructure to protect fisheries assets and prevent disruption in the fisheries market chain.
  - Examples of investments in purpose-built safer harbours for SSF in the region include the Bridgetown Fisheries Complex in Barbados, Grand Riviera fishing harbour in Martinique, Marigot Fisheries Complex in Dominica, and Basseterre fishing harbour in Saint Kitts all of which have substantive harbour walls and haul-out facilities. However, in all cases the facilities are not adequate for the entire fishery fleet. For example, limited access to sufficient safe harbour space and hauling sites was a key factor resulting in USD 2.9 million in damages and losses to the fisheries sector (mostly boats and engines) in Dominica with the recent passage of Hurricane Maria in 2017 (Government of Dominica, 2018).
- Mitigation of local-level, human-induced stressors that are degrading critical fishery habitats, and rehabilitation of damaged coastal ecosystems (e.g. coral reefs, seagrasses, mangroves and saltmarshes) to improve their resilience to future climate change and maintain their natural ecosystem services.
  - There are many small and large initiatives across the region that are relevant to these challenges. For example the Caribbean and North Brazil Shelf Large Marine Ecosystems (CLME+) 10-year strategic action plan politically endorsed in 2017 by 25 countries and six overseas territories across the Caribbean Sea and North Brazil LMEs outlines many actions to address the three key threats identified for these LMEs (unsustainable fishing, habitat degradation and pollution) and their root causes, along with climate change[4].
  - Another example is the Caribbean Challenge Initiative (CCI), a long-term, public-private partnership presently covering nine Caribbean countries, which has at its core, two time-bound "20 by 20" goals to: 1) effectively conserve and manage at least 20 percent of the marine and coastal environment by 2020, and 2) achieve by 2020 fully functioning sustainable finance mechanisms to provide long-term and reliable funding for the CCI in each participating country[5].

[3] http://www.cirp.org.tt/mfisheries
[4] https://www.clmeproject.org
[5] http://www.caribbeanchallengeinitiative.org

9.6.3 Mainstreaming climate change

- Mainstreaming climate change through incorporation into fisheries and coastal development policies, plans and legislation to improve the effectiveness of reducing climate change impacts on the fishery sector.
  - There are a number of regional examples of on-going efforts in this regard, such as the comprehensive 2013 to 2021 CRFM-FAO strategy and action plan for *Climate change adaptation and disaster risk management in fisheries and aquaculture in the CARICOM and wider Caribbean region* (McConney *et al.*, 2015). Under the 2017 to 2020 FAO CC4FISH project seven countries are receiving support to put mainstreaming of climate change in fisheries policies, plans and legislation into practice. This is intended to strengthen regional and national cooperation and develop capacity to address climate change impacts and disasters in the fisheries and aquaculture sector (particularly on SSF and small-scale aquaculture). This also includes development of a protocol to integrate CCA and DRM into the Caribbean Community Common Fisheries Policy, and ensure integration at all points in the fish chain (McConney *et al.*, 2015).
  - In the United States of America (covering much of the GOM and SE USA shelf LMEs) the NOAA Fisheries Climate Science Strategy was developed in 2015 to help reduce impacts and increase the resilience of the valuable living marine resources, the people, businesses and communities that depend on them, through increased production, delivery and use of climate-related information using a nationally consistent blue-print (Link, Griffis and Busch, eds., 2015).

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