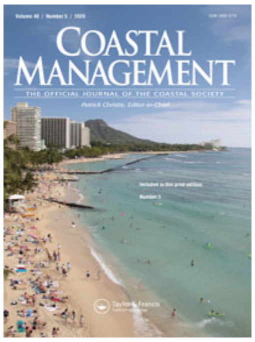

Coastal Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ucmg20

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To cite this article: Marianne Karlsson & Elizabeth L. Mclean (2020) Caribbean Small-Scale Fishers' Strategies for Extreme Weather Events: Lessons for Adaptive Capacity from the Dominican Republic and Belize, Coastal Management, 48:5, 456-480, DOI: 10.1080/08920753.2020.1795971

To link to this article: https://doi.org/10.1080/08920753.2020.1795971

Published online: 04 Aug 2020.

COASTAL MANAGEMENT
2020, VOL. 48, NO. 5, 456–480
https://doi.org/10.1080/08920753.2020.1795971

Caribbean Small-Scale Fishers' Strategies for Extreme Weather Events: Lessons for Adaptive Capacity from the Dominican Republic and Belize

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ABSTRACT
Understanding how Caribbean small-scale fishers can adapt to climate change is critical to sustaining coastal communities and livelihoods in the region. Fishers continuously adapt their practices to climate variability and recurring extreme weather events, such as hurricanes. However, it remains unclear how their "everyday" responses contribute to building their adaptive capacity for future changes and unpredictable extreme climate events. This paper identifies and analyzes strategies used by fishers in the Dominican Republic and Belize to deal with extreme weather events and climate variability. We draw on two separate case studies to identify their current autonomous adaptive strategies and explore how these align with broader dimensions of adaptive capacity. We find that fishers in both countries respond to changes and climate variability by relying on three strategies: (1) storing, saving and borrowing resources, (2) using experiential knowledge, flexibility and mobility, and (3) diversifying livelihoods and intensifying fishing. We show that fishers build their adaptive capacity on flexibility to sustain their livelihoods and on local knowledge to mitigate risk and damage from extreme weather events. The paper argues that the adaptive responses used by fishers in the Dominican Republic and in Belize can sustain their livelihoods but cannot enable a long term and transformative adaptation to ongoing and cumulative climate changes.

KEYWORDS
Adaptation; Caribbean; climate change; livelihoods; small-scale fisheries

Introduction

The sustainability of fisheries in coastal communities relies on peoples' ability to adapt and prepare for climate change and extreme weather events. The devastating hurricane season of 2017 was a wake-up call for many Caribbean Small Island Developing States (SIDS), placing climate change adaption high on many governments' agendas (UN-ECOSOC 2017). The Caribbean has a long history of living with disruptions from hurricanes, but the average intensity of tropical storms and hurricanes is only expected to increase in the coming decades (IPCC 2019) and interact with cumulative climate

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change impacts. In this context, it is important to advance the understanding of how people and ecosystems can adapt to such extreme weather events (Cox et al. 2017). Since coastal livelihoods in many SIDS are tied to fisheries resources, climate change impacts on ecosystems, such as coral reefs, have implications for the vulnerability and well-being of coastal communities (Cinner et al. 2012). These systems are already stressed from exploitation and overfishing trends that have decimated many fish stocks and threatened the integrity of coral reef systems (Hughes 1994). Hurricanes are a natural disturbance to coastal and marine ecosystems (Nyström, Folke, and Moberg 2000) that can provide opportunities for ecosystem renewal through the spread of larvae to other marine areas and by clearing algae-covered corals (Graham and Nash 2013). However, when most coral reef systems are under pressure from local human activities (e.g., untreated sewage, degradation of coastal ecosystems, fishing pressure) as well as global environmental change such as climate change and ocean acidification (Burke et al. 2011), hurricanes have primarily negative impacts on coral reefs and reef-dependent fisheries. Storms and hurricanes are destructive to physical reef structures and often severely reduce the structural complexity and extent of live coral cover. These changes can, in turn, alter fish population dynamics, such as recruitment, settlement and survival of fish larva with implications for biodiversity and fish quantities. Tropical storms and hurricanes unfold alongside other climate drivers, such as increasing sea surface temperatures, sea-level rise and ocean acidification that together have negative and cumulative impacts on coral reefs (Pendleton et al. 2016). Importantly, the dynamics of hurricane impacts on coral reef dependent communities are not linear but bi-directional, meaning that how people adapt to hurricanes will in turn influence coral ecosystems (Cinner et al. 2016). For example, damaged fishing gear may reduce fishing capacity benefiting the fisheries' resource, while, in contrast, fishers' responses to an extreme weather event may be to fish more intensely after and thereby compound the ecological effects of the hurricane over time. In this light, it is important to enhance understanding of how fishing communities currently respond to extreme weather events and how they can adapt and sustain their livelihoods amidst climate change.

Climatic changes interact with broader societal and political processes and influence communities' vulnerability and ability to adapt (Pelling 2010). Over the last 20 years, an increasing body of literature exploring the social aspects of climate vulnerability, adaptation and environmental risk in relation to small-scale fishers has emerged, primarily from the Pacific, Asian and African regions (Brouwer et al. 2007; Bunce, Rosendo, and Brown 2010; Coulthard 2008; Islam et al. 2014; Slater, Napigkit, and Stead 2013). However, there is a scarcity of empirical studies from the Caribbean, judged to be one of the world's most vulnerable regions to climate change (Nurse et al. 2014).

This study examines the adaptive response strategies of small-scale fishers to extreme weather events in the Dominican Republic (hereafter D.R.) and Belize. Both belong to the SIDS category and exhibit vulnerabilities known to other SIDS that have a high dependence on coastal resources as well as recurring hurricanes (Kelman and West 2009; Pelling and Uitto 2001). Other emerging literature, outlines adaptation challenges in coastal communities that includes: limited national resources, economies susceptible to fluctuations, and a scarcity of relevant and applicable scientific knowledge (Nurse et al. 2014; Vignola et al. 2009).

To understand how adaptive capacity is mobilized in practice, we focus on fishers' autonomous strategies to extreme weather events and climate changes. Our empirical data show that fishers' perceptions and responses comprise both short term weather events and long-term climate variability and change. We draw on Cinner et al. (2018) framework of domains of adaptive capacity to analyze adaptation strategies used by small-scale fishers in the D.R. and Belize. Our objective is to analyze the relationship between the fishers' observed strategies and their adaptive capacity, while illustrating broader commonalities and differences between the studied case communities. The results can be used to understand the current adaptation capacity of fishers in the Caribbean region, as well as recognize the existing gaps in management for the implementation of long-term adaptation processes.

Approaching adaptive capacity among small-scale fishers

We draw on the concept of adaptive capacity to analyze how the studied small-scale fishers respond to climate variability and extreme weather events. A community's adaptive capacity is typically defined as its ability to anticipate and respond to change and cope with and recover from perturbations, change and extreme events (Cinner et al. 2013; Cinner et al. 2012). Adaptation is the translation of adaptative capacities into strategies and actions that may be planned and proactive in response to a foreseen change, or autonomous and reactive, typically undertaken by individuals and communities to continuously adjust livelihoods in response to change (Smit and Wandel 2006). The outcomes of adaptive strategies and actions range from barely maintaining societal functions or livelihoods to effecting change in an incremental or transformational manner (Pelling 2010; Pelling, O'Brien, and Matyas 2015). Adaptation measures also run the risk of aggravating existing vulnerabilities and harming social groups or ecosystems, which is called maladaptation (Barnett and O'Neill 2010; Magnan et al. 2016).

The necessary balance of these potential outcomes can be seen in adaptation efforts related to coral reefs. In a recent review of climate adaptation for coral reefs, Comte and Pendleton (2018) found that most management actions seek to protect and maintain the current ecological functions of reefs by, for example, designating marine protected areas (MPAs) or mitigating local fishing pressure. Less effort has so far been devoted to actions seeking to rebuild ecological functions or to adapt reef-dependent livelihoods to ongoing or expected losses and shifts of ecosystem-services (Comte and Pendleton 2018).

It is difficult to anticipate how a community will respond to coming events and change, therefore adaptive capacity has emerged as a proxy for adaptation (Berrang-Ford, Ford, and Paterson 2011). Adaptive capacity approaches draw on the livelihoods literature (Scoones 1998), where the notion of assets (or capitals) such as human, natural, financial, social and physical capital enable primarily households (extended to communities, organizations, and nations) to maintain and build livelihoods (Allison and Ellis 2001). The literature on climate change and small-scale fisheries has analyzed how climate change (directly or indirectly) affects different assets (Allison et al. 2009; Badjeck et al. 2010). For example, physical infrastructure like landing facilities, roads, boats, and other equipment will, in many places, be damaged by intensified storms, sea-level rise and coastal flooding. Similarly, social and human capital in terms of place and occupational identity, local knowledge, and institutions are likely to be affected by relocation processes or profound changes in livelihood activities (Coulthard 2012). Adaptive capacity can often be latent, which implies that it is difficult to measure until it has been mobilized through a specific event, such as recovering from a hurricane (Mortreux and Barnett 2017). Thus, adaptive capacity needs to be translated into actions and strategies in response to disturbances and change processes. One way to approach this empirically is to investigate responses to past events or, as we do in this paper, examine everyday response strategies used by fishers to adapt to climate variability and change (Mortreux and Barnett 2017). The local strategies and knowledge used to cope with everyday stressors or extreme events are a necessary complement to planned and formalized adaptation primarily undertaken by other actors with different aims (Karlsson and Hovelsrud 2015).

Our analysis is inspired by the framework developed by Cinner et al. (2018) that combines concerns about activating adaptive capacity with the necessity of having actual assets to build on. Their framework, targeted toward tropical coastal communities, sketches five 'domains of adaptive capacity'. These categories are (1) assets that people can draw upon in times of need, (2) the flexibility to change strategies, (3) the ability to organize and act collectively, (4) learning to recognize and respond to change, and (5) the agency to determine whether to change or not. The first category of assets refers to the ability to access capital, credit, health services, infrastructure, insurance, and, subsequently, options to invest in technology and equipment such as gear, boats and storage facilities when the markets for, or composition and availability of harvest species change. Known indices of adaptive capacity have largely been based on the level of wealth in a particular country or community (Allison et al. 2009). Furthermore, impacts of hurricanes and storms affecting fisheries' assets can go beyond the fisheries sector and negatively impact other assets, infrastructure and supporting livelihoods, such as agriculture and forestry (Huitric 2005), as observed in communities on the French island of Dominica, who were devastated and their communications were cut off after the passage of Hurricane Maria (Pinnegar et al. 2019).

Flexibility is a critical element in climate change adaptation (Hovelsrud and Smit 2010). In a small-scale fishers' livelihood context, flexibility typically refers to the ability to move in and out of occupations, switching between gear and species, as well as changing fishing locations. Fishers' flexibility is often aligned with the possibilities of livelihood diversification (Allison and Ellis 2001). However, flexibility and diversification strategies are often hampered by specialization in certain types of fisheries and by the regulations in place to safeguard fisheries' resources and ecosystems, such as limited entry territorial use rights for fishing programs (TURFs), gear restrictions, sizes of fish, and marine protected areas (Bunce, Brown, and Rosendo 2010; Stoll, Fuller, and Crona 2017). Another important domain of adaptive capacity is how social groups are able to organize, cooperate and act collectively, what Cinner et al. (2018) refer to as 'social organization.'

Freduah, Fidelman, and Smith (2018) underscore that building social capital for adaptation and enabling fishers to organize and collaborate with external organizations such as NGOs is essential, especially since government support is often inadequate for small-scale fisheries. Very often in coastal–rural settings, community structure, collaboration, and sharing knowledge can be more important than the existence of a management system (Audefroy and Sánchez 2017). The importance of social capital in leveraging support from governments and other organizations has also been highlighted in other studies (Adger 2009; Pelling and High 2005).

Social organization and capital also relate to the domain of learning, namely, how well people can obtain and provide information and knowledge on how to live with climate change. This domain connects local or traditional ecological knowledge about fisheries resources and climatic features with scientific knowledge such as forecasting services (Mercer et al. 2010). Building adaptive capacity through learning may involve strengthening formal education systems as well as stimulating knowledge sharing between coastal communities within and across countries and regions (Cinner et al. 2018).

The fifth, and last domain of adaptive capacity agency refers to if individuals have faith in their own ability and capacity to accomplish change and steer their lives and livelihoods in a desired direction. Agency is necessary to mobilize the other domains of adaptive capacity and influence whether adaptive capacity is latent or mobilized (Brown and Westaway 2011).

We explore the domains of adaptative capacity through the observed response strategies undertaken by fishers. There are tradeoffs between adaptive capacities and strategies undertaken at different temporal and spatial scales and by different actors (Bunce, Brown, and Rosendo 2010; Cinner et al. 2018; Coulthard 2012; Finkbeiner et al. 2018). For example, increasing opportunities to invest in new technology—the capital investments that tie fishers to a specific mode of operation—can reduce flexibility. A focus on alternative livelihoods for diversification could also run counter to localized conceptions of identity and the value of being a fisher (Coulthard 2012). Acknowledging such tradeoffs when analyzing fishers' strategies is important, especially since strategies used to sustain current livelihood demands may compromise the future viability of ecosystems and fishing communities. Drawing on the literature outlined above, we will examine and contrast the adaptive strategies used by fishers in the D.R. and Belize and explore potential tradeoffs between strategies and domains of adaptive capacity.

Case sites

The fisheries of Belize and the D.R. differ in terms of markets, organization, targeted species and main fishing methods, but are both small-scale and susceptible to similar weather events and climate drivers. Small-scale fisheries, like many coastal fisheries are decentralized fisheries where fishers use small amounts of capital and energy and fish along the shore or by making short trips (e.g., Allison and Ellis 2001). This paper is based on two individual case studies, one undertaken in Sarteneja, the largest fishing community in Belize (Karlsson 2015), and one undertaken in the Samaná region, D.R. (Mclean 2016) (Figure 1). The research approach and methods vary between the two cases, as the Belizean case study draws on qualitative methods and the D.R. study uses a mixed quantitative-qualitative approach. The studies were not designed to be comparable but address the same themes, including perceptions of environmental and climatic change strategies to deal with climate variability and change, livelihood stressors and fisheries management. The main difference between the studies is that the D.R. case

Figure 1. Map outlining Belize and the D.R., and the locations of the case study communities. Source: Elizabeth Selig.

Table 1. Overview of fisheries characteristics in Belize and the Dominican Republic.

Fisheries characteristics	Belize	Dominican Republic
Number of fishers	3,184 licensed fishers (full and part time) (Villanueva 2010)	9,000 fishers (Caffrey et al. 2013)
Target species	Multi species: lobster, Queen conch and fin fish	Multi species, lobster, Queen conch (Herrera et al. 2011); Snappers, jacks, Kingfish mackerel, White grunt, etc. (Mclean and Forrester 2018)
Contribution to GDP	3% in 2016 (Chapman et al. 2016)	0.5% in 2011 (Caffrey et al. 2013) or, together with agriculture, forestry and fishing, 5.1% in 2018 (The World Bank 2018)
Harvesting techniques	Skin-diving, hook sticks, fish and lobster traps, handlines, harpoons. Diving fishers spend 6–10 consecutive days at sea.	Skin-diving, SCUBA, compressor diving, fish and lobster traps, handlines, long lines, nets, trawls, hooks and harpoons. Pelagic fin fishers spend 3–13 days at a time out at sea.
Vessels	Glass fiber skiffs or sail boats 6–10 meters with outboard engines of 15–40 HP, equipped with iceboxes and wooden canoes.	"*Cayucos*" wooden boats (6.4 m in length), "*yolas*" wooden or fiberglass boats (7 m in length), or other small boats (5.5 to 8.4 m in length), equipped with outboard engines and iceboxes.
Fishing areas	Shallow waters of the barrier reef and atolls, total area fished 4,700 km^2 within Belize's maritime area.	1,575 km of coastline in the D.R., 8,000 km^2 of platform, and 4,500 km^2 of oceanic banks and oceanic environments, and 238,000 km^2 of exclusive economic zone (Herrera et al. 2011; Mateo 2004).
Markets	Majority of lobster head and tail and conchs to USA, duty free import. Fin fish domestic markets (Harper, Zeller, and Sumaila 2011).	100% local consumption, landing of 1,300 tons (rough estimates) (FAO 2018).
Organization	Five Belizean-owned and operated fishermen cooperatives (66% of active fishers are members) buy, process and have exclusive rights to export marine products.	81% of fishers are not organized, 16% participate in associations, 2% in cooperatives, and 1% are members of unions (CEBSE 1994). (No current data available).
Fisheries regulations	Managed access fishery since 2016. Closed seasons for lobster and conch, minimum sizes. Special licenses required for spawning sites and sea cucumbers, ban on catching grassers. Network of Marine Protected Areas, totaling 20% of Belize's territorial sea, 3% no-take zone where fishing is prohibited.	Open access fisheries (Herrera et al. 2011). Regulations include closures, minimum catch size and gear. Coastal fishers require permission from the Coast Guard prior to departure (Lohman 2016). Yet, there is minimal oversight on regulations and access to fisheries is generally unrestricted.

focused more on the local ecological knowledge of fishers, while the Belizean study, focused on the contextual and political-economic factors that influence adaptation (Table 1). We discussed and exchanged ideas and concepts throughout the research period and the two case studies broadly addressed the same themes. In this paper, we therefore seek to present the main processes observed in the two cases and draw out commonalities and differences in the context of adaptation.

Samaná, Dominican Republic (D.R.)

Together with Haiti, the D.R. comprises the island of Hispaniola, a SIDS with a high frequency of damaging storms where vulnerability is worsened due to limited capital and resources (UNCTAD 2012). On top of hurricanes and seasonal challenges, the D.R. already experiences impacts of climate change on its coastal resources from floods and storms that cause coastal erosion, loss of coastal wetlands, loss of property and the expansion of marine dead zones (Duc 2013). During Irma in 2017, the category 5 storm inundated Samaná and other parts of the northern coast (Press 2017). Prior to that, in 1998, Hurricane Georges pounded this region and, in recent years, the D.R. was reported among the top ten countries in the Caribbean vulnerable to climate change (Caffrey et al. 2013). The D.R. has developed climate change policy and plans at the national level, and established regional organizations that can strengthen and expand climate adaptation capacity, but coordination is still lacking (Caffrey et al. 2013).

The D.R. case study was conducted on the Samaná peninsula, located in the northeast region of the island. This is one of the most important fishing regions in the D.R. SERCM/SEMARN 2004) and an important source of fish and shrimp fisheries (Herrera et al. 2011; Mateo 2004), supporting the livelihoods of a third of the D.R.'s fishers (Colom, Reyes, and Gil 1994; SERCM/SEMARN 2004). In the mid-1990s, this region witnessed the expansion of the fisheries sector with the adoption of different types of gear and the targeting of multiple species (Herrera et al. 2011). In 2013, approximately 9,000 individuals in Samaná identified themselves as participants in formal and informal fishing (Caffrey et al. 2013).

Fishers operate from small boats that range between 10 and 20 feet and can accommodate 2–8 fishers. Fishers engage in daily fishing activity in the nearshore, or a 3–10 days trip when they go farther. The boats are harbored on piers, beaches and landing sites from which fish are taken to the market. Trends pointing to a reduction of fish populations and the destruction of fishery habitats are attributed both to anthropogenic and climatic stressors (Herrera et al. 2011). Local fishers' concerns about declining fisheries were recorded in the early 90 s (McCann 1994), and this pattern continues today with low abundances of fisheries' targeted species (Eastwood et al. 2017).

Belize and Sarteneja

Belize is located within the Atlantic hurricane belt and during hurricane season (June through November) tropical storms and hurricanes affect citizens' lives, infrastructures and economic sectors. Major tropical depressions, tropical storms and hurricanes occurred in 1931, 1955, 1961, 1971, 1974, 1978, 2000, 2001 and 2007 (Bolland 2019; McCloskey and Keller 2009). Hurricanes and storms are natural disturbances affecting the reef system and fishing grounds, and the impact of hurricanes on reef systems has been researched since the 1960s (see Stoddart 1962). Major hurricanes have had significant impacts on fishing grounds and caused the destruction of processing plants, traps, boats and other equipment. However, fish landings reveal no significant decrease in yield during heavy hurricane years, and lobster and conch landings have been fairly stable since the 1980s (Gillet 2003; Gongora 2012; Huitric 2005). However, Huitric (2005) argued that stable lobster landings mask increasing individual efforts as well as decreasing individual yields, suggesting that the stocks may be overexploited. There is no reliable data available for fin fish landings, however, and individual studies suggest that fin fish stocks are declining (Graham et al. 2008).

Fishing in Belize is almost exclusively carried out in the shallow waters of the Belize barrier reef extending 280 km along the Belizean coast and covering approximately 1,400 km^2. The barrier reef consists of fringe reefs along the mainland coast and three offshore atolls, Lighthouse Reef, Turneffe Atoll and Glovers Reef. Belizean fisheries are small-scale, commercial and fishing activities are carried out in the country's barrier reef system (Gillet 2003; Villanueva 2010). Fishers target multiple species, using simple harvesting techniques that require low capital investment but rely on export markets (Gillet 2003; Huitric 2005). The Spiny lobster (*Panuliris agrus*) is the most valuable commercial species, followed by the queen conch (*Strombus gigas*). Both are export commodities with the U.S. market, a primary destination (Villanueva 2010). Fin fish such as the Mutton Snapper (*Lutjanus analis*) and Nassau groupers (*Epinephelus striatus*) are targeted for domestic markets. In general, fishers harvest lobster by diving with hook sticks and deploying lobster traps and shades (an artificial habitat). Conchs are caught by freediving, while fin fish are caught with traps, lines, or via spearfishing. In 2010, the fisheries sector employed 3,184 registered, full and part-time fishers (Villanueva 2010), with an estimated 15,000 people relying directly or indirectly on fishery resources (Gongora 2012). Occupations within tourism, in particular, nature-guiding, have been promoted primarily by international NGOs as a preferred livelihood diversification strategy for coastal communities. The expansion of tourism in Belize has been paralleled by the establishment of marine conservation measures such as MPAs. International NGOs such as the Wildlife Conservation Society (WSC), World Wildlife Foundation (WWF) and Conservation International are active in Belize and/or have established funding for local NGOs. Several of the MPAs in Belize are co-managed by NGOs, which also operate livelihood diversification programs in coastal villages such as Sarteneja.

Sarteneja is the largest fishing village in Belize with a population of 1,834, and is situated in the northeast corner of Belize in the district of Corozal (Statistical Institute of Belize 2010). The regional and local importance of the fisheries sector is well represented in Sarteneja, with around 800 active fishers, and where 80% of households are directly dependent on fishing as their primary source of income (Chapman et al. 2016). Sartenejan fishers engage in migratory fishing in all areas around the barrier reef and atolls. They embark from Belize City, where their vessels are harbored, and where the fishermen cooperative landing and processing facilities are located. Fishers utilize sailboats ranging from 20 to 60 feet, equipped with outward engines and iceboxes. Boats accommodate 9–15 divers that live onboard for the duration of the trip, which typically lasts 5–12 days, before returning to their communities for a couple of days in between trips. Sailboats are typically owned by a captain, who charges individual fishers a percentage of their catch for boarding. Fishers work independently from individual canoes in the proximity of the mother boat (Karlsson 2015).

Methods and data collection

The fishers in the D.R. were interviewed during a one-month period during the summer of 2012. The participants were identified using a simple snowball approach (Bryman 2012). The questionnaire was developed in consultation with Karlsson and local scientists, then tested for comprehensiveness on a couple of fishers prior to the research. We interviewed 82 male fishers from 10 different landing sites: Samaná, Sanchez, Sabena de la Mar, Las Galeras, Punta Corozo, Los Cacaos, Las Terrenas, La Pascuala and El Valle y Aguas Sabrozas. Although fishing is predominantly a male occupation, some women participate indirectly either by cleaning fish or by selling fish at the market. The fishers were 24–72 years old, with an average age of 48 years. Only 6% of the fishers were under the age of 30. On average, the fishers had over 34 years of fishing experience; 57% (47/82) of them described themselves as being primarily fishers. Fishing efforts included an average of 4 days of fishing a week and over 50 hours weekly (see Appendix A).

Aside from fishing, some individuals sold fish or engaged in non-fishing-related livelihood activities such as agriculture, construction work, masonry or carpentry. Additional informal exchanges and field observations were made at the docks, and fishers' group meetings, enabling a deeper understanding of the fisher organization and the issues it discussed among its members.

In Belize, fieldwork was carried out over two main periods, April to August 2011, and February to May 2012. Data were gathered from 30 semi-structured and open-ended interviews with fishers from Sarteneja (see Appendix B). The interviews followed an interview guide that focused on the following themes: (1) observed environmental changes in the reef system including climate change, (2) perception of causes of change, (3) challenges experienced in relation to livelihoods and (4) strategies used to deal with stressors.

The interview guide was initially tested on a couple of fishers and then modified to capture the fishers' reality. The informants were selected through a combination of purposive and snowball sampling (Bryman 2012). Criteria used for locating informants were primarily based on fishing as a livelihood occupation and included selecting for fishers of different ages, experience and status within the sector, such as crew members, captains and retired fishers. Commercial fishing is exclusively a male occupation in Sarteneja.

Participant observation of fishing trips was used to complement interviews and to gain a deeper understanding of fishing livelihoods. This included two conch fishing trips (June 2011 and March 2012) with different sailing boats and crews. In 2011, the trip consisted of a crew of nine fishers including a captain and cook and lasted for seven days in the vicinity of the South Water Caye area. In 2012, the crew was composed of seven fishers including the captain and a cook, and the trip took place near Glovers Reef over eight days. By joining individual fishers in their canoes during the day and spending the afternoon and evening at the mother boat, familiarity and rapport between the researcher and fishers were established. This allowed for in-depth and recurring conversations with fishers over the course of the trip. Being at sea enabled an understanding of specific fishing practices and facilitated conversations around what fishers viewed as challenging and what adaptive responses they used.

Results

Fishers in the D.R. and Belize, as in other parts of the world, continuously live with and respond to climate variability and extreme events, such as tropical storms and hurricanes. During the interviews, challenges related to climate stressors or 'bad weather' were described as a part of broader livelihood challenges. Therefore, the categories of responses we identified for coping with and adapting to climate stressors were also applied to a range of other livelihood challenges. These strategies can be grouped into three main categories: (1) storage, saving, borrowing and relying on family income; (2) using experiential knowledge, flexibility and mobility; and (3) diversification and intensification (following an adaptation from Agrawal and Perrin (2009).

All these strategies require local knowledge, namely, the knowledge local communities have developed over time, including perceptions, concepts and beliefs about the world that surrounds them. This type of knowledge is based on experience that individuals use to solve problems and validate new information (Warburton and Martin 1999). The strategies clustered in the first category of responses also require forethought and experience as defined by the management of material resources, but the second category refers specifically to decisions and actions guided by local knowledge, which people have accumulated throughout years of experience and which enables them to adapt. Lastly, the third category deals with alternating approaches to adaptation, including the selection of fished species, choice of gear, intensification of fishing efforts, or shifts to different livelihoods. It should be noted that fishers employ and combine all strategies, but the importance of each strategy varies according to the stressors and the season. Below, the empirical findings on response strategies are noted for the two study cases.

D.R. – Samaná

The fishers in Samaná described changes in weather conditions, such as: variance in rain, storms and hurricane patterns, as well as the presence of heavy fog and intense heat. Even experienced fishers explained that heavy fog made it difficult to sight the landmarks that help them find their landing sites. Fishers grieved not being able to go out and fish when high temperatures hampered their productivity and harvest as the ice melted faster and the intense heat made them feel weary. Some find it favorable when conditions are cold, saying: "Temperature changes—hot and then cold—during the heat, fishing is not good."

The effects of extreme weather events resulted in fishers having fewer days at sea, especially during hurricane season. Although newer technology is an advantage for predicting and reducing fishers' exposure to extreme weather, fishers are hindered by an unfavorable forecast. The Coast Guard lacks the resources to respond to multiple incidents and thus permission to depart from the dock is delayed when weather conditions are not favorable. During an extreme event, the Coast Guard is positioned on docks and restricts fishing activity by not giving fishers clearance to depart. However, some fishers choose to depart without a clearance to fish, regardless of the risks of losing their gear and licenses if they are caught. This clearance formality is not present in the inner bays where fishers depart from the beach and fish along the coast. Nearshore areas inside the Samaná peninsula like the neighboring marine protected area are less exposed to storms.

Saving, storing, borrowing and relying on family income

Fishers tended to save money instead of storing food staples for months when fishing was slow or when weather conditions were expected to prevent them from fishing. Tropical weather and regular power outages made it hard for people to store food without it going bad. Reliance on relatives for money occurred in several ways, either by a wife having her own income, a male fisher having an alternative livelihood, or by ensuring that fishing or agricultural activities could be carried out by a brother or a son if the fisher was injured. We expand on different sources of livelihoods in the diversification strategy below.

Other fishers relied on informal credit, described as advances in forms of loans and/or provisions from boat owners who provide what is needed for a trip. Boat owners generally have more resources; the informal credits are used to cover expenses such as gas, ice and other supplies needed, especially for an extended fishing trip. In extreme cases of difficult financial periods, Dominican fishers also resorted to pawning. For example, one fisher mentioned having to sell his backup boat motor in order to get by.

Experiential knowledge, flexibility and mobility

The study in the D.R. was part of a broader investigation that captured fishers' local ecological knowledge surrounding the fish they catch (Mclean 2016). This knowledge was vast, comprising many fished species, diverse fishing techniques, and different targeted fish habitats. The fishers knew how different species responded to cold and hot water temperatures. When weather conditions were unfavorable, fishers used their local knowledge to target other species by fishing along mangrove sheltered areas or in protected areas (or reserves) along the coast or in nearby reefs. By fishing illegally inside marine protected areas, fishers risked penalization such as fines or confiscation of equipment. However, their experience and knowledge often allowed them to avoid being caught when they harvested in those restricted areas. Many fishers chose to engage in these illegal practices rather than fail to provide for their families and incur shame.

Their experiential knowledge, familiarity and experience with different events and weather variability allowed them to prevent risks that would compromise their ability to fish or put their resources in danger. Furthermore, longtime fishers knew how to target different fishing sites in order to spread out the fishing pressure, thereby allowing stocks to replenish. One fisher said that, although there is a lot of pressure on many fishing sites, and although closures are not always observed, "the weather sets the closure," meaning that the fish stocks would benefit from not fishing during periods of bad weather. This awareness is part of their local knowledge and/or traditional knowledge. In remote and isolated rural areas, traditional knowledge is said to be static because it hardly interacts with other knowledge systems (Warburton and Martin 1999). Rather, this kind of knowledge is transferred from older to younger family members and refined through experience gained from spending large portions of life at sea.

In general, fishers considered their knowledge and existing strategies for dealing with weather events at sea enough to avoid personal injury or boat damage. If a fisher went missing or a boat was damaged during a storm, the fishers most often considered it a consequence of bad judgment, insufficient experience, or greed that had led captains to go out even when the weather forecast was hazardous.

Diversification and intensification

While more than half of the fishers in the Samaná region described themselves as primarily fishers (57%), many were used to shifting between alternative livelihoods when the fish catch was slow, when prices dropped, or when the weather prevented them from fishing. It was common for fishers to also engage in agriculture as an alternative livelihood for generating income and for personal consumption. Other occupations included construction work (masonry or carpentry), boating or working in tourism,

Table 2. Livelihood sources for fishers (men) and their households in the D.R. A primary source is what they rely on most, and a secondary source is what they rely on when fishing is not possible or profitable.

Description	n = 82	Percentages
Number of fishers whose single livelihood is fishing	47	57
Other primary livelihood sources		
Agriculture	28	34
Construction	11	13
Masonry	3	4
Carpentry	3	4
Other	23	28
Other secondary livelihood sources of the fisher		
Agriculture	11	13
Coconut plantations	4	5
Tourism	3	4
Other	19	23
Main occupation/livelihood of the wife		
Housekeeper	38	46
Bread seller	5	6
Other	13	16

making or repairing small fiberglass boats, electricians, gardeners and mechanics, among others. In some cases, fishers owned or helped run small convenience stores (Table 2).

Fishers also adapted to stock reduction through fished species diversification, adoption of newer gear and alternation of fishing locations. The Ministry of the Environment and Natural Resources encourages the diversification of fisheries, especially during the seasonal regulatory closures. Adoption of newer gear included fishing nets with smaller mesh sizes, which are illegal, but, due to the lack of regulatory enforcement, these new nets continue to be used to increase catches. Switching fishing locations involved alternating between the inner bay (shrimp fisheries), coastal line, and sea for pelagic and reef species.

Fishers mentioned traveling out to sea for 5–6 days to catch fish in deeper waters. This intensification practice allowed them to maximize gas costs as they traveled farther in hopes of catching more fish and recouping the money they invested in fuel. Other fishers mentioned working for months at a time on international waters, hired by larger vessels on the north coast. Although international opportunities were lucrative, they required a lot of sacrifice. Fishers forgo their sense of independence when they work for someone else, and they are bothered by having to work away from their homes. Their flexibility in fishing practices, i.e., switching between species, fishing gear, and fishing sites, allows them to adjust to changes in their daily catch.

Belize and Sarteneja

In Sarteneja, a number of interacting challenges such as 'bad weather', increasing number of fishers, marine conservation and Marine Protected Areas (MPAs) were cited to contribute to livelihood challenges leading to decreasing profitability. Extreme weather events such as hurricanes are a major concern for the fishers in Sarteneja, who had also observed changes in weather and climate patterns. These changes were mostly described as inconsistences in the occurrence of seasonal events, such as the timing and duration of cold fronts, difficulties in predicting the weather and less precipitation had been observed in the northern regions. Damage and change to the coral reef system had been observed by the majority of fishers, who linked such changes to lower productivity of fish stocks. Fishers mainly attributed coral reef degradation to damage from hurricanes and storms as well as to coastal development and tourists (touching or walking on corals). A couple of informants had observed warmer sea temperatures that led some fish to go deeper to find cool water.

Climatic events and changes were however considered challenging in the context of other social and economic factors that, taken together, were seen to threaten fishers' ability to sustain their livelihoods. Fishing was by many informants described as a calling an occupation characterized by a sense of independence that generated better incomes than for example farming, however, several wished to see more livelihood options within Sarteneja.

Saving, storing, borrowing and relying on family income

Saving, storing, borrowing or relying on other family income allows fishers to prepare and cope with lean times with little or no income from fishing. In Belize, such strategies were used in anticipation of the hurricane season. A combination of climate elements, such as strong winds, waves, and currents related to storms and hurricanes, challenge the seaworthiness and navigation abilities of sailboats and canoes. Strong winds, rain and flooding also reduce water visibility and fishers' ability to dive for lobster and conch. During the hurricane season and 'bad weather,' fishers are forced to stay ashore or to work with reduced capacity at sea. To prepare for such periods, the most common strategy was to buy and store staple foods such as rice, corn and beans immediately after the opening of the lobster season when catches and income were good. In Sarteneja, fishers prepared by saving and storing staple foods rather than putting aside money. As explained by a fisher, "… when you have money, you buy a stock of food that lasts a little while, then when the bad times come you still have a little food. That's how we survive … "

Similarly, to the D.R., Belize fishers' informal credit emerged as an important custom that ensured continuity in fishing activities. Prevalent forms of informal credit found in both cases were advances in the form of loans and provisions from boat owners or captains to fishers. In Belize, it was often younger fishers that turned to boat owners or captains for credit. This could take the form of cash, or postponement of payments for fuel, food, ice and boat rental until fishers had the ability to pay.

In Belize, fishers often obtained informal credit in food shops or from family members during times of financial difficulty. Previously, the Belizean fishing cooperatives provided formal credit, but this option has been largely restricted due to a debt crisis facing the two main cooperatives. Other forms of formal credit through banks were not readily accessible or viable options for fishers because of high interest rates, short repayment timeframes, and the fact that many fishers did not qualify for loans. Several informants wished that additional financial support and sustenance loans were available during the hurricane season.

Experiential knowledge, flexibility and mobility

Experiential knowledge, in terms of time-tested skills, experience and familiarity with the seascape and climate elements, was an important component in avoiding weather risks such as boat damage and personal injury. Mobility and flexibility were crucial to fishing strategies that averted bad weather or low productivity in specific fishing grounds. Moving between different fishing areas was emphasized as an important and commonplace strategy for minimizing income loss. One fisher explained, "*If the weather is bad in Lighthouse Reef,* [a fishing ground], *we move closer to Turneffe Atoll,* [a different fishing ground], *we like to move about in the barrier reef and fish in one area today and another tomorrow*." Normally, fishers tried to avoid bad weather by staying ashore or returning to harbor if they received bad weather forecasts whilst at sea.

However, at times, weather and climate elements such as storms could develop quickly when fishers were out at sea. In these cases, the response strategy was more reactive. When caught in bad weather, the captain and crewmembers' experience and knowledge were highly important. Once a storm and cold front developed quickly, fishers explained that they had to take shelter in the surrounding seascape, such as a channel (which is shallower) or a small island or cay and fasten the boat, place a tarpaulin over it, and wait for the weather to pass. Older, experienced fishers and captains often stated that they knew the sea 'like the back of their hand,' meaning that they knew how to read the weather, where to find suitable places for shelter, and what should be done to stay safe. This kind of knowledge was transferred from older to younger family members and refined through experience gained from spending large portions of life at sea. This knowledge and the existing coping strategies were seen as sufficient for avoiding personal injury or damage to boats in the event of sudden and extreme weather. As in the D.R., accidents during storms, such as lost fishers or damaged boats, were often seen as outcomes of bad judgment, insufficient experience or greed, rather than the result of natural elements.

Diversification and intensification

Diversification and intensification strategies were used in order to maintain fishers' livelihoods onshore or at sea. Diversification during hurricane season or periods with little income from fishing took the form of 'small jobs' in Sarteneja. These jobs typically involved helping out on a day-to-day basis in construction or maintenance of properties or other small businesses. Through interviews, it emerged that such jobs were obtained through social networks such as extended families. Due to programs run and funded by NGOs, some families gained extra income through pig rearing and occasionally by hosting tourists and volunteers in their home*s* (see Table 3). Although the majority of the interviewed fishers rely on fishing as their primary livelihood, 37% (11/30) relied on additional sources of livelihood activities as their secondary livelihood.

Table 3. A basic overview of main livelihoods and alternative livelihood schemes in Sarteneja.

Livelihoods in Sarteneja	Estimations of participating households/individuals/families
Fishing	70 % of households rely on fishing incomes (International C 2010; Pantin 2005)
Small-scale farming	20 % of households engaged in small-scale agriculture (Pantin 2005)
Tour guiding in Belize City	35 former fishers (Karlsson 2015)
Home stay (tourists and volunteers)	13 families (Karlsson 2015)
Tilapia farming	30 fish farmers (interview data 2012) (Karlsson 2015)
Pig rearing	42 families (Karlsson 2015)
Bee keeping	No estimations

Diversification strategies were also used at sea. For example, when weather conditions inhibited diving, fishers used hand lines from their boats to catch barracuda or fin fish. Strategies also involved fishing outside of fishing seasons, inside marine reserves, and below minimum size limits. Fishers explained that such responses were closely linked to their need to compensate for lost income. These weather strategies were related to intensification strategies used to compensate for periods when income from fishing had been low. Fishers tried to recuperate income during subsequent trips, as explained by a fisher who stated, "You have to go to the sea again and work harder, more days. If you take 4-5 days off from fishing in a hurricane, we have to go 8-10 days to try to pay back." The ability to increase fishing efforts and thereby regain income was seen by fishers as a token of their independence and as security against livelihood failure.

Discussion

From studying fishers in the D.R. and Belize, we find that their adaptive strategies comprise saving, storing, borrowing and relying on other family's income; using experiential knowledge, flexibility and mobility; and diversification and intensification in their fishing efforts. Below, we analyze how these relate to the different domains of adaptive capacity outlined by Cinner et al. (2018).

The first response strategy used by fishers in both countries, in order to prepare for lean or difficult times, involved saving money or storing food, or using informal sources of credit and other family member's income during periods of extreme weather events such as the hurricane season. While Belizean fishers tended to prepare by buying and storing staple foods, the D.R. fishers—given their conditions—preferred to save money. Similar to what Haque et al. (2015) observe in small-scale fishers in coastal areas of Brazil, relying on informal credit was a well-known coping strategy for fishers in Belize and in the D.R. because formal credit is often inaccessible to them (Haque et al. 2015). The above strategy relates to the domain 'assets to draw on in times of need,' as well as to the domain of social organization, because fishers acquired access to credits through their social networks (Cinner et al. 2018). In our case studies, informal credit was used by the fishers to cover loss of income during periods of 'bad weather'. The debt accumulated during these periods, however, lead fishers to intensify their fishing efforts in order to pay back their debt. While access to credit can be a means for fishers to build assets and to invest in equipment or training to extend their livelihood opportunities, we found that for fishers in both Samaná and Sartejena, access to informal credits was used to continue to reinforce their current livelihood practices, rather than to open up to other alternative livelihoods. Reliance on loans and small credits is a true challenge. Decades ago, Bee and Gingerich (1977) noted that there are small communities where a small group has control over productive operations while the others, named 'field ranks', supported the labor. Unfortunately, many small-scale fishers face this challenge, because their small communities rely on the economic vitality of both public and private sector, this reliance perpetuates a dependency loop (Bee and Gingerich 1977).

The contributions of women in upholding economic and social security and building adaptive capacity in fishing communities are well-acknowledged (Koralagama, Gupta, and Pouw 2017). This was observed in the D.R. case study where incomes from spouses enhanced fishing households' ability to support their families during an extreme weather event. In Sarteneja, employment opportunities for women are few. Prevailing gender norms and expectations that men should be the sole breadwinner, in combination with fishers spending most of their time at sea, limit women's opportunity to leave their homes to earn an income. There are thus clear gender related dimensions to building adaptive capacity that merit further exploration in the Caribbean region (Ravera et al. 2016).

The second response strategy, experiential knowledge, flexibility and mobility emerged as an important approach to sustain livelihoods and mitigate risk from extreme weather events. The flexibility to move between fishing areas and target different species is not inhibited by strict regulations on fishing quotas, TURFs and large MPAs, although we note that fishing regulations are moving toward this direction in Belize (Stoll, Fuller, and Crona 2017). In Belize, the introduction of managed access was feared by Sartenejan fishers for its potential to limit their flexibility. However, the scheme has been adapted so that fishers, who traditionally work in several areas across the reef are granted access to two fishing areas and can continue to move between these in times of need. In the D.R., shifting between fisheries during varying weather conditions can help in securing livelihoods, e.g., by fishing for shrimp, gill net or long line fishing, when seasonal closures are in place. We link this strategy to the domain of learning and responding to change (Cinner et al. 2018), from fishers having learned to live with cycles of disruption to their fishing activities caused by storms, hurricanes and extreme weather events. Compared to Belizean fishers, fishers in the D.R. expressed more in-depth knowledge about how fishing pressures affected different fish sites and about the necessity of changing fish sites to allow stocks to replenish. The presence of different organizations in the Samaná region, and their forums and workshops have contributed to the fishers' environmental awareness (Lohman 2016). Environmental NGOs in Belize engage fishers in training and information campaigns about climate change and its impacts on coral reefs and their fisheries. However, our results indicate that efforts to integrate fisher's local ecological knowledge and scientific knowledge need to be enhanced to both enable learning and building the fishers' capacity to plan and adapt to climate change and extreme weather events.

In both cases, fishers considered their local and experiential knowledge to be sufficient to secure their personal safety during extreme weather events. However, under rapid and synergetic climate change impacts (Pendleton et al. 2016), this sense of resilience can be deceptive (Amundsen 2012). Although yearly hurricane seasons and other events are to be expected, fishers' preparedness and the availability of the necessary knowledge could be increased through collaboration, promotion and acquisition of weather forecast tools.

The third response strategy, diversification and intensification, was commonly utilized in both case studies, related to the flexibility to change strategies domain (Cinner et al. 2018). Diversification and flexibility of income, as well as occupational mobility, have been highlighted by others as a prevalent form of social and ecological adaptation (Whitney et al. 2017). Diversification strategies outside fisheries were more common in the Samaná region than in Sarteneja where fishers remained highly dependent on the fishing sector. Fishers who rely directly on marine resources are often characterized as having a higher occupational attachment (Pollnac, Pomeroy, and Harkes 2001; Shaffril, Samah, and D'Silva 2013). This lack of interest in alternative livelihoods can be used as an indicator of vulnerability given the direct relationship between occupation and life satisfaction (Pollnac, Pomeroy, and Harkes 2001; Shaffril, Samah, and D'Silva 2013). In Sarteneja, the limited success with alternative livelihood programs can in part be linked to the occupational identity of being a fisher and to the limited economic viability of available alternatives. A study in the D.R. from 2010 estimated that fishers that depend on the reef could earn 90% of their present income through tourism activities (Wielgus et al. 2010). However, it is important to align livelihood diversification schemes envisioned by conservation NGOs and government bodies with fishers' conception of well-being and their desired adaptation trajectories (Coulthard 2012).

This last strategy relates to the third domain of adaptive capacity, the ability to organize and act collectively (Cinner et al. 2018), which emerged as being less developed in both case studies. In Belize, the fishing cooperatives have played an important role in organizing fishers and developing coastal communities in the past (Gibson 1978; Huitric 2005). While the main fishers' cooperatives in Belize currently suffer from a debt crisis following previous losses from past hurricanes, as well as from mismanagement of funds, the cooperatives could play a key role in enabling adaptation in future. Dominican fishers that participate in cooperatives and associations have an advantage over those that do not because these organizations facilitate communication with branches of government that regulate the fisheries. In D.R., NGOs and universities can promote a positive experience by bringing needed expertise to the fishers organizations that can assist in the development of relevant national climate change initiatives (Lohman 2016; Rosa 2016). Ultimately, developing new livelihoods require significant investment in assets in infrastructure and public services like education and health. Such investments along with broader risk reduction measures including reducing CO2 emissions necessitate the activation of adaptive capacity such as social organization and agency at higher governance levels than in the studied fishing communities (Morrison et al. 2020)

We observe tradeoffs between the fishers demonstrated agency in their determination to sustain livelihoods, and the flexibility that enables them to intensify fishing efforts in times of need. Using smaller mesh sizes for fishing gear, fishing out of season, fishing under minimum sizes fish and fishing inside protected areas, were all tactics described as flexibility and diversification strategies, but at the cost of undermining ecological assets. These strategies thus emerged at the expense of the health of coral reefs, and increased pressure on fisheries' resources (Mumby et al. 2011). As observed by others, the fishers' adaptive responses to extreme weather events can aggravate impacts on coral ecosystems (Cinner et al. 2016), be maladaptive (e.g., Magnan et al. (2016)) in the long-term and also exacerbate social vulnerability by undermining the resource base.

Conclusion

Through the perspective of domains of adaptive capacity (Cinner et al. 2018), this study has analyzed the strategies small-scale fishers in the D.R. and in Belize use to respond and adapt to extreme weather events and climate change. We have identified three main categories of response strategies used by fishers in both countries (1) storing, saving and borrowing resources, (2) using experiential knowledge, flexibility and mobility, and (3) diversifying livelihoods and intensifying fishing. In line with the broader literature on small-scale fisheries (Daw et al. 2009; Finkbeiner 2015), we show that the fishers' strategies predominantly build on the flexibility to shift between fishing area, species and to intensify their fishing efforts to make up for income losses during periods of unfavorable and extreme weather. Learning from previous events and local knowledge is used to mitigate risk and damage from extreme weather events. The study suggests that policy direct adaptation measures, such as financial support mechanisms or temporary forms of employment during the hurricane season when fishers experience seasonal vulnerability, could make a positive difference. Seeking to improve fishers' access to formal credit and rendering small loans less expensive could strengthen the fishers' capacity to respond to climate variability and change, and possibly also reduce the need for intensification practices. Our findings point to the potential to build on experiential knowledge and flexibility strategies to increase adaptive capacity (as discussed by Daw et al. (2009) and Badjeck et al. (2010)). However, it is important to acknowledge the tradeoffs between sustaining livelihoods with short term strategies such as intensifying fishing efforts and long-term approaches that can protect fisheries and key ecosystem functions. In addition, there may be tradeoffs between the individual agency and determination to sustain present livelihoods and the communal efforts and social organization needed to adapt and transform livelihoods with synergetic and cumulative climate changes (Cinner et al. 2016, 2018; Pendleton et al. 2016).

In conclusion, we argue that the domains of adaptive capacity proposed by Cinner et al. (2018) can be used to advance our understanding of fishers' adaptive responses. Our analysis of small-scale fishers' adaptive responses to extreme weather events contributes relevant knowledge to debates on how adaptation policy should be devised and implemented in order to sustain livelihoods in Caribbean SIDS communities.

Acknowledgements

We extend our deepest thanks to the fishers for participating and contributing to this research. Funding support of this research was generously provided by a grant from the Research Council of Norway, grant number 199380/H30 through the Many Strong Voices program. We are also grateful to the anonymous reviewers for their feedback and recommendations. We thank Elizabeth Selig for helping us with the map. Mclean also thanks the Coastal Institute Fellowship, of the University of Rhode Island, Kingston RI, the Puerto Rico Sea Grant program, and the Centro para la Conservación y EcoDesarrollo de la Bahía de Samaná y su Entorno (CEBSE) in Samaná, D.R. for their support, and valuable guidance. Karlsson also thanks the Caribbean Community Climate Change Centre (CCCCC), Center for Climate Research Oslo (CICERO) and the Norwegian University of Life Sciences,

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Appendices

Appendix A

Table A1. Distribution of some demographic variables for fishers in the Dominican Republic.

	Min.	Max.	Mean
Age	24	72	48
Number of years fishing	10	64	34
Age at which they started fishing	3	33	13
Fishing effort (#hours; #days)	4 h/week; 2 days/week	84 h/week; 7 days	50 h/week; 7 h/day
Percentage of income from fishing	20%	100%	86%

Appendix B

Table B1. Some demographic variables from Sarteneja, Belize.

	Min.	Max.	Mean
Age	21	70	39
Number of years fishing	5	40	23
Other secondary livelihood activities among informants			
	Occupation	No.	
	Maintenance	2	
	Tilapia farming	2	
	Shopkeeper	1	
	Tour guiding	2	
	Pig rearing	3	
	Construction	2	