Chapter 2
Fishers' Perceptions of Environmental and Climate Change in Puerto Rico: Implications for Adaptation and Sustainability

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Abstract Marine fisheries in the Caribbean are vulnerable to a wide range of environmental and climatic change impacts. Direct and indirect effects of these impacts on fish species affect the ability of fishers to harvest them resulting in reductions in revenue and food security. Understanding factors impacting and transforming fisheries from the viewpoint of the fishers is crucial for developing adequate strategies to maximize coastal communities' resilience and adaptation to change, particularly under future climate change scenarios. This study uses qualitative and quantitative data collected from 212 surveys with Puerto Rican fishers to explore aspects of fishers' subjective perceptions of environmental and climate change and investigate factors influencing these perceptions. Our findings show that fishers perceive the local environment and climate to have undergone significant changes in the past couple of decades and they believe these changes have been affecting the fishery and consequentially leading them to adapt. Adaptations to these impacts, which consist mostly of seeking new fishing grounds, have led them to increase their exposure to risks, particularly among SCUBA divers fishing in deeper waters and farther away from the coast. Results also show important relationships between fishers' perceptions of the status of fishery resources, demographics, levels of environmental awareness, and concern about climate change. These findings have significant implications for the development of policy and educational strategies aimed at increasing sustainability and well-being in fishing communities.

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2.1 Introduction

Marine ecosystems and resources worldwide are being transformed and threatened by human activity at an increasing pace. In the Caribbean region, economic development and population growth have generally occurred without effective policies to safeguard the sustainability of natural resources, resulting in rapid degradation of coastal waters and critical ecosystems (Valdés-Pizzini et al. 2012). Ecological deterioration and overexploitation and overfishing have contributed to the collapse of many important fishery resources in the region, reducing biodiversity, revenues, and the resilience of fishers, their families, and communities. Marine fisheries in the Caribbean are also vulnerable to a wide range of climate change impacts. Among the most significant are loss of critical habitat such as mangrove forests and seagrass beds (Short et al. 2016; Alongi 2015), coral bleaching and disease (Baker 2014; Randall and Woesik 2015), changes in patterns of freshwater flows (Holding and Allen 2015), and ocean acidification impacting shell formation for corals, plankton, and shellfish (Rhein et al. 2013). Climate change impacts also affect the life cycles, abundances, and distributions of fish species (Perry et al. 2005). Fishing is an important cultural and socioeconomic component in the Caribbean context. Understanding factors impacting and transforming this activity from the viewpoint of those directly involved, that is, the fishers, is crucial for developing strategies that will maximize coastal communities' resilience and adaptation to change in the region, particularly under future climate change scenarios. This study uses data collected from surveys with Puerto Rican fishers to explore aspects of fishers' subjective perceptions of environmental and climate change and investigate factors influencing these perceptions.

2.1.1 Climate Change and Fisheries

In fishing communities, direct and indirect impacts of environmental degradation and climate change on species that are important for income and subsistence affect the ability of fishers to harvest them (Sumaila et al. 2011; Pinsky and Mantua 2014; McCay et al. 2011; Allison et al. 2009; Weatherdon et al. 2016) resulting in reductions in revenue and food security. Declines in revenue impact fishers and their families as well as local economies by negatively affecting supporting businesses such as seafood dealers and distributors, fish markets, and restaurants and associated sectors such as tourism. Impacts on the ability of fishers to catch fish for their subsistence result in reduced food security. In small-scale fishing communities, and as evidenced in Puerto Rico (Garcia-Quijano et al. 2015; Griffth and Valdés-Pizzini

2002), it is common practice for fishers to give a portion of their catch to family and other community members. Thus, reductions in catch also affect practices that foster the development and maintenance of social ties that are important for generating social capital. Natural resource decline also influences changes in fishery management, for example, prompting reduction of allowable catches and extended closures, contributing to pressures associated with resource scarcity and further affecting fishing communities' socioeconomic well-being. In addition, from a human dimensions perspective, fishing communities are typically located in low-lying zones which are at risk from sea level rise and present high exposure to extreme weather events (Nicholls and Cazenave 2010), potentially compounding their socioeconomic vulnerability under climate change.

Transformations associated with environmental and climatic change and the potential impacts of indirect effects on range and productivity of commercially important species require that fishers adopt strategies to respond adaptively. Adaptive responses may include *within-fishing* adaptations, for example, finding new fishing grounds and exploiting different species, or *outside-fishing* adaptations, that is, finding alternative income or employment (Pinsky and Mantua 2014; Cinner et al. 2011; McCay et al. 2011). Poverty and other types of marginalization in fishing communities may reduce the ability of fishers to adapt to changes (Daw et al. 2009), particularly through *outside-fishing* adaptations. In addition, a great deal of research suggests that fishers are reluctant to leave the occupation of fishing even under economic hardship due to a combination of sociocultural and psychological factors (Smith and Clay 2010; Pollnac et al. 2015). Job satisfaction in fisheries has long been recognized as an important aspect related to fishers' adaptation to change (Pollnac and Poggie 1988). Although satisfaction with aspects of one's job is important in any occupation, it is especially significant in fishing jobs. Among fishers, the structure of job satisfaction includes attributes of "adventure," "challenge," and "being outdoors" that are infrequently found in other occupations (Apostle et al. 1985; Pollnac and Poggie 1988, 2008; Binkley 1995; Pollnac et al. 2008; Seara et al. 2017a, b). Understanding these satisfactions derived from fishing is important because the more attached people are to their jobs, the more difficult it is to either leave or deal with significant changes to their occupation. For people presenting strong occupational attachment, the prospect of losing their jobs may represent not only the loss of income but of part of their self-identity (Marshall et al. 2007). Therefore, leaving the occupation of fishing altogether as an adaptation strategy is unlikely and of particular concern for individual, familial, and community well-being (Pollnac and Poggie 2008; Pollnac et al. 2015). In a detailed ethnography of Puerto Rican fishers, Griffith and Valdés-Pizzini (2002) describe that a great deal of them consider fishing as "therapy." Many Puerto Rican fishers who work on land jobs (e.g., farming) during the fishery off seasons return to the sea, to what they describe as a healthy activity that keeps their minds occupied on useful things and that provides relief from stress (Griffith and Valdés-Pizzini 2002). In a study comparing Southeast Puerto Rico and other fishing communities in the USA and the wider Caribbean region, Seara et al. (2017b) found that Puerto Rican fishers presented the highest levels of job satisfaction among compared samples. The authors

argue that high job satisfaction among Puerto Rican fishers is associated with freedom to pursue their own inclinations in fishing and other livelihood activities and spend time with friends and family, coupled with a sufficient material well-being and strong social ties within their communities (Seara et al. 2017b). Therefore, changes resulting from climate change and other anthropogenic impacts affecting the fisheries in Puerto Rico will have significant impacts on the psychological and social well-being of fishers and their families. According to Daw et al. (2009), "climate change impacts on fisheries will occur in the context of, and interact with existing drivers, trends and status of fisheries." Specifically in Puerto Rico, evidence of the significance of fisheries to economic, cultural, psychological, and basic subsistence aspects further emphasizes the challenges associated with fishers' adaptation to environmental and climate change.

2.1.2 Puerto Rico Fisheries

Fishing activities in Puerto Rico are predominantly dependent on nearshore coral reef systems (Appeldoorn 2008) and adjacent ecosystems such as seagrass beds and mangrove forests. Coral reef ecosystems in the Caribbean have been declining for at least the last 40 years, although pinpointing the beginning of the decline has been difficult (Appeldoorn et al. 2009). Overfishing and climate change are considered two of the most significant threats for the great majority of Puerto Rico's reefs and marine ecosystems (García-Sais et al. 2008; Rogers 2009; Ramos-Scharrón et al. 2015; Loh et al. 2015; Hernández-Delgado et al. 2014). In 2005, a widespread coral bleaching event associated with record high seawater temperatures in the Caribbean region heavily impacted Puerto Rico's coral reefs (Wilkinson and Souter 2008). Following the bleaching event, researchers in the region reported an average of 50% decline in live coral cover and up to 90% mortality of coral colonies at specific monitoring sites (Miller et al. 2006; García-Sais et al. 2006; Woody et al. 2008). Donner et al. (2007) attributed this particular event to anthropogenic warming. The study suggests that greenhouse gas emissions increase the probability of events of extreme thermal stress in the region by an order of magnitude, which could result in events, such as the one that occurred in 2005, becoming biennial occurrences within the next 30 years (Donner et al. 2007). The authors further stated that expected increase in hurricane activity in the region, also as a result of human-induced climate change, would critically damage and endanger corals already weakened by bleaching events (Donner et al. 2007). The 2017 Atlantic Hurricane Season (AHS) was one of the most active in history producing six hurricanes above category 3 and breaking the record for most consecutive storms in the satellite era (NOAA 2018a). The most intense hurricane of the 2017 season, category 5 Maria, made landfall in Puerto Rico in September and was the most intense storm to hit US territory in recorded history (NOAA 2018a). The 2017 AHS, particularly the two most intense storms Irma and Maria, caused catastrophic damage to Puerto Rico communities and resulted in substantial damage to the island's shallow water coral reefs (NOAA

2018b). Storm damage to Puerto Rico coastal communities' infrastructure and to coral reefs and adjacent ecosystems can significantly impact productivity in the island's marine fisheries.

The Puerto Rican fishery sector is comprised mainly of small-scale operations that often consist of an owner and a crew of typically no more than three members that fish from small vessels with limited horsepower. According to Garcia-Quijano (2009), the Puerto Rican fisheries' socioeconomic context can be typified by "heterogeneity and unpredictability of opportunities for employment and for covering the basic needs of subsistence." Research suggests that, even though the fishery sector in Puerto Rico is generally characterized by occupational multiplicity, fisheries and coastal-based resource extraction constitute important components of the cultural and socioeconomic context of most coastal communities (see Garcia-Quijano et al. 2015). According to the latest census of Puerto Rican fishers conducted in 2008, approximately 900 individuals engage in the activity throughout the island (Matos-Caraballo and Agar 2011). There is indication, however, that the actual number is higher, ranging between 1500 and 2000 as suggested by qualitative data, since many fishers in the island are not fully licensed (Tonioli and Agar 2011). The licensing system in Puerto Rico requires that fishers provide proof of income deriving from fishing in the form of tax documentation in order to be considered eligible for either part- or full-time fishing licenses (Matos-Caraballo 2009). As mentioned above, the fishery sector in Puerto Rico has been historically characterized by occupational multiplicity (Garcia-Quijano et al. 2015; Griffith and Valdés-Pizzini 2002) which may be in conflict with the current licensing system, therefore unintentionally creating an incentive for unlicensed and, thus, under- or unreported fishing activity.

Fishers in Puerto Rico are typically organized around fishery centers/associations (*villas pesqueras*) or along coastal townships. Catches consist of relatively low quantities of diverse species (Griffith and Valdés-Pizzini 2002) including snappers (Lutjanidae), groupers (Serranidae), and a variety of crustaceans and mollusks that are sold to the *villas pesqueras* and private fish markets (*pescaderias*), or more informally from fishers' houses or directly to buyers or restaurants. Puerto Rican fishers typically engage in multiple gear activities including nets, traps, hook and line, and harpoon. In recent years, the percentage of fishers practicing SCUBA diving has increased considerably: from approximately 35% in the mid-1990s to between 40 and 50% in 2008 (Matos-Caraballo and Agar 2011). According to Matos-Caraballo and Agar (2011), this reflects a necessity for fishers to become more specialized as a result of declines in coastal catches. Down trends in commercial fish landings in Puerto Rico have been reported since the 1970s (Matos-Caraballo 2009; Bryan et al. 2016) with an alarming decline of approximately 69% occurring between 1970 and 1990 (Appeldoorn et al. 1992). The species predominantly targeted by SCUBA divers are spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*).

Awareness of the importance of understanding human dimensions of fisheries has been increasing considerably in the past few decades (see Weeratunge et al. 2014), and, with that, a new focus is given on fisheries *governance* as opposed to

merely management (Daw et al. 2009; Pittman et al. 2015). A focus on governance provides a more holistic approach in which both formal and informal arrangements and institutions are involved in decisions affecting the use of natural resources (Juda 1999), thus allowing for more opportunities to incorporate human dimensions and resource users' involvement in decision making. In the face of environmental degradation, resource decline, and climate change, successful adaptation in fishing communities will require the implementation of policy strategies that are informed by human dimensions in order to properly consider crucial aspects such as job satisfaction, food security, social networks, and overall well-being, while safeguarding natural resource sustainability and ecological resilience. Government intervention and policies must facilitate adaptive capacity, particularly within vulnerable communities (Adger 2003; Daw et al. 2009). In general, the *objective* capacity of individuals or societies to adapt to change is determined by availability of resources and an individual's or group's access to those resources. On the other hand, *subjective* aspects of adaptation are associated with peoples' perceptions of the adequacy of available resources in aiding them to cope and adapt, as well as the extent to which they feel prepared to endure such changes or impacts and actively cope with them, that is, their perceived vulnerability. The focus of this study is on the latter.

Climate change vulnerability and adaptive capacity frameworks often either fail to or poorly incorporate aspects of subjective perception (Adger et al. 2013; Limuwa et al. 2018). Perceptions are largely shaped by one's experiences and, along with values, beliefs, knowledge, and culture, are important motivators of people's behaviors (Taylor et al. 1988; Grothmann and Patt 2005). Understanding people's perceptions of and vulnerability to environmental and climate change is crucial since in the face of stressors, people often act upon their subjective perceptions rather than objective measures (Grothmann and Patt 2005; Smith and Clay 2010; Seara et al. 2016). Programs directed at increasing human resilience and adaptive capacity need to seriously consider these perceptions (Aswani et al. 2015; Cinner et al. 2018). In the case of fishers and fishing communities, adaptive capacity is also closely linked to observed and future changes to marine ecosystems (Daw et al. 2009). This study analyzes the perceptions of fishers in Puerto Rico communities toward environmental and climate change as well as factors potentially influencing these perceptions and their ability to adapt. It is proposed that literature reviewed and the relationships discovered in the data can be used to generate a heuristic model to function as a general hypothesis which will be tested here using path analysis.

2.2 Methods of Data Collection

This study used surveys to collect quantitative and qualitative information from fishers in ten different municipalities in Puerto Rico (Fig. 2.1). Between August 2016 and January 2017, a total of 212 fishers were surveyed using an intercept sampling method that consisted of approaching fishers at different fishing associations (*villas pesqueras*) and other locations where they were known to land their catches

Fig. 2.1 Map of Puerto Rico showing municipalities included in data collection. (Adapted from USDA 2012)

or congregate. This sampling technique was considered the most effective to maximize sampling of the studied universe since no comprehensive list or directory of Puerto Rico fishers is readily available from which to draw a random sample (e.g., Seara et al. 2017a, Pollnac et al. 2015). The questionnaire included demographic and fishery attributes, job satisfaction, perceptions of the status of fishery resources and the environment, and climate change. Questions to collect information about fishers' perceptions of changes in the marine environment and climate used a combination of dichotomous, Likert scale, and open-ended methods to collect data that could be analyzed quantitatively while allowing respondents to elaborate on their views and experiences to aid in interpretation of results.

2.3 Measurements and Analyses

2.3.1 Fishers' Characteristics

For the majority of fishers interviewed (69.8%), fishing was their only source of income. For those who had additional occupations (24.1%) or who did not consider fishing an occupation (subsistence and/or recreational) (6.1%), the most common types of employment were construction (10.9%), owning a business (9.1%), and farming (9.1%). Fishers were on average 50.5 years of age (sd = 13.96) with 35.9 years of fishing experience (sd = 16.07) and 9.1 (sd = 3.72) years of formal education. The majority of the fishers interviewed were married (71.7%) and the average household size was 3.0 people (sd = 1.37).

The sample is characterized by a majority of SCUBA (32.5%[R1]) and trap (*nasas*) (14%[R]) fishers. The species most important for fishers' incomes were spiny lobster (*Panulirus argus*) (36.7% [R]), silk snapper (*Lutjanus vivanus*) (14.3%[R]), queen conch (*Strombus gigas*) (9%[R]), and yellowtail snapper (*Ocyurus chrysurus*) (8.1% [R]). The

[1] Refers to percent of responses as each fisher could indicate more than one option per response.

majority of fishers (72.3%) owned the boats they used to fish which were on average 20.4 feet long (sd = 3.43). Fishers surveyed spent on average 10.9 months out of the year (sd = 2.17), 14.9 days out of the month (sd = 7.41), and 6.6 hours a day (sd = 2.13) fishing.

2.3.1.1 Job Satisfaction

Job satisfaction was measured using a 9-item scale (Table 2.1) derived from a 22-item scale developed by Pollnac and Poggie (1988). The 9-item scale was developed by using a principal component analysis (PCA) from a geographically diverse data set and selecting the three items with the highest loadings on each of the three components commonly derived from the PCA. In the present sample, mean values for all job satisfaction variables, measured on a Likert scale of 1 (*very dissatisfied*) to 5 (*very satisfied*), are above 3.7 suggesting that, in general, fishers present high levels of job satisfaction. Aspects of the job with which fishers are most satisfied relate to independence and adventure.

2.3.1.2 Environmental Ethic

A list of 10 items (Table 2.2) were used to assess aspects of environmental beliefs among fishers by asking their level of agreement with each item on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), reversed, reversed for negatively worded items. Mean scores were above three for all items with the exception of the item concerning whether or not fishers agreed that the presence of houses near the coast had an effect on the fishery. Items with the highest scores concerned the need to take care of the land and sea to safeguard sustainability and the impacts of coral death on fishing (see Table 2.2 for all mean scores). A *total environmental ethic* scale ranging from 10 to 50 was created by summing up the responses to all ten items.

Table 2.1 Job satisfaction variables with mean values and standard deviation measured on a 5-point Likert scale ranging from very dissatisfied to very satisfied

Item	Mean	Std. deviation
Opportunity to be own boss	4.64	0.624
Adventure	4.45	0.528
Time spent fishing	4.34	0.676
Challenge	4.25	0.606
Earnings	4.08	0.843
Safety	3.97	0.737
Healthfulness	3.92	0.735
Predictability of earnings	3.83	0.759
Fatigue	3.70	0.752

Table 2.2 Environmental ethic variables with mean values and standard deviation measured on a 5-point Likert scale ranging from strongly disagree to strongly agree except for items marked with an asterisk for which scale was reversed

Item	Mean	Std. deviation
We have to take care of the land and the sea or they will not provide for us in the future	4.43	0.496
If the corals die, it will make a difference for fishing	4.41	0.628
If our community works together, we will be able to protect our resources	4.23	0.704
Tourism around/near the coast can have an effect on the fish	3.38	1.105
Agriculture around/near the coast can have an effect on the fish	3.11	1.036
Industry around/near the coast can have an effect on the fish	4.04	0.897
Houses around/near the coast can have an effect on the fish	2.91	1.142
∗If we throw our garbage on the beach, the ocean takes it away and it causes no harm	4.34	0.848
Unless mangroves are protected, we will not have any fish to catch	4.17	0.766
∗There are so many fish in the ocean that no matter how many we catch, there will always be enough for our needs	3.44	1.255

2.3.2 Perceptions on Status of Fishery Resources

Results indicate that in general fishers perceive the fishery resources in the region to be in good shape. On a *current status of fishery resources* scale of 1 (*very bad*) to 5 (*very good*) responses averaged 3.51 (sd = 0.84), with 50.2% of the fishers indicating resources to be in *good* shape. When asked if resources are currently in worse, equal, or better shape (a scale of 1 to 3) when compared to 10 years ago, the average was 1.70 (sd = 0.63), with 51.7% of the fishers stating resources are *equal* and 39.3% stating they are *worse*. The most frequent reasons stated by fishers for resources to have worsened during the past decade were pollution (40.4%^{R}), over-exploitation (19.2%^{R}), changes in climate (15.4%^{R}), government regulations (6.7%^{R}), and environmental degradation (5.9%^{R}).

2.3.3 Perceptions of Climate Change and Other Anthropogenic Impacts

The majority of fishers surveyed (72.6%) believe the local climate to be changing, and in general they perceived these changes to be negative, averaging 2.35 (sd = 0.76) on a scale ranging from 1 (*very bad*) to 5 (*very good*) (*climate change status*). Overall, fishers' level of concern with climate change can be categorized as moderate to high, averaging 6.67 (sd = 2.50) on a 10-point *concern over climate change* scale (1 = not worried and 10 = very worried). Just under half (46.0%) of fishers said they have observed changes to the fish, shellfish, and/or local marine

Table 2.3 Factors potentially affecting fishery and percent of fishers who responded affirmatively

Factors	%
Pollution	92.9
Coral bleaching	84.4
Increase in water temperature	59.7
Overfishing	36.8
Increase in frequency and intensity of storms	34.4
Increase in seaweed/algal blooms	32.9
Sea level rise	31.9
Change in behavior of marine animals	30.0
Increase in air temperature	21.8
Increase in droughts	17.5

environment that they believe to be related to climate change. The most common changes observed were resource stock decline (34.1%^{R}), habitat shifts (14.6%^{R}) which include perceptions of species moving into deeper waters or to areas farther away from the coast, change in composition of fish species (11.4%^{R}), and changes in water temperature (6.5%^{R}). Fishers were also asked about whether or not they believe a series of different factors associated with anthropogenic impacts and climate change to be a threat to fisheries. The factors with the highest frequency of affirmative responses were pollution (92.9%), coral bleaching (84.4%), and increase in sea temperature (59.7%) (Table 2.3). The sum of dichotomous responses, no = 0 and yes = 1, to the 10 factors included in Table 2.3 was used to create a scale of perceptions on *anthropogenic impacts* ranging from zero to 10.

2.3.4 Factors Influencing Perceptions of Climate Change

The variables and analyses used in this study deal with a number of important factors that can influence perceptions of the potential negative impacts of climate change on the marine environment and the fishers. We would like to suggest a simple model that is proposed to reflect the interrelationships between these factors to provide an understanding that will facilitate developing targeted policies and educational programs to aid in helping fishers and other coastal dwellers cope with and become more resilient to the impacts of climate change. In general it is proposed that age, education, and exposure (here exposure is assumed to increase through the act of fishing) have an influence on perceptions of the environment, including *current status of fishery resources* and the different ways human behaviors can influence the resource (*anthropogenic impacts*) and the status of the fishery. All this is expected to influence beliefs about the impacts of human behavior on the coastal environment (*total environmental ethic*). Years of formal *education* will also have an independent effect on items forming the *total environmental ethic* scale. It is proposed that these resource beliefs (*anthropogenic impacts* and *total environmental ethic*), along with *education,* will influence perceptions of ongoing climate change and its impact, positive or neg-

ative (*climate change status*), and this will be related to concern about climate change (*concern over climate change*), a concern that could lead to human action to reduce its impacts and increase the resilience of the coastal communities.

As a means of more thoroughly testing the causal relationships suggested by the proposed model (Fig. 2.2), we use path analysis; more specifically we use RAMONA, which is based on a modification of the McArdle and McDonald (1984) reticular action model which can fit a path model to a correlation matrix allowing both endogenous and exogenous latent variables to have unit variance producing estimates of standardized path coefficients (Browne 2009). Dependence paths include path coefficients (nonzero) reflecting degree of influence of the variable emitting the path on the variable at the arrow end of the path; for example, the path coefficient associated with the arrow between *climate change status* and *concern over climate change* is −0.404, and like a standardized regression coefficient, it indicates that a change of 1.0 in the *climate change status* score would result in a decrease of 0.404 in the standardized *concern over climate change* score. The model was tested using the maximum Wishart likelihood method. Goodness of fit was evaluated using the root mean square error of approximation (RMSEA). For our model, RMSEA is equal to 0.047 (90% confidence interval 0.000 to 0.100). According to Browne (2009) an RMSEA less than or equal to 0.05 is a "close fit." All path coefficients are strongly statistically significant (most $p < 0.001$) except for the paths between *current status of fishery resources* and the two variables *fishing experience* ($p = 0.02$) and *total environmental ethic* ($p > 0.05$). The number in parentheses next to the path between *fishing experience* and *current status of the resource* is the zero-order correlation between the two variables ($p < 0.05$). This relationship is important in the analysis, and the path coefficient could be misleading. It is both

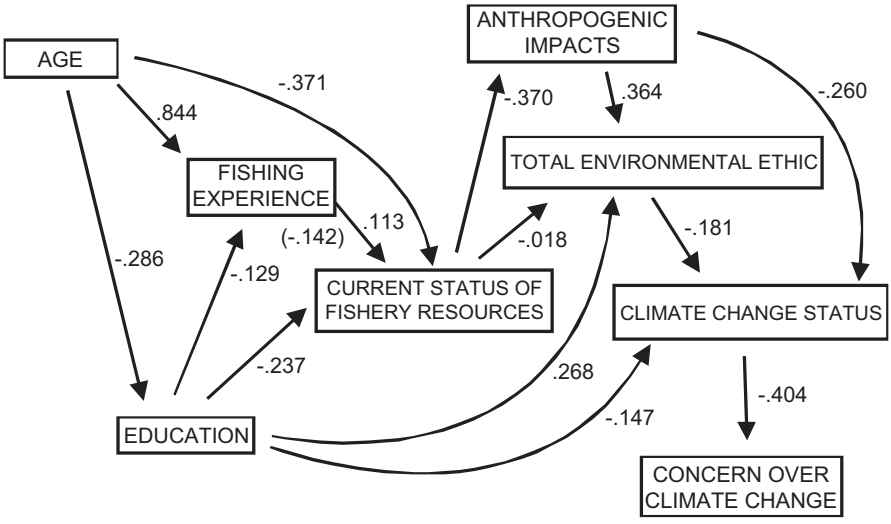

Fig. 2.2 Model of interrelationships between variables tested using the RAMONA path analysis method

weak (90% confidence interval between −0.177 and 0.403) and is the value with all other variables in the model impacting *current state of the resource* controlled.

2.3.5 *Fishers' Adaptations to Change*

Turning to currently reported adaptation to change, fishers who have observed changes to the local marine species and/or environment that they believe to be related to climate change were asked whether or not they have changed any aspect of their fishing activity to adapt to the changes observed. These responses may provide some indication of adaptation to future changes. The majority (62.5%) have changed some aspect of their fishing activity including changing fishing grounds (42.5%^{R}), gear changes (13.8%^{R}), and fishing in deeper waters (11.3%^{R}) and further away from shore (8.8%^{R}) (Table 2.4).

2.4 Discussion

This study examined the perceptions of fishers in Puerto Rico toward changes in the coastal and marine environment and resources, as well as changes specifically related to climate change. Puerto Rican fishers are highly dependent on marine resources for income and subsistence while also presenting strong attachment to the occupation. Therefore, they not only hold important knowledge about environmental change and its impacts, but it becomes crucial to understand how these changes affect natural resource users to inform the development of more effective strategies and policies to address overexploitation and other anthropogenic impacts without disregard for environmental justice and human well-being. The model tested identifies interrelationships between factors associated with perceptions of the seriousness of climate change as well as characteristics of fishers that can be used to target extension activities.

Table 2.4 Adaptation strategies adopted by fishers in response to changes observed in marine resources and environment

Adaptation strategy	%^{R}
Change fishing grounds	42.5
Change/diversify gear	15.0
Fish in deeper water	11.3
Fish farther away from shore	8.8
Change time of day to fish	5.0
Change target species	3.8
Use better equipment/technology	2.5
Increase effort	2.5
Others ($N < 1$)	8.8

2.4.1 Perceptions of Change and Adaptations

Our findings suggest that Puerto Rican fishers present high levels of environmental awareness and, in general, perceive the local marine environment and climate to have undergone significant transformations which they believe have been affecting fisheries in different ways. The climate change impacts fishers have observed and experienced relate mostly to resource population declines in general, as evidenced by mentions of stock decline, habitat shifts, and changes in species composition. Changes in species composition were sometimes mentioned as the result of the introduction of non-native species. For instance, some fishers mentioned the increasingly large population of lionfish (*Pterois*) in Puerto Rico waters: "Now we see different types of fish not common here like the lionfish." Lionfish species, native to the Indo-Pacific region, have in the past couple of decades been introduced by human activity (e.g., intentional or inadvertent release of aquarium species) and spread into different shallow and deep habitats in the Western North Atlantic and the Caribbean (Whitfield et al. 2007; Betancur-R et al. 2011). Although their invasion is not linked directly to changes in climate, lionfish are voracious predators and there is evidence that this behavior is contributing to the rapid degradation of already stressed (e.g., bleached and overfished) coral reef habitats (Albins and Hixon 2013), thus further affecting species composition and consequently fisheries in the Caribbean region.

Besides fishery resource decline and changes in species composition, fishers frequently mentioned increase in seawater temperature as a significant effect of climate change. One fisher explained: "Usually from October to December, the water gets colder and there are more lobsters. Now, the water is warmer and it is affecting the lobsters." Increased water temperature was also one of the major factors in the anthropogenic impact scale fishers believed to be affecting the fishery. They were also highly aware about the impacts of coral bleaching on the fishery, a phenomenon that is related to warmer sea temperatures. It is important to note that our findings show that fishers have a clear understanding of the importance of healthy coral reefs for the local fishery. One of the items with the highest scores in the environmental ethic measure was the idea that if corals die, it will affect the fishery negatively. This awareness of the ecological importance of coral reefs can be included in conservation and restoration strategies in the region in addition to minimizing potentially impactful and destructive fishing practices.

Overall, fishers expressed overwhelming concern over increased pollution affecting the marine environment and the fishery. Responses to the items included in the *environmental ethic* scale demonstrate that fishers are particularly aware of the impacts of solid waste and industrial activity near the coast. Even though fishers overall perceive the local marine resources to be currently in reasonably good shape, many have expressed concern over declines in the population size and health of these resources over the past decade. Fishers most frequently linked the observed declines to pollution, but many attributed declines to overfishing, climate change, and, at a lower degree, regulations and environmental degradation in general. Our

results are in line with previous research conducted in Puerto Rico (Griffth et al. 2007; Matos-Caraballo and Agar 2011; Valdés-Pizzini and Umpierre 2014). Griffth et al. (2007) found that the majority of fishers they interviewed shared the opinion that fishery resources declined through time and the most commonly attributed cause was pollution and to a lesser degree overfishing and fishery regulations. Similarly, in interviews conducted in 2008, Matos-Caraballo and Agar (2011) found that the majority of Puerto Rican fishers believed the island's fishery resources to be worse off at the time of the study, when compared to "other years." Among the most important reasons fishers in that study mentioned as causes for declining fish stocks were overfishing, pollution, habitat degradation, regulations, weather and ocean conditions, and climate change (Matos-Caraballo and Agar 2011). These studies support our findings indicating that fishers in the region have been observing these changes and dealing with their impacts for the past couple of decades.

Changes experienced by fishers have triggered adaptations transforming aspects of their fishing activities. The most frequent adaptation mentioned by fishers relates to changes in fishing grounds, with fishers having to seek other more productive areas. The number of fishers who mentioned specifically having to fish in deeper water and farther away from the shore also indicates that changes in location have been a significant way fishers have adapted to changes. Fishers also mentioned the need to change or diversify gear to increase productivity and target different species. The significant increase in the number of fishers using SCUBA in recent decades in Puerto Rico has been documented by Matos-Caraballo and Agar (2011) as a response to declines in resource abundance. Adaptations that involve traveling farther from the coast and fishing in deeper waters present serious implications for the safety and health of SCUBA diving fishers, particularly the risk of decompression sickness. One study suggests that decompression sickness among artisanal fishers is much higher worldwide than that of recreational or military divers (Huchim-Lara et al. 2015). Research suggests that fishers typically manifest high risk-taking behavior (Poggie et al. 1995, 1996; Pollnac et al. 1998; Davis 2012; Pfeiffer and Gratz 2016; Huchim-Lara et al. 2016). Pollnac and Poggie (2008) attribute reduced perceptions of risk among fishers to a personality type that can be characterized as being active, adventurous, aggressive, and courageous. Our findings show that Puerto Rican fishers present high levels of satisfaction with aspects of independence, adventure, and challenges associated with their job. These factors are likely to result in increased exposure of fishers to potentially dangerous situations, which combined with the need to travel farther and dive into deeper waters, increase the likelihood of decompression sickness. Moreover, SCUBA diving fishers do not receive formal training and Puerto Rico coastal communities have limited or no availability of resources and infrastructure for proper treatment. It is also important to note that in this study, aspects of the job relating to safety, healthfulness, and fatigue were among the ones with which fishers expressed the lowest satisfaction levels, possibly reflecting concern over these increased risks associated with newly adopted adaptation strategies.

Many of the questions about impacts of climate change on the marine environment and resources were met with answers that referred to declines in resource abundance. Similarly, responses referring to adaptations (seeking new fishing

grounds, traveling farther from shore, and fishing in deeper waters) allude to resource decline and scarcity, particularly in nearshore areas. Marine resources are heavily impacted by changes in climate, as well as pollution, and the changes fishers are experiencing are likely in part due to these factors. Research conducted on the causes of reef-estuarine ecosystems degradation indicates that other factors along with overfishing can significantly contribute to fish mortality (Mora 2008; Mumby et al. 2004; Nellemann et al. 2008). However, these observations also evidence the occurrence of overfishing in Puerto Rico's marine ecosystems. The relatively high percentage of fishers who stated overfishing to be affecting the fisheries when asked directly about different anthropogenic impacts supports the idea that many fishers are particularly concerned about the effects of overexploitation. However, it is difficult to differentiate fishers' perceptions of the different causes of the changes observed, that is, climate change impacts versus overfishing. This may be due to limitations of the data collection methods or because fishers themselves are not able to clearly discern between these different experiences and perceptions.

2.4.2 Factors Influencing Fishers' Perceptions

The model tested in this study (Fig. 2.2) shows that higher levels of education, older age, and more fishing experience among fishers lead to more negative perceptions of the current state of the fishery resources. Those with more negative perceptions of the state of the resources scored higher on the anthropogenic impact scale, which means they tended to perceive more items in the scale as affecting the fisheries (see Table 2.3 for the complete list of items). Higher scores on the anthropogenic impact scale are associated with higher levels of environmental ethic, which, in turn, leads to more negative perceptions of climate change status, that is, those with higher levels of environmental ethic tend to perceive climatic changes to be more negative than positive. Negative perception of climate change is strongly correlated with expressing more concern about climate change in general. The model also indicates that higher levels of education lead to higher scores on the environmental ethic scale, and both higher education and environmental ethic levels result in more negative perceptions of climate change. The relationships tested in the model emphasize the importance of education as a factor leading to higher environmental and climate change awareness. It is also important to note that, although not strong, a statistically significant zero-order correlation exists between fishing experience and more negative perceptions of the current state of fishery resources. In this sample, more experienced fishers present lower levels of education; thus, the relationship between fishing experience and perceptions of status of fishing resources indicates that perceptions are also shaped by fishers' gained knowledge through experience and involvement, that is, local environmental knowledge (LEK). This is particularly relevant given the fact that the model indicates that fishers' awareness of degradation of local marine resources is an important factor leading to awareness of anthropogenic impacts and ultimately concern about climate change.

Negative perceptions of the status of fishery resources and climate change as well as concern about climate change can be important drivers of changes in behavior that could lead to increased support for conservation strategies as well as climate change mitigation and adaptation plans. Understanding factors influencing fishers' perceptions and experiences will aid in the development of policy strategies and educational programs that focus on factors that are appropriate within the context of fishing communities. For instance, in Puerto Rico, programs to address fishery sustainability may benefit from incorporating aspects of pollution and climate change impacts, such as coral bleaching, in addition to overfishing, to increase the likelihood for acceptance of and compliance with fishery management strategies. Our findings also further highlight the importance of education and the value of LEK in shaping fishers' perceptions of environmental and climate change. This supports the idea that policy strategies that emphasize education and adequately incorporate LEK may lead to more successful long-term outcomes of sustainability and climate change adaptation in fishing communities.

2.5 Conclusion

Frameworks to conceptualize vulnerability and adaptive capacity to environmental and climate change often fail to incorporate aspects of subjective perceptions of those impacted and undergoing adaptation processes. Subjective perceptions are important drivers of behavior and are crucial in determining success of adaptation strategies as people are likely to act on the basis of their perceptions, beliefs, and cultural context, particularly under stressful situations. Understanding factors affecting perceptions of environmental and climate change in fishing communities will aid in the development of strategies for sustainability and adaptive capacity of vulnerable fishing communities. Fishers are highly dependent on natural resources, greatly attached to their occupation, and typically reside in areas of high exposure to natural hazards and climate change. In this study, we examined the perceptions of Puerto Rican fishers to changes in the marine environment and climate. Our findings show that fishers perceive the local environment and climate to have undergone significant changes in the past couple of decades and they believe these changes have been affecting the fishery and consequentially leading them to adapt. Changes and adaptations mentioned by fishers support research that shows that the Puerto Rico marine environment and fisheries are at risk from pollution, climate change, and overfishing. Fishers' adaptations to these impacts, which consist mostly of seeking new fishing grounds, have also led them to increase their exposure to risks, particularly among SCUBA divers fishing in deeper waters and farther away from the coast, thus presenting implications for their safety and health.

Our findings show that having more negative perceptions of the status of fishery resources is related to higher levels of environmental awareness and awareness of anthropogenic impacts which in turn lead to increased concern about climate change. Education as well as age and fishing experience, an indicator of LEK, were

both important factors influencing fishers' perceptions of the status of fishery resources. These findings have significant implications for the development of policy and educational strategies aimed at increasing sustainability and well-being in fishing communities. Strategies that take into account fishers' perceptions and factors influencing these perceptions are not only more context appropriate but are more likely to be met with higher acceptance and compliance levels, thus resulting in more effective and just outcomes.

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