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Local Ecological Knowledge of Fishermen in Rhode Island and the Dominican Republic: State of Their Fisheries, Changes and Adaptations

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LOCAL ECOLOGICAL KNOWLEDGE OF FISHERMEN IN RHODE ISLAND AND THE DOMINICAN REPUBLIC: STATE OF THEIR FISHERIES, CHANGES AND ADAPTATIONS

BY

ELIZABETH LAYLI MCLEAN

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
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DOCTOR OF PHILOSOPHY DISSERTATION

OF

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UNIVERSITY OF RHODE ISLAND

2016

Abstract

The failure to sustain fisheries is attributed to simultaneous effects of overfishing and to natural disturbance on fish habitats. Many conservation and management efforts are not successful in sustaining the fisheries. There is a growing need to broaden our understanding of people's knowledge and their fisheries and to consider new approaches that will lead to effective conservation that enables us to sustain fisheries and protect the environment. This study examines the use of fishers' local ecological knowledge (FEK) to characterize fishing communities and their practices, to assess the state of the fisheries, and the usefulness of this knowledge for conservation management. I studied the local ecological knowledge of lobster fishers for one of the main ports in Rhode Island (RI), and for fishers across 10 communities in the North East coast of the Dominican Republic (DR), using *Grounded theory*, *Cultural Consensus Analysis*, and standard statistical methods.

For the RI study, the FEK was collected through a series of meetings. After the FEK was collected and compiled, it was matched to the corresponding science-based data – when available – in order to analyze overlap and differences that exists between the two forms of knowledge. Furthermore, I looked at the lobster fishers' arguments that describe their ecosystem view of the fisheries, and their arguments over management implications that affect them in their fisheries. Although in general, the lobster fishers' FEK corresponded with the best available SEK, the few exceptions regarding reproduction and habitat preference for reproduction could lead the way for collaborations and further study. Scientists and managers could benefit from the ecosystem view that lobster fishers have, one that integrates historical timeframes and the complexities of systems that interact together. Furthermore, collaboration is needed to address differences that hamper management collaborations: from not being included in science and monitoring processes, and also from disagreements regarding standard

monitoring practices used to survey areas that the fishers do not consider to be lobster's habitat.

For the study in the DR, surveys were conducted during two field trips, the survey instruments were designed to compile the ecological knowledge fishers have on the fish that they catch, and perceptions on their fisheries. The assessment of the content of the FEK was completed using a qualitative-quantitative methodological sequence. Furthermore, the methods for coding descriptive responses were also evaluated. The results revealed a shared cultural model of ecological knowledge for four of the eight commonly fished species. The cultural consensus analysis index of fisher's individual knowledge (competence score) was found to be unrelated to the fishers' perceptions on the state of their fisheries and how they are managed. These results underline the need to better explain the fundamental basis of fishers' perceptions.

The usefulness of fishers' local ecological knowledge on the size-at-maturity relative to the size-at-capture, and the maximum body size were tested as an indicator for overfishing. The comparison of the estimates on the size at capture and size-at-maturity tested whether the fishers perceived themselves to be catching adults or juveniles; comparisons between the FEK and the science based knowledge (SEK) served to assess whether the fishers and the scientists agreed on the composition of the catch. Lastly, comparisons on the maximum body size harvested (FEK) relative to the known maximum size known to scientists (SEK) served to assess whether the largest fish had declined.

The perceived composition of the catch differed between scientists and fishers. Fishers perceiving their catch to be generally comprised of juvenile and adults, when in fact, the scientists would describe them as catching mostly adults. No correlation was found between fishers' perceptions on the state of the fishery, nor the changes in the fisheries, and the fish size estimates they gave. The majority of the fishers categorized the state of their fisheries as bad and agreed that their fisheries had changed, and that the changes had been for the worst.

These results suggest that the potential for overfishing can be estimated from these comparisons, but the use of FEK in the absence SEK is not recommended for fish size estimate values. The FEK that fisher's posses, in both RI and the DR, attest to the changes in the state of the fisheries indicative of a serious decline, met with adaptations or regulations that either extend the unsustainable fisheries or limits fisher's ability to sustain their livelihoods.

Acknowledgements

This work is about knowledge and relationships; in pursuing this work, my own knowledge and relationships have deepened. Today, I bow in recognition of all the unique individuals & friends who supported me, motivated me, guided me, and inspired me! You are “solid shoulders”, “rustling winds” and “gentle waters”, you have ushered me forward and on ward, and I am deeply grateful!

This study would have not been possible without the kind generosity of the fishermen in the Samaná region (Dom. Rep.) nor without the generosity of the lobstermen in Southern New England, who participated and shared the depth of their knowledge with me. For them fishing, more than a livelihood, is a way of living.

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for including me early on in the local endeavors with the RI lobstermen and passing on the "bug" of FEK to me. I thank the members of my advisory committee for guiding me in formulating my research questions, for their interest, support and guidance that helped me develop as a professional; for their feedback and input that has improved the quality of this work. I thank Tracey Dalton, for sharing with me her expertise on MPA management; Ilan Kelman, for opening an entire network of Island studies before me, for his diligence and leadership; Art Gold for being a great listener; and Judith Swift for guiding me in the process of local inquiry. You are all a source of inspiration to me! I look forward to following your work in the years to come.

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Dedication

For those who are not free to learn

Preface

This dissertation has been written in manuscript form with a general introduction providing a general overview of the topics covered in my work. The three chapters are written as a separate manuscript and will be submitted for publication separately to different science journals; these are, therefore, formatted as required for each journal submission.

Manuscript 1 is formatted for *Journal of Environmental Management*

Manuscript 2 is formatted for *Human Ecology*

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MANUSCRIPT 1

Lobstermen's local ecological knowledge: Expanding the base of the science knowledge that informs management in South NE lobster fisheries

by

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I. Lobstermen’s local ecological knowledge: Expanding the base of the science knowledge that informs management in South NE lobster fisheries

Abstract

Lobster fishermen in Southern New England (SNE) come from a longstanding tradition of fishing. Their local ecological knowledge (LEK) on the American lobster, *Homarus americanus*, can be an important source of information for management, yet it is, in our opinion, underutilized in regional fisheries management. We recorded LEK and open discussions between stakeholders during three meetings where lobster fishermen, also known as lobstermen, participated with managers and scientists. The recorded information was transcribed and systematically organized by topic. LEK was matched to the corresponding science-based ecology knowledge (SEK) through a careful literature review. We explored lobstermen’s LEK and their ecosystems view, considering their opinions on an adaptive fisheries management in the context of historical trends. Generally, lobstermen’s LEK corresponded with the best available SEK with a few exceptions on reproduction and habitat preference. We found that lobstermen’s LEK is compatible with an ecosystem view of the fishery that integrates the complexities of interacting systems. Fishers view their fishing grounds as “managed landscapes”, areas that are being used productively, maintained and protected by them. Our findings are a starting point to broaden the base of knowledge that is used in fisheries management. Topics of LEK and SEK convergence are promising common ground, while topics where lobster fishers and managers views differ should be addressed to enable cooperative management. Both can be a basis for cooperative hypothesis testing.

Key words: Lobster fishers, local ecological knowledge, qualitative methods, ecosystem view

1. Introduction

The commercial lobster fishery in the United States dates back to the early 1800s. At that time the lobsters were so abundant that fishers could collect them by hand along the shoreline in the North East Atlantic – New England region (Visel 2012). However, the history of the lobster fisheries is also marked by stock declines. One historical collapse of the lobster fishery in Rhode Island is documented from 1886-9, followed by a rise in harvests from 500,000 lbs to capturing 1.5 Million lbs in 1924 (Visel 2012). In 2002, Cochrane (2002) argued that the decrease in the lobster stocks was threatening the capacity and quality of life of many fishers. In Rhode Island, this threat grows, and the lobster fishermen are suffering the consequences of a long-term decline in the lobster fisheries.

Studies on lobsters and stock assessment are important for sustaining the fisheries. One key aspect in lobster fisheries is the survival of the young of the year (Incze et al. 2000); monitoring efforts on these are important to be able to predict the future stocks. At this stage, lobsters are vulnerable to multiple factors. For instance, changes in lobster young of year abundances on the Gulf of Maine are attributed to changes in the environment's physical factors (Hovel and Wahle 2010): currents and summer winds that entrained larval stages to the north (Incze et al. 2000) and to oxygen depletion (Miller et al. 2002). When the early stages of the lobsters are greatly impacted, their stocks decline. In order to maximize the survival of the American lobsters, hatcheries were developed as early as 1800s (Aiken and Waddy 1986). Other survival measures include closures and changes in the regulations.

In 1905 a closure of the lobster fisheries followed closely after the historical "Great heat" and the heavy rains of 1898 in Providence, RI, when "thousands of tons of organic matter: manure, leaf and forest litter and human sewage were dumped into the upper Narragansett Bay"- documented by Professor Mead at Brown University (as cited by Visel 2012). Unfortunately, it can take a long time for lobster populations to recover after the magnitude of impacts caused by the “Great heat” of 1880-1920 (Visel 2012). Additional, declines in lobster populations have been correlated to local oil spill events (Atema and Stein 1970, Wells and Sprague 1976, French McCay 2003) and to changes in the water temperature (Wahle et al. 2015).

Over the last decades, the effects of water temperature on lobster distributions and health have raised widespread concerns regarding the impact of climate change on US lobster fisheries (Caputi et al. 2013, Wahle et al. 2015). The effect of water column temperature is a driving force that restricts lobster’s life stages to suitable habitat (Watson and Jury 2013, Goldstein and Watson 2015); this also influences patterns of winds, sedimentation, and the removal of key lobster substrates such as kelp and cobblestone (Wahle and Steneck 1991, Visel 2012).

The presence of key vegetation is key to the growth of different lobster stages. As an example, during the “Great Heat”– lobster recruitment levels fell sharply due to the decline of kelp and the spread of eel grass to deeper waters. With the growth of eel grass (1905) and changes in the tidal exchange, the lobster fishery collapsed and blue crab populations increased in SNE (Visel 2012). In the SE Pacific, similar environmental factors have affected the key substrates for young lobsters accelerating the decline of the fisheries (Linnane et al. 2010). Assessment of suitable available habitat is important for understanding the dynamics of lobster populations. Successful management requires the integration of numerous complexities of a system that responds to multiple factors at the same time; expanding our approach to integrate fishers’ local ecological knowledge can increase both the spatial and temporal scales used to understand these systems.

1.1.Local ecological knowledge and fishery histories

The knowledge that people, especially experts like fishers, have about their local environments, can be of great value. LEK is increasingly recognized by ecosystem-based management approaches as a desirable part of the toolkit (Berkes and Folke 2000, Olsson and Folke 2001, Maclauchlin 2006, Beaudreau and Levin 2014). LEK alone can help fill in major gaps in understanding rapidly changing ecosystems and conditions that scientific surveys do not capture well.

Lobstermen accrue the local ecological knowledge that they possess over years of observations, and generational learning (Murray et al. 2006). They not only learn from what they see and experience in the present, but from the recollections from their fathers and forefathers; many lobstermen today are third and fourth generation fishermen.

History is important to assess current impacts and their consequences. In reference to human impacts on the planet, Visel wrote that the “fishery history is one of the few instruments that can provide [a] reflection” by looking at historical landings. He argues that multiple factors are affecting the lobsters, and that climatic cycles have also occurred in the past. Furthermore, he finds that “capacity for understanding our long term ecological impacts from natural cycles are far too short” (Visel 2012). In 2009, the ASMFC expressed that “data with sufficient spatial and temporal resolution” was needed “to be able to track trends in the fishery and the stock”, so as to establish” effective fisheries management” (ASMFC 2009). From this point of view, fishers’ LEK can be valuable for reconstructing the past–long–term fishery histories. Along these lines, Ames (2004) collected and analyzed retired cod fishermen’s knowledge to reconstruct historical data on cod fishing and spawning grounds back to the 1920’s (Ames 2004). Ames argued that it “is difficult to sustain healthy populations when the movement, distribution and behavior of populations were unknown”. To circumvent the missing data, he used a systematic approach to validate the historical patterns described by the fishermen, and found consistency with their described patterns on spawning behavior of the cod and was able to verify recorded historical trends with the present day data. The LEK data served to support how the process leading to the decline of cod populations had started as early as the 1880s (Ames 2004), explaining for present day population and for the records described in the literature. In the Gulf of Maine fishers' knowledge has been useful to explain the increase in the lobster populations due to the release of predator pressure (Boudreau and Worm 2010), meaning that the populations of fish that preyed upon lobsters had decreased, and therefore, influenced the increase in their abundance. Local fishers are good living records of these histories, and have knowledge of events and changes that affect them and their fisheries.

1.2.Scientific management of lobsters

Regular lobster stock assessments serve to inform management, providing the scientific knowledge needed to support the regulatory measures. Scientific knowledge founded and tested within the empirical domains of biology and ecology, has served over decades to inform fisheries management. For example, multiple researchers have explored the biology, ecology, and the behavioral responses of the American lobster, *Homarus americanus* (Herrick 1895, 1909, Hughes and Matthiessed 1951, Cobb 1971, Campbell and Stasko 1986, Wahle and Steneck 1991). Others have investigated the physical and biological gradients that explain its distribution (Cobb et al. 1983, Ferrero et al. 2002, Wahle et al. 2015).

Research based on bottom trawl surveys, vent-less trap and settlement surveys, together with commercial landing records, are used to create estimates of lobster stock abundance that are used by both federal and state agencies. Fishermen sometimes cooperate in these research surveys; sometimes their LEK is used to enhance the survey design (Wahle et al. 2015). Other times the data that are collected across sites and regions are moderately different making it difficult to compare them directly (ASMFC 2015).

In the lobstering trade, record keeping of lobster landings in logbooks is customary. The use of a developed system of tags and markings on the lobster's carapace allows fishers to monitor the movement of the lobsters from inside the bay to the outer coasts. Through this system and other long-term logbooks and observations, lobstermen gain a sense for what the lobsters are doing, and how they are responding throughout the seasons and other changes.

Just five years ago, tension grew when science studies on the state of the lobster fisheries in the near shore of Rhode Island pointed to an imminent moratorium (Lovewell, 2011). Fishers questioned the appropriateness of stock assessment practices, and claimed that the views and knowledge of the lobstermen were not considered. While conducting surveys of fishers' attitudes and concerns, fishery researchers in Rhode Island found that lobstermen are less likely to accept management measures if these differ significantly from their observations and knowledge of the fishery (unpub. 2011). On the other hand, fisheries managers have likened the participation of fishers in the surveys to "foxes guarding the henhouses"(Wilson and McCay 1998).

For a long time, culturally and politically the "local" environmental concerns regarding changes were generally eclipsed by the dominant western scientific knowledge (Forsythe 2013). Recently, information originating from LEK is emerging as a powerful tool for natural resources sustainability (Wilson 2003, Pilgrim 2006, Gerhardinger et al. 2009a). Some studies have looked at the congruency between LEK and science based ecological data (SEK) (Pitcher 2005), and emphasized how the cultural context of LEK broadens the ecosystem view that the fishers have regarding their fisheries (Shackeroff and Campbell 2007). LEK, when used correctly, is valuable for attaining greater appreciation of the higher degrees of trust among stakeholders (Wilson 2003, Grant and Miller 2004). The challenge still remains on how to best collect LEK and use it.

In this paper, we focus on a systematic qualitative analysis of the recorded LEK. We looked at lobstermen's LEK next to the corresponding science-based lobster ecology data from the literature. This paper is organized as follows: First, we elaborate on the methods, the theoretical framework, how the data were collected, organized and categorized. Second, we elaborate on the LEK parallel to science-based data and we analyze the overlap and differences that exist between the two forms of knowledge. Third, we draw upon lobstermen's arguments and views to present an ecosystem view of how they regard their fisheries. Finally, we present some implications of our data for lobster management in Rhode Island. At this critical time, with declining lobster stocks and the threat of a moratorium (in 2011), integrating the two types of knowledge and understanding is important for the rebuilding and management of SNE lobster fisheries.

2. Methods

2.1. Study Site

Rhode Island sustains a long standing lobster trap fishing tradition along with other commercial fishing ventures harvesting finfish, crabs, horseshoe crabs, and shellfish. Of these, the lobster fishery used to represent the most valuable species attracting many people into the fishery. A total of 17 town-ports serve as lobster landing sites in Rhode Island. SNE corresponds to area two of the six delimited fishing zones for fisheries management; it comprises both near and outer shores fishing grounds in the North Atlantic. Below is the Atlantic States Marine Fisheries Commission (ASMFC) framework, for the management of the American lobster resource and fishery; these are managed by the states and the National Marine Fisheries Service, as written in the amendment 3 to the Interstate Fishery Management Plan (FMP) – Addenda I – XXIII:

> *"The goal of the American lobster management plan is to increase egg production. Amendment 3 establishes seven lobster conservation management areas (LCMAs): Inshore and offshore GOM (Area 1), Inshore SNE (Area 2), Offshore Waters (Area 3), Inshore and Offshore Northern Mid-Atlantic (Area 4), Inshore and offshore Southern Mid-Atlantic (Area 5), New*

> *York and Connecticut State Waters (Area 6), and Outer Cape Cod (Area 7). Lobster Conservation Management Teams (LCMTs), composed of industry representatives were formed for each management area. The LCMTs are charged with advising the American Lobster Board and recommending changes to the management plan within their areas. The commercial fishery is primarily controlled through minimum/maximum size limits, trap limits, and v-notching of egg-bearing females* (R.I.D.E.M. 2012).

There is great concern over the gradual decline of the SNE lobster population since the 1990s. This decline affects the capacity and the quality of life of many people (Cochrane 2002). We can observe a reduction in the number of lobstermen by contrasting 1998, when 1,600 commercial lobster licenses were distributed and 2013, when only 874 were distributed. This signals that the lobstermen in Rhode Island are quitting the trade. Most recent changes require for the reduction of Lobster trap allocation by 25% in LCMA 2 (Fig.1). Lobster fishers' in LCMA-Area 2 abide by the management regulations set by the Interstate Fishery Management Plan (FMP). Commercial fishery is mainly controlled by size limits (minimum & maximum), v-notching of egg bearing female and trap limits. Changes in the status of stock assessments found by peer review findings are assessed by working groups of Board and Technical Committee members who develop further considerations for the Board. The American Lobster Board monitors stocks and approves addenda, aligning both state and federal measures, in order to address needed reductions (on exploitation), to rebuild the fisheries, by proposing reductions and the closing of areas to fishing. Presently, federal lobster licenses are assigned to vessels, not to individuals (Atlantic States Marine Fisheries Commission) (ASMFC 2015). However, the state of RI licenses individuals, not vessels. The license restricts the vessel or the person to a certain area of fishing.

> *Each owner of a fishing vessel that fishes with traps capable of catching lobster must declare to National Marine Fisheries Services (NMFS) in his/her annual application*

> *for permit renewal which management areas, as described in regulation no.697.18, the vessel will fish in for lobster with trap gear during that fishing season. The ability to declare into Lobster Conservation Management Areas 1, 2, 3, 4, 5, and/or the Outer Cape Management Area, is first contingent upon a one-time initial qualification. The Area 3, 4, and 5 qualification programs are concluded and the Area 1, 2, and Outer Cape Area qualification programs are set forth in paragraphs (a)(7)(vi) through (a)(7)(viii) of this section. (iii) A lobster management area designation certificate or limited access American lobster permit shall specify in which lobster management area or areas the vessel may fish. (iv) Once a vessel has been issued a lobster management area designation certificate or limited access American lobster permit specifying the lobster EEZ management areas in which the vessel may fish, no changes to the EEZ management areas specified may be made for such vessel for the remainder of the fishing year* (DoC 2014).

Historically, lobstermen used to place up to 2,000 lobster traps, while today the maximum numbers of traps allowed are 800 in SNE (Federal Regulations, as cited by NOAA fisheries). The fishermen explained that the limits of the licenses (by boat, by site) and trap limitations (full gear level 800 pot limit) have made it less lucrative because they lack flexibility to adapt. Their constraint is heightened by the increasing cost of fuel; even the traditional practices of having deckhands on board are not as prevalent as before given the limitations in income opportunities. In the recent past, deckhands were allowed to keep by-catch, which served as an incentive.

In the summer of 2010 the American Lobster Management Board voted against a five year lobster fishing moratorium that had been proposed in 2009 (Plante 2010). This provided a temporary relief to the inshore SNE fishers. However, the newest stock assessment conducted in 2015 showed further decline of the lobster resources in Area 2. Therefore, new trap reductions and other biological measures have been introduced. The difficulty in implementing heavier regulations at this time is that, besides fishing pressure, the lobster fishery is also affected by environmental factors of unknown magnitude (Wahle et al. 2015). The last years has also seen an increase in the occurrence of diseases that affect the stocks recruitment in SNE (Castro and Factor 2006). Thus the collaboration and communication among all stakeholders is timely and important. The proposed theoretical framework promotes the integration of lobstermen's LEK and their ecosystem view with the science based knowledge in order to widen the base of knowledge needed for an ecosystem base management.

2.2. Group meetings – data collection

Different approaches can be used to collect LEK, including participant observation, one-on-one interviews or surveys or group discussions like focus groups. Indifferent of the approach, it is important to take into account some general considerations: (1) the survey instrument objectives must be defined, (2) the individuals attending need to volunteer their time, (3) their privacy must be respected, and (4) the meeting place needs to be accessible to all (Cochrane 2002).

In the fall of 2010, a research team began a process of consultation on the objectives of the project and outlined the LEK survey questions. This pilot project was funded by the RI Sea Grant National Fisheries extension with the aim of expanding the base of the knowledge that informs management. Focus group meetings with the stakeholders served to collect lobstermen's LEK. From this initial project, an extended study program is projected to survey fishers in the Southern New England area.

The lobstermen were invited in advance. They were informed of the goals for collaboration and where the meetings would take place. The Commercial Fisheries Center of

Rhode Island in Kingston was chosen for the meetings. From February to April 2011 the group meetings took place monthly: (1) February 17, (2) March 16 and (3) April 20. Each meeting took approximately three hours. Those attending the meetings were lobstermen (5-6), scientists/university professors (6), students (4-5) from the University of Rhode Island and a representative from the department of environmental sciences (DEM). The scientists' background comprised: fisheries, anthropology and biological sciences.

During each meeting, discussions were held on the local ecological knowledge of the American clawed lobster, *Homarus americanus*, with the lobstermen. One of the scientists would lead the discussion following the interview questions (Table 1). Initially, the questions were broad, narrowing in to the more specific data. Examples of questions are: What is the state of the lobster populations in the areas where Rhode Island fishermen fish? How do you think about an ecosystem? What do you think are the parts of the ecosystem you work in? The informal face to face approach allowed for an open discussion. The lobstermen were third and fourth generation fishers who fish from two of the main ports in Rhode Island: Newport and Galilee. They were encouraged to contribute their knowledge, views and opinions. The lobstermen's responses can be categorized as: new knowledge or validation of a previous statement. At times other participants present would seek further clarification on a question. The advantage of focused group surveys is that the information generated is instantly peer validated by other fishers being in agreement with the responses (Mackinson 2001).

The meeting's discussions were documented using an *MP3* recorder. Following the guidelines of the Institutional Review Board for human studies, participant's permission was requested for the recording. The participants were informed of the anonymity of the surveys and were given a copy of the informed consent form (Appendix B). The recordings were then transcribed and revised. Additional notes and observations were also recorded by the students.

The responses were coded and organized into categories for compiling fishers' LEK (Table 2). The different categories were assessed through a process of iterations. The interconnectedness between categories was considered, and the LEK was organized in function of the questions these responded to. After the LEK was organized, the corresponding SEK was recorded from the science literature by a lobster fisheries scientist. In order to evaluate the congruency between LEK and SEK, we looked at both sets of information next to each other when this was available (Table 2).

We recognize that fishermen's LEK and their perceptions on the changes in the lobstering are interconnected. The interconnectedness serves to represent the fisher's responses within an ecosystem view illustrated herein (Figure 2) (Appendix C & D). In order to evaluate whether we are meeting the fisheries management objectives on the sustainability of practices and culture, we present the lobstermen's LEK related to the management of their fisheries (Table 3).

3 Results & Discussion

3.1. LEK parallels to science-based ecological knowledge (SEK)

The presence of congruency across LEK and SEK is supported by a wealth of knowledge that the lobstermen have of their fishery, as well as their experiences (Davis and Wagner 2003). This knowledge comprises general observations as well as – what could be considered – generational knowledge that is transferred from one generation of lobstermen to the next. The key informants' knowledge in this case study expanded – at times – to the knowledge and reference of scientific studies on the lobsters in this area (Table 2).

The lobstermen relayed information on the population diversity, indicating that the lobsters they harvested were genetically diverse. They inferred the diversity from morphological differences observed on the length and width of the carapace; they noted that these differences would ultimately influence the effectiveness of the traps. For the NE Atlantic region, lobster genetic diversity has been covered in the literature (Botero and Atema 1982, Harding et al. 1997, Rycroft et al. 2012). There was general agreement between LEK & SEK on lobster's habitat preference being driven by substrate type. Younger lobsters initially prefer gravel substrates and gradually transition to rock covered, benthic macro-algae areas, and mix substrates with rock and sand, or mud and sand (Botero and Atema 1982, Pottle and Elner 1982, Wahle and Steneck 1991, Nelson et al. 2006). Next to habitat preference, scientists and lobstermen agreed that lobsters year classes are subjected to stochastic, environmental (Harding et al. 1983, Miller et al. 2002, Watson and Jury 2013, Wahle et al. 2015) and human induced pressures that vary from year to year. Lobstermen noted that similar to crayfish, larger lobsters exhibited an escape response to harsh weather, by retreating to deeper water, while smaller lobsters preferred the shallows but sometimes left, entering into a prey-predator battle. This is also documented in the literature (Jury et al. 1995), explained as an occasional response to the warming of the waters (Wahle et al. 2015), or a change in their sheltering behavior when in the presence of predators (Cobb 1971, Barshaw and Spanier 1994, Wilkinson et al. 2015).

Given the importance of impacts on the lobster population, great effort is made to monitor habitat, environment and human driven impacts. Understanding how lobsters, more specifically juvenile (or early year classes) respond to different conditions, helps to forecast lobster population response years in advance (Watson and Jury 2013). In the ecosystems view section that follows, we will also expand on the influence predators have on lobster population densities.

3.2. Lobstermen's integrated ecosystem view of the fisheries

The participating lobstermen described their fishing grounds as 'managed landscapes' which they productively maintained over the years. Their practices and timing, as well as the layout of their traps contribute to this landscape. The traps become shelter and habitat in areas where normally the lobster would have limited burrows. Several lobstermen reported that they regarded their fishing with baited traps as being an intermediate activity between capture-fishing and aquaculture or a place where fish farming occurs. In this regard, concrete evidence was found on the effect of baited traps on inner-shore fisheries in Maine, supporting that consumption of fish from the traps could be feeding (food availability) for a quarter, to a third of the lobster catch (Saila et al. 2002).

In simple terms, the lobster traps become habitat that protect the lobsters from their predators and even protects the female eggers entering the traps, because these are later released by the lobstermen. This resonates with science-based research that has documented that the inshore grounds serve as nurseries; as lobsters grow, they will migrate out of the bay, and shelter becomes limiting (Cobb 1971, 1977). Scientists emphasize that migration in mature lobsters maximizes their needs for molting and gonadal development (Campbell and Stasko 1986, Goldstein and Watson 2015). Hence, larger lobsters are generally found in deep-water.

3.2.1. Making connections: What does the pot say?

In traditional fisheries, lobster pots tell a story, they illustrate what happens with abundance, predation, lobster quality and diseases in a fishing area. The lobstermen in our study explained that some of the changes in the abundances and distributions are due to cyclical fluctuations (seasonal, lunar). Low lobster densities was observed in the past (1990s) and recorded in the University of Rhode Island (URI) trawling surveys. At that time, lower egg densities were also recorded, meaning that the female lobster tails had fewer eggs, explaining for reduced reproductive output. Because for the lobstermen the fishing abundances are cyclical; they related post-larval densities to the known historical record of 2006-2007 relative to densities of 1976, 77, 78 for Buzzards Bay.

In an ecosystem view many factors can influence the overall state and abundances of the lobsters. Temperature increases are seen to have contributed to habitat failure at different time periods. Fishers recognize that lobsters have optimal temperature ranges (12-18°C), lobsters being known as “cold water species” (Visel 2012). However, other factors like disease, pollution and predation are also important, and shell disease is a true concern. Lobster fishermen believe that effects of pollution on stocks are unfairly attributed to overfishing; that the real causes of mortality affecting different stage lobsters need to be addressed (Fig.3). Historically, this has happened before, lobstermen were blamed for the “ruin” in the fisheries” of 1898, but eventually fishery managers caught on. As an example, the 8,000 gallon oil-spill of 1996 near Moonstone Beach in South Kingstown, lobstermen reported to have witnessed massive mortality of lobsters and other bay life (French McCay 2003). An interesting observation by some lobstermen, based on years of observations on lobster behavior, is that lobsters seem to be attracted to oil based/kerosene products that can affect them. Scientists have confirmed this behavior (Atema et al. 1982).

3.2.2. Shell disease

There is a difference of opinion on what causes the lobster shell-disease. Lobstermen indicated that the shell disease is influenced by oil pollutants and the presence of heavy metals in the water, and not temperature. The literature indicates that both warmer water temperatures and environmental conditions influences the manifestation of the epizootic shell disease (Castro and Factor 2006). More specifically, the impoundment shell disease is attributed to the break-down of the integrity of the lobster’s cuticule caused by a bacteria that breaks down the chitin. Infected lobsters appear to have a soft shell (Malloy 1978; Bell et al 2012). These bacteria have also been documented for infecting the Blue crab (*Cancer pagurus*) (Vogan et al. 2008). Often time the shell disease bacteria is present even when it is not visually obvious (Smolowitz et al. 1992, Cobb and Castro 2006, Tarrant et al. 2012). So far, they are not able to transfer the shell disease in a lab setting (Shields 2011). When researchers placed a lobster with the disease inside a tank with other healthy ones, the presence of the first does not result in disease transfer to the healthy ones. On the other hand the soft shell can be influenced by the lobster's diet (Laufer et al. 2012). Lobstermen reported descriptions of their observation on the shell disease and mentioned that the shell disease lobsters found inside the traps are appear to be starving and not feeding (Table 2).

3.2.3. Pollutants effects

Another possible factor regards environmental pollutants; the concern that has driven the lobstermen into activism. Local lobstermen have been instrumental in the banning of methoprene, an arthropod (mosquito) growth-molting inhibitor (Gibson 2008), used by city and state government to treat storm drains that empty into the bay; and the promotion of research on its effects on the juvenile lobsters. Methoprene is indiscriminately lethal to lobster juveniles and mosquitoes (Walker et al. 2005, Zulkosky et al. 2005).

3.2.4. Predators are making a comeback

Lobster fishermen have observed that protected fish are making a comeback and juvenile lobster stages are reduced. Back in the 1970s, they had also observed an abundance of predators; they commented on the observed interactions when they returned sub-legals to the waters, tautogs and black sea bass would target them (Visel 2012). For them, the top-down balance is off, given that the long term protected species restore their populations and their stocks prey upon the young lobsters. The surveyed fishers, participating in the study, said that in 2009 when hauling 100 pounds of sea bass in a tank in a boat, by the time it arrived to the dock, the bottom of the tank was covered with pink baby lobsters that came from the sea bass' stomach. They explained that as sea bass, cod and other predatory fish populations rebound, it is natural that the lobsters' population will also be affected due to an increase of the predators. From what the lobstermen have observed, the striped bass, cod and eels render the lobster sampling collectors ineffective by predating on the lobsters before these are surveyed. In their words, they express:

"It seems to me like they are just trying to get these numbers of fish sky high…"

The opposite is observed in the Bay of Fundy, where fishers reported that a decline in predation pressure has triggered a lobster recovery (Boudreau and Worm 2010). Size, bait and time between setting of the gear influences the catch ability of the traps (Miller 1990) and the predators access.

3.2.5. The importance of history to an ecosystem view

Ignoring a historical backdrop blinds us from understanding the buildup of conditions, over the years that brought about the rapid lobster decline. Lobstermen regard processes on a long-term framework; their ecosystem view integrates multiple systems interacting with one another. For the lobstermen, habitat dependence explains for the benefits of fishing, and fish gear that simulates habitat; for them fishing has a positive influence on lobster population; when fishing, the removal of lobsters, increases habitat availability. Changes in the natural habitat, as seen in the historical presence of kelp in New England coastal areas in the 1940s and 1950s would have provided essential habitat for juvenile lobsters (stage four lobsters) (Visel 2012).

When suitable habitat is limiting, this also influences the lobsters' population abundances. Historically, the presence of kelp in the near shore provided habitat and shelter for the lobsters. The lobstermen explained that the flounder fishers have a good recollection of the

1970s warm period (1960 – 1970s) when the kelp got in the way of their traps and annoyed the fishers. With the warm weather, followed by hurricane, the cobbler habitat became buried under silt and the kelp forests began to fail.

3.3. LEK & SEK lack of congruency

In the absence of convergence between LEK & SEK, lobstermen have a hard time accepting the science that informs fisheries management. In the remaining section, below, we expand on the differing views lobstermen have regarding the ‘trawl survey’ data that informs management. The few concepts about which the lobstermen and scientists disagreed, suggest areas where research investment would be helpful. As an example, there was lack of congruency on the preferred habitats for reproduction; scientists associate hard bottoms to early growth and molting stages of the lobsters, while lobstermen believe that lobsters prefer soft bottoms to both shed and reproduce; they also believed that a male lobster would find the territory and that the female lobster would come afterwards, different from what scientist have observed (Boudreau et al. 1990).

As a second example, lobstermen believe that the type of bottom where lobsters are found influences the hardness of the shell. They explained that during a period in the 1970s, lobsters fished on soft bottoms on the West of Block Island, were always dark green (this was favorable, as green lobsters sold well); whereas presently, soft mushy lobsters are caught in soft bottoms and hard shell lobsters are in hard bottoms. However, scientists believe that the softness of the shell is not associated with substratum, but to the molting stage and dietary intake (which could be a result of habitat), and that in general, the lobsters’ preference is for large stone with algal cover versus soft sediments (Hudon 1987). In the words of the lobstermen:

"An old timer told me, look at your lobster and that tells you where they've been at. You know that if you squeeze them and they're hard as a rock, there on the hard bottom. "If you're catching soft crappy lobsters— these are in soft bottoms…"

3.4. Views on management and adaptive strategy

The predictability of what lobster populations –and other organism – are doing is important to fishers in general. The ability to predict relates directly to the continuity of their livelihoods. One of the most important practices is, from what lobstermen observe in a collected pot, they can make inferences about the habitat and the environment in which lobsters live; they can also infer ecological interactions and the conditions under which they are fished. One of the major constrains in their ability to predict regards the regulation of vents on traps and who conducts the vent-less trap monitoring. In the past, smaller vents on the traps allowed to get a better picture on the range of size classes entering the traps. Scientists agree that the present lobsters population sizes and composition have changed (Castro and Factor 2006). Larger vents are designed to release some legal sized lobsters, rendering the traps less efficient. The lobster fishermen regard that:

"When lobster vents went from a conservation tool to a management tool it was a bad thing for us"

This step took away their ability to predict what the lobster populations were doing; they say that their

"Hands [are] *tied and* [we are] *unable to tell what is coming down the pipeline"*

"Changes in the fisheries, without being consulted is like being prosecuted without ever telling one side of the story"

Today, constrains in the fisheries from regulations, limits the ability of fishermen to make predictions, or to adapt. Lobstermen's LEK and views regarding fisheries management is compiled on table 3. Fishers doubt the data on the stock assessments report from 2011 that guides present regulations. Lobstermen perceive a lack of correlation between reported low levels for the stock assessment from one period (2009), because this was followed by an 800 thousand tons catch during the subsequent summer catch (2010).

Lobstermen reported widespread concern about the Rhode Island state *Trawl survey* (Trawl Survey Data RI 2015) sampling methodology that estimates the lobsters stocks. Lobstermen who have been observing the distribution and behavior of lobsters indicate that the lobsters are not distributed at random, but rather they are clustered. This is knowledge the fishers use in the placement of their traps to fish efficiently (García-Quijano 2009). An open conversation with the fishermen has lead to some views on how lobstermen could adapt and continue to fish for a living (listed below). Regarding how other fisheries impact the lobster catch, lobstermen explained that in the past they use to benefit from fishing on the edge of where trawlers fished because “the fish were fed”, but not anymore. Changes in the current trawling practices has trawlers extracting new shell lobsters that are found buried in the mud and the lobster fishers believe that they are getting ‘cut on the edge of the toe’.

4 Conclusion

On many counts the LEK the lobstermen shared was comparable to the science-based ecological knowledge. The fishers and scientists differences regarding the habitat that are monitored for stock assessments, and differences regarding the female behavior and habitat preference during reproduction, can serve as an opportunity for new hypothesis testing and further research and collaborations. More specifically, a continued conversation of topics where both agreement and disagreement were found can orient researchers to formulate questions that can be studied more carefully. Implementing regulations that control and reduce fishing capacity is an unpopular option for the fishermen, however if the limited resources are left to dwindle this would result in more serious social and economic impacts.

Regarding the stock assessments, when science data looks back, fishers have the ability to view both the past and the present, seeing the ecosystem as a whole. What is happening in their "managed landscapes" can –to some extent- be regarded as cyclical; for the fishers, there are degrees of uncertainty in their trade that outdates them, as expressed below:

> *"Sometimes, there is no explanation for where the lobsters are going to show up, I have been doing it* [fishing] *for 50 years, and with my grandfather I would ask and I says, "Okay Grandpa, where we gonna catch them now?" He says "When we put the pots in the water, I'll tell you."*

One of the long-standing objectives of the fisheries management plan regards that *"management program* [be] *sensitive to the need to minimize social, cultural and economic dislocation"*. Regarding present day fisheries regulations the lobstermen said:

> [the inefficiencies of vents are] *'buying us into retirement'*

And their continued mistrust is reflected in:

> *"we need our own science. We need our own people behind us*
> *and there is no guarantee you are going to get what you want"*

A positive outcome from the pilot project would be to put forward recommendations that take into account the importance of using a sampling scheme that can best assess non-random clustered lobster populations. Monitoring efforts could benefit from mapping suitable lobster substrate in conjunction with the lobstermen; and broadening the ecosystem view by integrating fisher's observation on the prey-predator interactions; and taking into account population shifts that can influence stock assessment on juvenile lobsters.

Other important leads from the recorded lobstermen's LEK include the effects of sediments, or pollutants found in the sediments, on the lobsters. There is a strong believe that remnants from oil spills in the past (1996 or 2000) that persist in the sediments are affecting the lobsters, and that the methoprene that is used to combat the mosquitoes, is also having a negative effect on the lobsters juvenile larvae.

Further studies could explore how fishery management councils can benefit from using different types of knowledge. Moving forward on management and conservation efforts, and failing to integrate different types of knowledge can result in falling under the impression of having “data rich language”, [while] lacking the “knowledge and good judgment that is based on experience” (Avis et al. 1972), or on the historical knowledge (Visel 2012).

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Tables

Table 1.1 Questions for the guided discussion with the lobster fishermen meetings – Spring 2011.

General

a) What is the state of the lobster populations in the areas where Rhode Island fishermen fish?
b) How do you think about an ecosystem, what do you think are parts of the ecosystem you work in?
c) What are some of the environmental changes you have seen in the bay?
d) What are the main factors affecting your fisheries?
e) What are the lobsters predators, which do you think is the worst predator for lobsters?
f) What do you think the biggest change is between the wood vs. wire traps.
g) Where are they at different life stages?
h) What are the perceived constraints of the science driven management plans?

Shell Disease

i) How big a role do you think temperature plays in the shell disease puzzle?
j) Where and when is shell disease occurring the most?
k) Have you seen any behavioral changes in lobster population that you think are associated with shell disease?
l) Do you think that shell disease has contributed to the smaller size of maturity that we are seeing in females?
m) Do you think that shell disease has affected the female molt cycle? Egg production?
n) What percentage of shell diseased lobsters do you think molt out of it and survive?

Table 2.1 Lobster Fishermen Local Ecological Knowledge and the science based knowledge on similar topics. LEK comments capture both knowledge and observations. Where the matching science base data was found, we looked for agreement (√) or absence thereof (≠).NOTE: The SNE lobster may exhibit different behaviors than those in the GOM in regards to movement or established migration. Many of the scientific references are from the GOM rather than SNE.

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Populations *Genetic Diversity*	The RI lobsters are believed to be from multiple populations (is this what they said?) Narragansett Bay different genetically than Browns ledge. As an example, their carapace length and width are different.	Existence of a hierarchical genetic structure, first separating lobsters from the northern and southern part of range (From Canada to RI), then revealing 11 genetically distinguishable populations providing strong evidence for weak, albeit fine scale population structuring within each region .	Benestan et al. 2015; Harding et al. 1997 Wahle et al. 2015	√
Young of year **settlement**	Recruitment index low "we haven't seen anything good looking at the young-of-the-year since, what, six or eight years ago?" (2005-2003)	A model integrating larval distribution and hydrodynamics in SNE suggested that passive drift was insufficient to deliver offshore recruitment subsidies to inshore but could be possible with directional swimming of 4th stage postlarvae.	Katz et al. 1994 Chiasson et al. 2015	√
		Rapid changes in water temperature affects behavior of larvae. Larvae can acclimate to given temperatures.	Wahle et al. 2015	
	Theory "our females have moved off into deeper water because of warmer water and now larval supplies are not sufficient in the inshore areas".	Females prefer water of 15.9 degrees C and males selected warmer temperatures.	Goldstein & Watson 2015	
		(Some egg bearing females (not all) make seasonal inshore-offshore movements in the fall). Temperature affected speed of egg development; time of hatching; No effect on larvae size or survivorship. However, eggs exposed to offshore water temperatures took longer to hatch compared in inshore water temperatures. This data suggests that inshore-offshore movements do not accelerate egg development.	Templeman 1937; Wahle & Steneck, 1991	
Taking shelter	Young ones of the year are hiding until they feel it is safe to come out. I am finding up to 31-34mm (about 3 year old lobsters)			LEK Observation

Table 2 continued

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Low recruitment *Other factors affect them*	This low in the fishery recruitment hasn't been seen since the mid 1990s (URI trawl survey).	"Interaction between predator and thermal regime dominates at cold and warm, extremes but not at center of the species range. Support for positive climate effect on lobster recruitment at warm range extremes. Fishing effort followed rather than led changes in lobster abundance over time. (Note this paper did not identify black sea bass as a predator)	Boudreau et al. 2015	LEK cites SEK
Eggers	"A lot of eggers now, but not full tail of eggs … sections missing." "Whether that's due to, you know sometimes I wonder if it was handling, but most of us are pretty careful.	Females normally lose between 30-50% of their clutch over the 9 months.	Perkins 1971	√
		Nemertean infection will cause extreme egg loss	Shields et al. 2006	
		Capture and handling of gravid females will also cause clutch attrition	Herrick 1909	√
	Female lobsters with (few) green eggs were reported by 2 fishers.			LEK observation
		Presence of moderate to severe disease shell affects egg quality. Egg size and energy content increase as ESD becomes more severe. Could implicate environmental conditions as well.	Ouellet & Plante 2004, Miller et al. 2013	
		Reduced fecundity seen in Canadian lobsters between 2008-2013 possibly due to warming temperatures.	Koopman et al. 2014	
		Release of larvae affected by water temperatures	Tlusty et al. 2008	
Habitat				
Settlement	Environmental condition for the larvae to settle is important.	Settlement bottleneck is related to substrate although tunneling in mud is often observed in areas with little cobble bottom.	Wahle 1992, Cobb 1983; Wahle & Steneck 1991; Berill & Stewart 1973; Pottle & Elner 1982	√
4th stage lobsters	They come up in traps pulled from 120 feet deep. Different places in the Bay and around Fort Adams.	Mud bottom has become an important juvenile habitat in recent years in Bay of Fundy.	Tang et al. 2015	√
Nurseries	Inshore grounds are nurseries. When lobsters grow they leave the bay. With tags and bands we monitor them when we block a gage and track them elsewhere.	Substrate preference for benthic macro-algae covered rock, followed by rock and sand, mud and sand substrates. Both adult and juvenile lobsters are found in varying depths that may vary seasonally.	Botero & Atema 1982; Pottle & Elner 1982; Wahle 1992; Nelson et al. 2006	√

Table 2 continued

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Breeding habitats	Preference for stone and cobble			
General	Larger dominant lobsters take available territory, the rest have to move on.	Large and mature lobsters are mainly found in the deep-water (40 – 100 m)	Campbell & Stasko 1986	√
Adult *Densities habitat dependent*	Lobster densities are suitable habitat dependent.	Seaweed substrates. Rocks, eelgrass in sand	Johns & Mann 1987, Barshaw & Bryant-Rich 1988,	√
		Habitat is shelter dependent and behavioral dependent (food, predation, competition)	Cobb 1977, Karsnofsky et al. 1989, Wahle & Steneck 1991; Cooper et al. 1975	√
		Habitat is limiting: presence of boulders and cobblers.	Howard 1980	√
		Absence of shelter in these areas may limit lobster distribution	Cobb 1971	√
		Habitat dependence was tested with artificial shelter resulting in increased populations.	Stein & Magnuson 1976, Wahle & Stenek 1991	
Large (rocky)	Lobsters prefer rock bottom, or stay longer in those places than at hard sandy bottoms.	50mm CL preferences for large stone	Hudon 1987, Watson & Jury 2012	√
Migration MOON	Full moon is when they migrate from soft to hard habitats. In shallow water they move out in functions of the storms and the swells.	Lunar cycles entrain crustaceans biological rhythms	Ferrero et al. 2002	√
STORM	During the storm lobsters move to deeper water. After the storm they go back to the shallows.	Deeper waters are used to retreat from predators and adverse environmental conditions.	Cobb 1971	√
		Small lobsters avoid currents and need rocky outcrops	Howard & Nunny 1983	√
Historical	Presence of kelp benefitted the lobsters. Present we see some kelp growing now. Some years we get mussels.	Although rocky substrates considered to be preferred habitat of both newly settled and older lobsters, preference for specific substrate diminishes as lobsters grow out of early benthic phase	Wahle & Stenek 1991	√
Substrate influences quality	In the 1970s, West of Block Island, the bottom was soft, and the lobsters where always dark green (got more money for them)	Hardness or softness of shell associated with molting stage development and to dietary intake	Wahle & Stenek 1991; Leavitt et al. 1979	√
	Soft and mushy lobsters are in soft mud, hard lobsters are in hard bottom. Knowledge of what the lobsters are doing			LEK Observation

Table 2 continued

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Diseases				
Shell disease (sd)	1962 – Early mention of shell disease on 'Life Cycle of a Lobster book'	'During stages of the normal molting cycle there is histological appearance of the cuticle' of the bacteria assoc. with shell disease, but it only manifests itself in some.	Aiken 1980, Travis 1955, Skinner 1962	√
		Earliest mention: shell disease described by Hess 1937 (not epizootic shell disease).	Hess 1937	
Shell characteristics	The lobster shell itself has an outer coating, almost like a wax ". If that wax coating is kept intact, that bacteria will not affect the lobster—will not get shell disease.			
Cause	"Lobster disease not associated to water temp but rather to the oil spill."	sd associated to the presence of a bacteria		≠
Growth/Molting	"Larger lobsters keep the shell longer. Some only shed every two years. They are also getting it so bad to the point where they die."	Larger lobsters and mature females do not shed as often as smaller lobsters. However shell disease now observed in very small juveniles.	Hughes & Matthiessed 1962	√
		Several genes, including arginine kinase (AK) and hemocyanin were expressed differently in sd lobsters. AK plays a role in energetic homeostasis. Evidence of disruption of endocrine signaling and ESD.	Tarrant et al. 2012; LeBlanc & Prince 2012; Hughes & Matthiessed 1962	√
Do not feed	"Shell disease lobsters don't feed" "the genes that have to do with metabolic capacity are turned off and they lose body mass" "… the long and short of that research is that the lobsters are starving… They were having severe physiological issues." "They don't feed, still they crawl into the traps"			LEK Observation
Meavy Metals	Shell disease is associated to places with higher heavy metals (Cadmium and arsenic). These heavy metals are also found in the sediment.	Presence of shell disease was not correlated with heavy metal concentration in lobster or sediment	Tarrant et al. 2012, LeBlanc & Prince 2012	≠
Target for predators	Shell disease lobsters are target for predators: Flounder and sea bass and sea stars.			LEK Observation

Table 2 continued

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Diseases cont.				
Soft shell	It takes them 3 times longer for the shells to harden.	Alkylphenols interfere in shell hardening during molting	Malloy 1978, Bell et al. 2012	
		Diet is important in shell thickness- Lobsters fed a diet of herring have thinner shells; those fed a diet of cod have a thicker shell	Myers & Tlusty 2009, Danahue et al. 1998	
		No evidence that consuming fish bait increases chance of shell disease	Bethony et al. 2011	
	Soft lobsters would not live in the tanks	The bacteria can be present in the water, the mud in NE aquarium and other aquariums.	Laufer et al. 2012	≠
		Soft-shell is influenced by diet. All lobsters might have the bacteria and only some manifest it // the alkylphenols.	Shields et al. 2012	
		Studies on chemical bioaccumulation suggests that "methoprene affects the normal pathway of lobster cuticle synthesis and the quality of the post-molt shell."	Vogan et al. 2008	
Blindness	"Soft-shell appear blind. They bio-accumulate stuff. Not sure if it is transferred", "Lobsters described as having white out"	No relationship between shell disease and blindness	Walker et al. 2005	
		Idiopathic blindness present in 54% of lobsters sampled from RI and 16% of lobsters from Maine.	Shields 2013	

Table 3.1 Lobster fishermen Local Ecological Knowledge regarding fisheries management and the science based knowledge or regulations on the pertaining topics presented when available. Where the matching information was found, we looked for agreement (√**)** or absence thereof (≠).

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Fishing Regulations				
Limits	Catches are limited by boat. Catches should be limited by fisher. They can combine efforts, save on fuel and less carbon imprint.	Rules are: Catch limits LTA lobster trap allocation 2015 LCMA 2 LTA 800		
Constrains				
Trawlers	Trawlers catch lobsters near the sides where the pots are. The vast majority catch new shell lobsters that are in the mud and they dig them out.			LEK Observation
Stock Assessment data	It is three years old (2011)			LEK Observes that the data is old
Collectors ineffective	There are too many predators (eels- this big-, black sea bass, Strip sea bass, ie choggies). Rocks in collectors are too big for larvae to hide, something small like a beehive would be good.			LEK Observes methods are innefective
Lack of correlation	(1997) 90% of the design of the collectors that we put out inside the harbor were different, they had a mesh in the bottom, there was rubber in them. They were weighted down and they tested every bottom.	In shore trawl survey and off shore fishery would be different**.**	Fisheries scientist (pers.comm)	≠
	For fishers' low estimates from the trawl survey followed by a good 800K summer catch.			
Predators	(2009) Hauling 100 pounds of sea bass in a tank on the boat, by the time the fisher got the dock the bottom of the tank was covered in pink (baby lobsters).			LEK Observation

Table 3 continued

Topic	Lobstermen's LEK	Science based knowledge	Source	Agreement (or not)
Vents (regulating tool)	Traps are unable to retain legal size lobsters. A 3 inch lobster can escape a 2 inch vent.	(SC) There are changes in the sizes, and the composition of the catch, and landings.	Castro and Factor 2006	
Escapement of legal size lobsters	Different size vents - the head has a large escapement	Changes in morphology = low trap retention, or trap saturation avoidance of lobster from go into a trap once other lobsters are in to avoid aggression.	Jury et al. 2001, Miller 1990	√
Monitoring Program	Vent-less traps with 0.8 inch mesh size do not retain little lobsters.	Universal Citation: RI Gen L § 20-7-11 (2012): all traps must have a vent no smaller than 1 3/4 inches (44.5mm) by 6 inches (152.5mm).	US Law – 2012	
Vent-less traps	With vent measuring 51mm (50.8) and the general measurements on a survey being 47, 48, 49 mm, not a single measured 53 to stay inside the trap.	Ventless traps captured about 10 times as many lobsters as standard traps.	Clark et al. 2015	≠
Timing affects	The timing on the sampling with ventless traps makes a big difference.			LEK Observation
Computer random selection of monitoring sites (inadequate)	"Downtown Pawtucket, Providence, Central falls). Computers cannot tell what the bottom is like or if it is suitable habitat "The practice of wrong assessment drives us (lobstermen) to the ground."			≠
V-notch program	V-notch program stopped			
Fall trawl surveys	Depend on the right temperature. Timming influences the outcome.	Well known correlation between catch and water temp. But exact mechanism unknown- i.e. is it increased metabolism of lobsters and higher activity levels or is it lobster movement? Impossible to determine which of these were most responsible for causing this correlation.	Fisheries scientist (pers.comm)	√

Figure Legends

Figure 1.1 NOAA shapefile of the National Marine Fisheries Services (NMFS) lobster management areas in the Northeast and the Mid-Atlantic Waters. Posted on the website 9/15/2014.

Figure 2.1 Different categories of local ecological knowledge discussed with the Southern NE lobster fishermen.

Figures

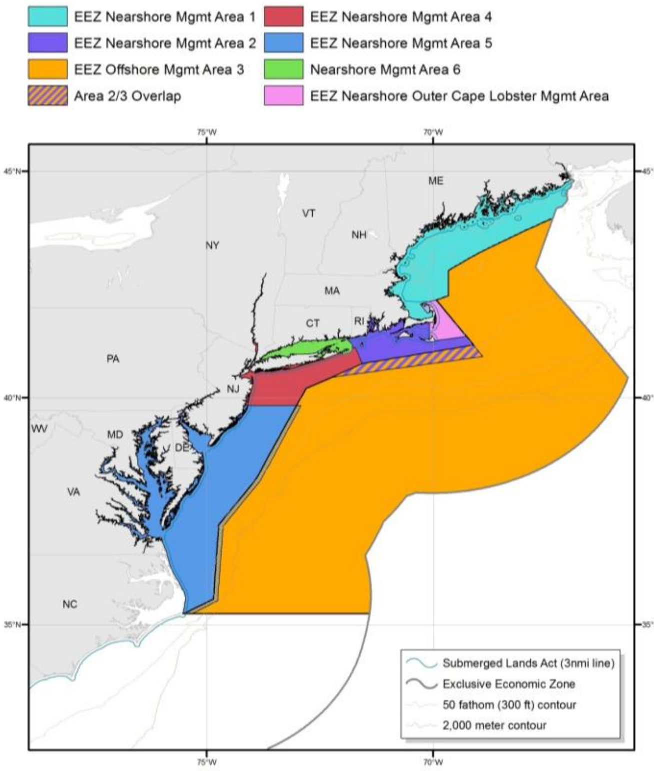


Figure 1.1 NOAA shapefile of the National Marine Fisheries Services (NMFS) lobster management areas in the Northeast and the Mid-Atlantic Waters. Posted on the website 9/15/2014.

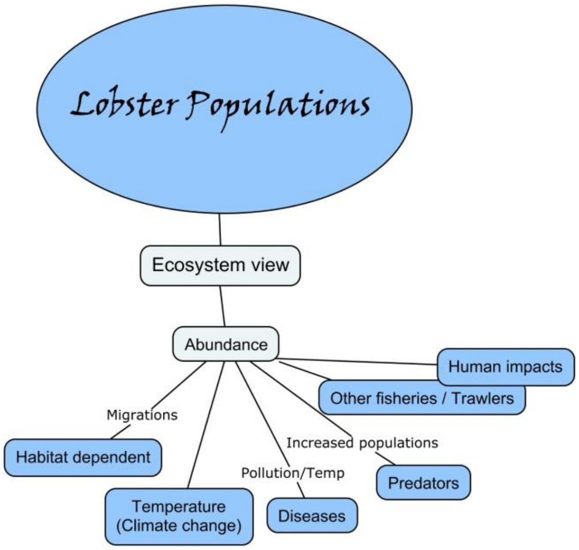


Figure 2.1 Different categories of local ecological knowledge discussed with the Southern NE lobster fishermen.

Appendices

Appendix A. Table 1. Summary of the recorded local ecological knowledge from the Rhode Island Lobstermen fisheries study- Spring 2011.

Populations

Biodiversity

- Multiple lobster populations are present in Narragansett Bay, different genetically than the lobsters in Browns ledge; the carapace length and their width are different.

Abundance

- Inshore RI fishers have seen an increased sub-legal lobsters in the last three years (2008-2011). Sub-legal lobsters disappear after they shed.

Predictability

- Historical, smaller vent traps were a great tool for drawing estimates on abundance or knowing what was coming up the pipeline.
- Gauging for abundance on effort in the commercial lobster harvests is not possible [according to scientists] unless effort is constant and steady.

Historical LEK

- [Cyclical aspects of fisheries] “We didn’t have any lobster in ’64, when I was in high-school, ’65, ’66, basically. Next year we had five and seven pounds per pot.”
- [Historical] “A lobsters place is in different place/s.” “Grandpa in 1965 would fish the beach, the pier, the bells, east ground, and then back to the pier. We do the same thing, fifty years later. The next year we had five and seven pounds per pot.”
- In the 1970s the stocks were down, but not drastic. Connecticut saw a gage effect, and also a decline after the spill.
- In the past there was no trap limits; fishers had up to 1600-1800-2000 pots in the bay. They used a lot of gear and the gage size was much smaller.
- When traps were of wood fishers spent less time fixing and banging on them and more time fishing.

Habitat

General Characteristics

- Lobster density is habitat (suitable habitat) dependent.
- Lobsters like to eat kelp; they also like to stay in the rocks. Strong clawed lobsters can be found there. (Perhaps they go to the rock bottoms for food).
- Lobsters prefer rock bottom, or stay longer in those places than at hard sandy bottoms.
- Some are found in soft bottoms: from pulling traps in the spring and seeing them.

Changes [Population/Abundance]

- In the past when kelp was present it benefitted the lobsters. Today some kelp is growing now.
- Some years we get mussels.

Nurseries

- Inshore grounds serve as nurseries. When lobsters grow they leave the bay.
- [Citing ME-study] when lobsters are small they hit the spot and they hide and they do not come out. They pick a spot (referring to the larvae) cobble bottom or whatever it is … ‘till they get to a certain size where they feel like they are safe from predators.

Juvenile

- Young ones of the year are hiding until they feel it is safe to come out.

Adult

- Bigger lobsters need larger areas.
- Dominant lobsters take the available territory, and the rest of the lobsters take off.
- “Massachusetts is seeing large lobsters in their pots: 1 per pot after a 24 hour soak, its 53mm carapace width”. In RI “we I haven’t seen one hit 50 yet”.

Migrations

- When lobsters get to 3 and 3/8th (maturity) they are heading out.
- A full moon is when lobsters migrate from soft bottoms to hard bottoms. In shallow water they move out in functions of the storms and the swells.
- Not enough suitable habitats, is one of the reasons why the lobsters leave.
- Lobsters feed in the offshore waters (theory)
- There is a <u>reverse migration</u> where they come back to us (into the bay), it is a migration that goes out and comes back in until they reach a certain point or a certain size where they do go out.
- Banding system allows for fishers to monitor the movement of the lobsters, from the bay, mid bay and beavertail. After lobsters leave the bay, fishers do not see them.
- Past West passage tagging of sublegal lobsters (3 3/16th) before they shed in June: these were later caught repeatedly with carapace tags; and after they molted they were getting them at a 100 fathom perimeter, across 45 days.

Lobster Run

- The timing is generally December – January
- In 2009, many male lobsters were caught. Fishers said “I have never seen such a good male run in quite a few years”. Then 2010 there was practically none. Possible connected to a lot of rain (then).
- Fall 2010 - there were no lobster run in the inner shore of RI. We think it has to do with the water temperature.
- There was a lobster run in February 2011. In that year they got the male run before the female run, was very weak this year.
- 2010 – Lobster run represented a good catch.

Monitoring Lobsters

- As they grow and leave the near-shore nursery grounds, with tags and bands we monitor them when we block a gage and track them elsewhere.
- Maine Science study: tubes simulating habitats: lobsters like holes that are the right diameter - not too large (Sheehy 1976).

- Last 2-3 years fisher would be catching lobsters in the winter time (December and January). This year they didn't come in December, they started to come January, and last week we had the marine biologist with all of us, and I mean we had one of our biggest days we've had in February ever [emphasized] not only for legals, but sub-legal.
- I tag them a bunch of them again two weeks ago, and some deep under were under the gage, males and females and they had already shed out this winter, but they hardened up, I went back the other day and all those sets and we didn't even catch one of them, and I must have released about 50 of them.

Sightings (Feb-March 2011)

- Fishers are seeing up to 31-34mm (about 3 year old lobsters).
- Winter 2010-11: A lot more small lobsters with carapaces about an inch and half were seen than what is ever seen during this time of the year.

Growth

General

- Fourth stage lobster come up in traps pulled from 120 feet deep. Different places in the Bay and around Fort Adams. They prefer stones, cobbler-out in those small islands - where they can hide from predators.

Molting / Shedding

- This is regulated by hormones.
- I tag many two weeks ago, some deep were under the gage, males and females and they had already shed out this winter, but they hardened up. I went back the other day and all those sets and we didn't even catch one of them, and I must have released about 50 of them.
- It takes 7 years for lobster to reach maturity and lays eggs, and another 7 years for those to reach maturity (14yrs).
- When sub-legals shed they increase 40% roughly.
- [Citing literature] Lobster grows faster in warmer waters, and molts more to.

Affected by:

- Small lobster found in a section of the bay in the fall, are not molting for 5-6months do to chemical impact.
- Shell disease slows lobsters' growth.

Reproduction

Habitat Preference

- In shore acts as a nursery, when they grow they leave.
- Lobsters like soft bottoms to shed and reproduce. Male lobsters acquire the territory and then females come.
- Recruitment failure affected by the number of Sea Basses that are in the bay.

Shell Disease

Recounts

- "There's something that took place this year (2011) we don't know what caused it but the last few weeks we've seen a lot of soft shells, more so than normal for this time of the year." [Changes]
- [Historical] From what was observed: shell disease started in the big (female) lobsters first. These seemed to get worse right away. Especially in the East Passage… Huge spikes (numbers) of shell diseased lobsters are in East Passage. Still it is the hot spot and it's because of the egg-bearing population in that area.

Cause

Habitat

- Soft and mushy lobsters are in soft mud, hard lobsters are in hard bottom.

Quality

- Development of taste bud. The harder lobsters with thicker shell and difficult to crack, has powerful texture, taste. The soft lobsters are easier to break, are sweetness to them that the more mature lobsters that are hard don't have.
- There is a bigger ratio of soft shells to hard shells (2011).
- "Ten years ago there was a lot of kelp - hard shell lobsters coincided with the kelp".

Predation

Sea Bass

- Eats small lobsters.
- Their populations are large with an increase in recent years. There's a need for a balance.

Fishing Lobsters

Populations

- In the 80s catching 16,000 pounds of lobsters all a 1.25 p meant they target a single year class.

Site Variability

- (2011) Legal lobster appeared in sites where in the past they would have never have caught them.

Landings

- Landings are down because regulatory measures are in effect to prevent higher catch: vent size, gage size.

Changes

- In the past: setting pots anywhere and catching a pound. You didn't need to know anything.
- *Past: use to be able to catch 3 and a quarter (the <u>chicken market</u>).*

Constrains

- "Legal lobsters are escaping the current vent size (Area 2). We invest money in fuel and food to catch legals, and we are not catching them."
- Inability for fishers to keep Sea Bass that enters into their traps. Federal regulations do not allow it.

Traps

- Gear provided habitat - or protection for some lobsters. (Big females like to stay alone).
- Fishers find cod, dog fish, striped bass and flukes in the traps. Some days there is one in every trap. This was not seen in the 80s. [Changes].
- Inside they are finding: Sea Bass, Mantis shrimp, skates and Sea robins [Changes].

Affected by

- The tide, currents and how the traps bleed the bait scent
- In the bay clarity of the water affects landings, when it is cloudy, not depth related. It happens seasonally.
- Wind: "A good year comes when the winds are blowing right".
- Sport-fishers going a certain limit in their catch also affect the fisheries.
- Draggers affect stocks.

Economy

Value

- (Historical) In the 1970s the West of Block Island, the bottom was soft, and the lobsters where always dark green. Fishers got more money for them.
- Market value prices shell disease lobsters as lower quality, although taste wise they are preferred by some.
- Season (areas) all year around. Dealers own multiple permits.
- Catches are limited by boat. Catches should be limited by fisher. They can combine efforts, save on fuel and less carbon imprint.

Management

Relations

- Fishers feel harassed by DEM.

Need For

- The main issues affecting fishers is not the stock assessment, but the management goals.
- Fishers need information that they can rely on, to have security.
- Collaboration to be better informed (they could be losing 50%).

Regulation Constrains

Stock Assessment

- The value of vent-less trap assessment and the industries involvement - ability to predict.
- "Sea sampling data is needed (maturity, growth and ranges). Measuring lobsters in the dock gives a poor picture of the fishery I think." "I mean you are not seeing all the shorts, you are not the eggers the V-notches, the oversize any of that stuff".

Alternatives

- Is the blue crab a new resource? "There is a commercial fishery for blue crabs. Blue crab traps work better than lobster traps. Efficient: 2-4 in every trap" "People like blue crab that is soft as hell. I'd be the same to put soft lobster into a sandwich or a torpedo roll".
- The American glass eels (*Anguilla rostrata*) "Are worth more than drugs or something" "a little bag of them it's like a thousand bucks".

Endangered

- Yellow eels have a moratorium - they are endangered.

Appendix B. Informed Consent Form developed in fulfillment of IRB requirement.

TO BE READ OR HANDED TO THE PARTICIPANTS

Informed Consent Form- Anonymous Research
(Anonymous meaning no one on the research team will ever have access to any identifiers.)

The University of Rhode Island
Department of Natural Resource Sciences
Address: Coastal Institute, 1 Greenhouse rd., Kingston, R.I. 02881

TEAR OFF AND KEEP THIS FORM FOR YOURSELF

Dear Participant,

You have been invited to take part in the research project described below. If you have any questions, please feel free to call Elizabeth McLean or Graham Forrester, the people mainly responsible for this study.
The purpose of this study is to assess the role of fisherman's local ecological knowledge in the management of marine protected areas in coastal communities of the Dominican Republic. Responses to these items will be collected by direct interviews with key informants and direct surveys with fishermen. The data will be anonymous and confidential with no names nor signatures. Hard copies will be stored in a locked file cabinet in the office of Elizabeth Mclean and electronic files will be stored with a password access in a computer with firewall.

YOU MUST BE AT LEAST 18 YEARS OLD to be in this research project.

If you decide to take part in this study, your participation will involve filling out or responding a survey questionnaire pertaining to local ecological knowledge, marine protected areas and management of these.

The possible risks or discomforts of the study are minimal, if you regard the information asked to be too personal, you can choose to respond or not.
Although there are no direct benefits of the study, your answers will help increase the knowledge regarding fishermen's local ecological knowledge, the functioning of marine protected areas and management of these in the Dominican Republic.
Your part in this study is anonymous. That means that your answers to all questions are private. Scientific reports will be based on group data and will not identify you or any individual as being in this project.
The decision to participate in this research project is up to you. You do not have to participate and you can refuse to answer any question.
Participation in this study is not expected to be harmful or injurious to you. However, if this study causes you any injury, you should write or call the Elizabeth McLean or Graham Forrester, at the University of Rhode Island at (401) 874-7054.
If you have other concerns about this study or if you have questions about your rights as a research participant, you may contact the University of Rhode Island's Vice President for Research, 70 Lower College Road, Suite 2, URI, Kingston, RI, (401) 874-4328.
You are at least 18 years old. You have read, or been read, the consent form and your questions have been answered to your satisfaction. Your filling/answering out the survey implies your consent to participate in this study.
Thank you, Elizabeth McLean

Appendix C. Concept map for lobsters and their fisheries.

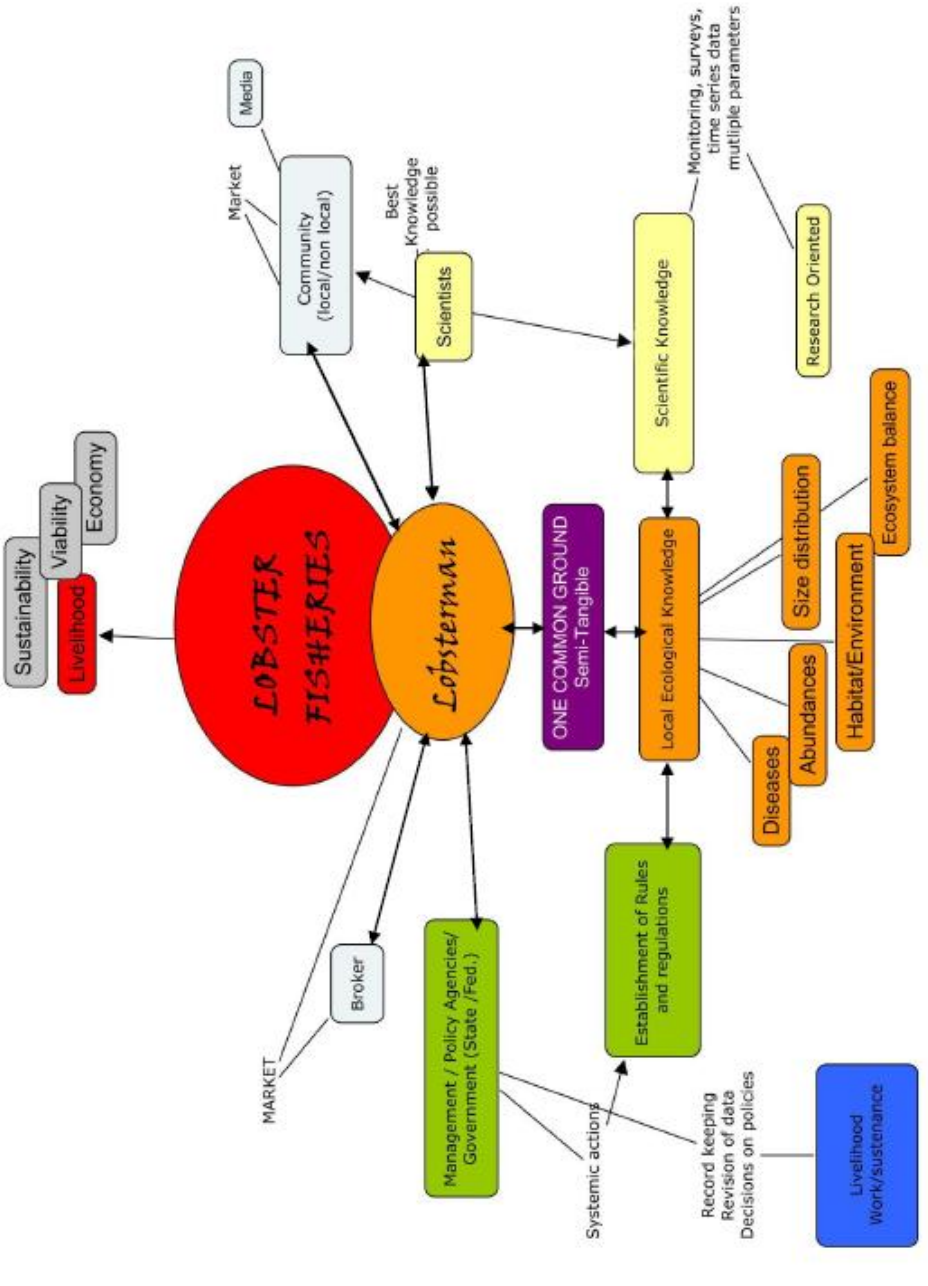
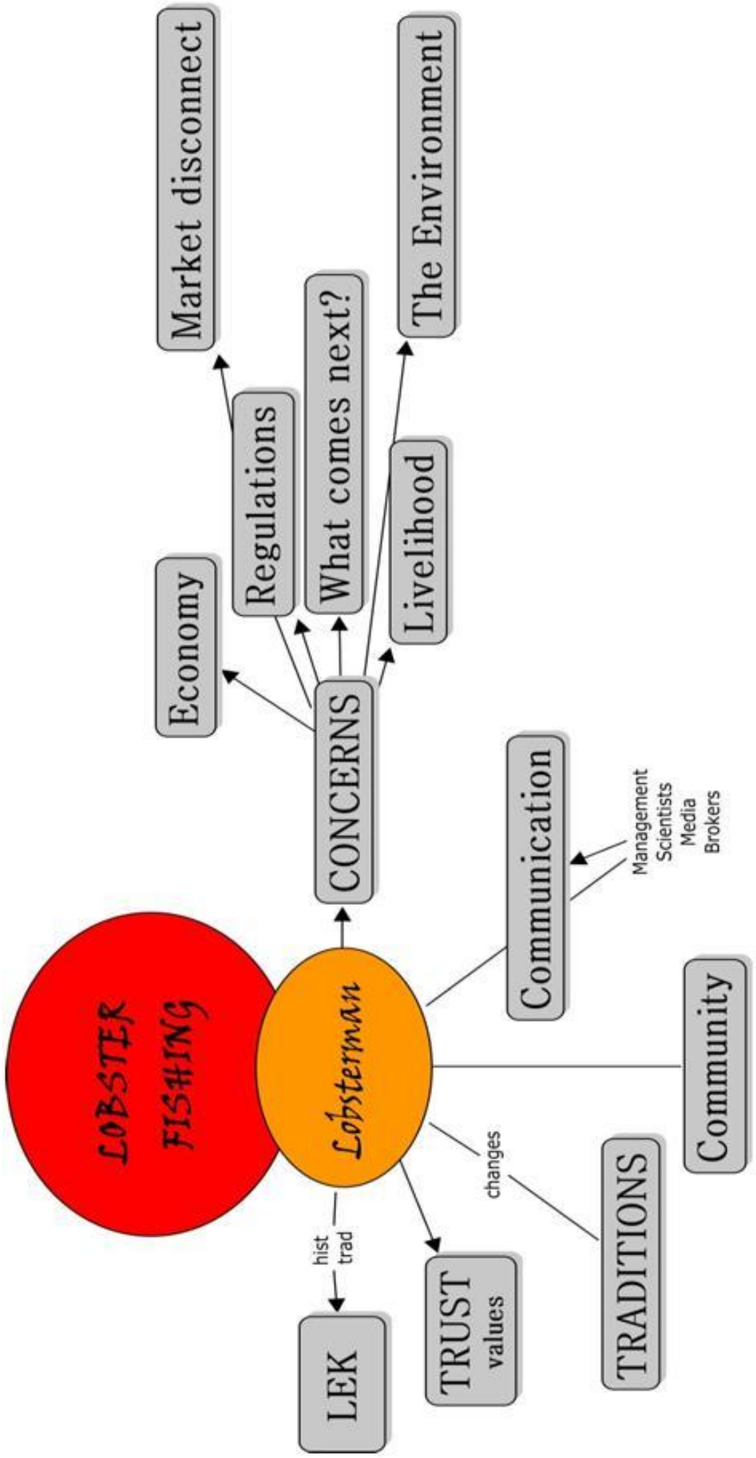


Fig. 1. Concept map for lobstermen and their fisheries. Integrative path towards a common ground with all the interacting members.

Appendix D. Mapping of discourse and Lobstermen's concerns - Mclean 2011.



MANUSCRIPT 2

Fishers' local ecological knowledge has no apparent influence on how they perceive the state of their fishery or how it is managed

by

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II. Fishers' local ecological knowledge has no apparent influence on how they perceive the state of their fishery or how it is managed

Abstract

Consideration of stakeholders and the local ecological knowledge they have can support effective coastal management programs. We examined fishers' knowledge on the ecology of species they fish. A survey of fishers in the Dominican Republic explored their understanding of fishes' habitat use, depth distribution, seasonality and predator-prey interactions. A qualitative-quantitative methodological sequence assessed the content, sharedness and distribution of knowledge among the fishers. We evaluated the methods for coding descriptive responses, and then performed a cultural consensus analysis (CCA) that revealed a shared cultural model of ecological knowledge for four of the eight commonly fished species. For these four species, an index of fishers' individual knowledge derived from the CCA (competence score) was unrelated to their perceptions on the state of their fisheries and how they are managed. These findings underline the need to better explain the fundamental basis of fishers' perceptions.

Key words Local ecological knowledge ⋅ coastal fisheries ⋅ cultural consensus ⋅ perceptions

Introduction

The widespread failure to sustain fisheries has been attributed to simultaneous effects of overfishing and to natural disturbance on fish habitats (Hughes 1994, Jorge 1997, Pandolfi et al. 2003b). The circumstances are increasing the pressures with a growing dependence on coastal resources (Salas et al. 2007), and a scaling uncertainty for people's subsistence. Therefore, we need to broaden our understanding and consider new approaches that will enable us to sustain fisheries, conserve our ecosystems through the establishment of efficient management programs.

Fishermen in coastal communities are key stakeholders and possessors of a wealth of coastal knowledge (LEK). Although they are a great source of information, their knowledge was often ignored in the past (Huntington 2000, Johannes et al. 2000). One reason why LEK had been ignored was that fishers' knowledge was viewed by the science community as less precise, and different, both philosophically and epistemologically, from the Western scientific knowledge used in fisheries management (Johannes 1991, Raymond et al. 2010b).

In 2000, Johannes wrote that by ignoring fisher's views we were "missing the boat", neglecting critical, or long term data that could assist us in our management practices (Johannes et al. 2000). Furthermore, the failure to sustain the fisheries was also attributed to overlooking social factors surrounding the fisheries (Mascia 2004). In the fisheries, the benefits of using LEK go beyond understanding the challenges that small scale fishing communities face; in some cases the use of LEK is often seen as more cost-effective (Moller et al. 2004, Aswani and Lauer 2006) than other monitoring programs, having also the benefit of leading to higher degrees of trust among stakeholders and managers (Wilson 2003). Today, LEK serves as a powerful tool to understand coastal communities as social-ecological systems (Berkes and Folke 2000, Pollnac et al. 2010, Cinner et al. 2012), complement scientific research (Berkes 1999, McGregor 2004, Gilchrist et al. 2005, Anadon et al. 2009), inform management (Johannes 1991, 2007, Ruddle and Calamia 1999, Berkes et al. 2000a, 2000b, Huntington 2000, Johannes et al. 2000, Davis and Wagner 2003, Wilson 2003, Olsson et al. 2004, Lundquist and Granek 2005, Wilson et al. 2006, Silvano and Valbo-Joregnsen 2008, Gerhardinger et al. 2009b), and expand our understanding of the ecosystem (Miller et al. 2004, García-Quijano 2006, 2007, 2009, Pilgrim 2006, Shackeroff and Campbell 2007, Rasalato et al. 2010, Silvano and Begossi 2012).

This study presents the local ecological knowledge for the fishers of Samaná Bay and the perceptions they have surrounding their fisheries. LEK is defined as knowledge about the ecology of the species that fishers catch. LEK has been described as a knowledge that is passed on from generation to generation and influences the nature, timing, and location of fishing (Johannes and Hviding 2000). Different from knowledge, perceptions are understandings that are formed through experiences and interactions (Bernstein 2011), where social networks play a major role in their reinforcement (Krackhardt 1986). The associations of knowledge and perceptions through cognitive networks (Brewer 1985) and social networks (Olsson et al. 2004, Turner et al. 2014) serve to explain fishers behaviors and decision making. Because perceptions are built through networking and experiences (Bernstein 2011), they reflect people's understanding of the social and physical world around them and their expectations in their society (Uddin and Foisal 2007). Hence, together with LEK, perceptions can reduce or increase fishers willingness to support conservation (Stankey and Shindler 2006, Martín-López et al. 2007). Studies on peoples' perceptions have been used to examine their views on vessel safety regulations (Poggie et al. 1995) and for the management and the establishment of MPAs (Williams 2002, Dalton et al. 2012, Veiga et al. 2013, Kincaid et al. 2014).

Although the study of LEK has steadily expanded, to quantify and understand it remains a challenge. In order to assess people's knowledge, some social studies use cultural consensus models (hereafter CCM) (Romney et al. 1987, Weller 2007). This cultural model assumes that knowledge is transmitted socially, internalized with complex configurations, and used by individuals to interpret the world (Romney et al. 1986, Borgatti and Halgin 2005). The cultural model serves to define shared domains of knowledge from individual domains, and resulting patterns and regularities are defined to be representative of a collective group (Romney et al. 1986). Given that the formal CCM is limited to categorical data (Romney et al. 1996, Weller 2007), this makes it only useful for qualitative LEK when survey responses can be organized in categories. The coding of qualitative responses into categories for formal CCM is a process that requires skilled interpretation. Differences are also commonly observed between coders when a more than one researcher examines the same responses (Hruschka et al. 2004). For these reasons, we examined the influence of varying the coding level scheme on the outcome of CCM.

It is important that the studied populations meets the CCM assumption of having a common background (Romney et al. 1986); when interviewed fishers share experiences from harvesting common local resources (Charnley et al. 2008, García-Quijano 2009). Shared knowledge is then assumed based on their common livelihood (Shackeroff and Campbell 2007). We measured the connections between fishers' LEK and their knowledge and perceptions regarding MPAs, the state of the fishery, and the factors that affect the fishery. Our goal was to answer the following questions:

(1) What is the nature and content of fishers' LEK about important fishery species and how does LEK vary intra-culturally among fishers?

(2) How do fishers vary in their knowledge, values, and perceptions concerning the establishment of MPAs, the changes in their fishery and factors affecting their fishery?

(3) Is there a relationship between the fishers' shared knowledge and the perceptions they have surrounding their fishery?

We hypothesized that: (a) fishers share a common body of LEK which is based on their common experiences fishing in the local ecosystem, and (b) that those more conversant with this body of knowledge would perceive more negative changes in the fishery, and would be better informed about the local MPAs and more supportive of their objectives. If fishers' LEK is not related to their perceptions, other factors must be considered when attempting to understand fishers' perceptions and characterize coastal fishing communities. The conceptual model is that by understanding the distribution of LEK and fishers' perceptions, we can understand how people relate to their natural environment (Fig.1). Based on the premise that there is a direct relationship between people's habitual way of life and their expectations in their societies, these relationships need to be considered for conservation and coastal resource management to succeed.

In previous studies, cultural consensus analysis has been used successfully to assess several aspects of fishers' knowledge on the ecology of harvested fishes (García-Quijano 2007; 2009; García-Quijano and Valdés-Pizzini 2015) and to evaluate how that knowledge can inform management (Wilson et al. 2006, Haggan et al. 2007). Furthermore, CCA has been useful to identify distinct sets of knowledge among fishers and to capture the values they share regarding MPAs (Grant and Miller 2004, Fox and Bushley 2007).

Studies on the perceptions fishers have on MPAs have outlined misconceptions on the purpose of their establishment as well as mixed feelings due to reduced level of involvement in the decision making process (Williams 2002). Other studies found differences among communities to be linked to varying gears used (Kincaid et al. 2014).

In the interest of managing and sustaining fisheries and protecting the environment, we need to achieve a better understanding of local people's knowledge, ecological processes and how people relate to their environment (Williams and Baines 1993, Lubchenco 1998, Berkes 1999, Marshall and Fenton 2005). To the best of our knowledge, this is the first small-scale fisheries assessment to correlate individuals' competence, as a knowledge (LEK) indicator, with perceptions of the state of fisheries and fisheries management and to systematically test the effect of coding descriptive questions on CCA results.

Study Area

The studied communities are located in the province of Samaná in the North East Coast of the Dominican Republic (D.R.). This region sustains one of the most important fisheries in the D.R. (Núñez & Garcia 1983, SERCM/SEMARN 2004) where numerous coastal communities rely on coastal resources for both income and food security. The fishers concern for the decline in their fisheries had been recorded two decades earlier (McCann 1994). The mid 1990s witnessed the expansion of the fisheries sector, with the adoption of different types of gear and the targeting multiple species (Jorge 1997, Sang et al. 1997, Herrera et al. 2011). This is a common practice where fishers start to fish harder, and target more species on the food web (Pauly et al. 1998, Cinner et al. 2011) in response to decreased stocks.

In response to overfishing, the government in the D.R. has established MPAs and fishing regulations. Starting in the 1970s, and most recently in 2009, seven MPAs have been established in this region (Geoghegan et al. 2001). The goals of these MPAs are to conserve natural, historical and cultural resources, sustain ecological services, and provide opportunities for education, recreation, research and environmental monitoring. Although MPAs are meant to promote public participation and to contribute to the wellbeing and the betterment of surrounding communities (Kappelle 2009, Ministerio de Medio Ambiente y Recursos Naturales 2013), the established restrictions and regulations disrupt peoples habitual ways of life.

The management of the MPAs is under the responsibility of the Ministry of the Environment and Natural resources of the Dominican Republic acting through the Vice-Ministry of Protected Areas and Biodiversity. Additionally, there is a national office for protected areas with local park rangers at the province level and other personnel from the National Service for Environmental Protection (Ministerio de Medio Ambiente y Recursos Naturales 2013).

In Samaná, the terrestrial National Park of Los Haitises was established 4 decades ago (1976), but enforcement of park regulations was implemented much later in the 1990s. Closure, enforcement and exclusion of people from traditionally used lands in the protected area have impacted the economy in the Samaná region. Some residents previously alternated between farming and fishing to secure their livelihoods and income (McCann 1994). Therefore, pressure in the fisheries has increased due to more people having to rely on coastal resources (Lockward and Pozo 1995, Jorge 1997).

Methodology and Research design

Field interviews

We visited ten different communities in the Samaná region, which were recommended by local scientists and fishers (Fig. 2). To assess the LEK and the perceptions of fishers, we interviewed a total of 152 individual fishers who resided in those communities during a 4 week period in the summer of 2011. In accord with the Institute Research Board, before each interview the respondents learned about the purpose of the study, and were given a copy of the informed consent form. Their permission was obtained verbal. This method was chosen to avoid tension or their loss of interest in participating in the survey. Additional field observations and informal conversations took place at fishers' association meetings and capacity building workshops organized by local institutions. When visiting each new community, we first went to docks and landing stations and fishers were approached as they were encountered. Further respondents were identified using snowball sampling; at the end of the survey respondents were asked if they knew of other fishers in their communities (Johnson 1990, Babbie 2010). Each fisher was interviewed separately, and use of their responses in the

CCM is based on the assumption that responses from each fisher are independent and that the questions are of equal difficulty.

Survey Questions

The coastal fishers in the region of Samaná have local ecological knowledge about multiple species occupying diverse habitats, and fish with several gear types (Jorge 1997, Herrera et al. 2011). We asked fishers questions that addressed different aspects of the ecology of each of the main species harvested, such as habitat use, depth distribution, seasonality, predator-prey and host-disease interactions (Table 1). It is believed that the complexity of multi-species fisheries, poses conceptual problems, for ecological management and knowledge assessment alike (e.g. Polunin et al. 1996, García-Quijano 2006). In our case, the interviewed fishers reported catching more than 66 species, with considerable variation among fishers in the species of fish (Appendices A & B) and invertebrates (Appendix C) they targeted most. We selected 8 key species for detailed analysis, because they were singled out by the surveyed fishers as being important commercially during at least one season (Table 2). The fishers' responses to the LEK questions were tabulated separately for each species fished, so sample sizes for the 8 key species varied depending on the number of fishers who considered that species an important target (Table 3). We also asked the fishers descriptive questions about their knowledge and perceptions concerning the establishment of MPAs, the changes in their fishery and factors affecting their fishery (Table 1).

Assessing LEK with Cultural Consensus Analysis

We used cultural consensus analysis (CCA) to assess the degree to which fishers shared a common information pool for LEK (Boster 1984, Romney et al. 1986, Weller 1987), and explored variability and intra-cultural differences among respondents (Garro 1986). CCA uses factor analysis of an agreement matrix calculated from responses to a group of questions and tests whether the respondents' answer pattern is consistent with a shared underlying cultural model. In this study, we consider each harvested species as a separate information domain (Romney et al. 1986; Weller 2007; García-Quijano 2009). Because not all groups of respondents fit the Cultural Consensus Model, we tested the fit of the data on each harvested species to the model using the ratio of the largest eigenvalue (the principal vector) and the second largest eigenvalue (Romney *et al.* 1986 & Weller 2007). An eigenvalue ratio greater than 3, coupled with the absence of negative factor loadings, has been suggested as a threshold indicator of acceptable model fit (Borgatti 1996).

The output of the CCA includes estimates of the cultural correct response for each question asked, and a score for each individual respondent. A negative score, or a negative factor loading, results when an individual provides responses that are different from those culturally shared (Romney et al. 1986) . For the fishers targeting a given species, their factor loading score can be used as an indicator of cultural competence (Romney *et al.* 1986 & Weller 2007). In other words, the cultural competence of each respondent is estimated based on how familiar they are with the knowledge that is shared, representing a shared cultural model of knowledge (Romney *et al.* 1986). In addition to generating the "culturally correct" responses, the CCA also produces a 'weighted frequency' value. For the analyzed group, the weighted frequency represents the number of respondents out of the total that have agreement on the LEK response on a given category. LEK questions with a higher weighted frequency are important because these are indicative of knowledge that is common to the majority of fishers.

LEK Coding Scheme

"I do not know" answers to the LEK questions were assigned a random answer from the possible categories of responses given by the other respondents, simulating a guess by the respondent. This approach has been used by García-Quijano (2006; pers. comm.) to deal with "I do not know" answers in consensus analysis and is consistent within the CCM assumption that the individuals with less knowledge will have less agreement with others (Weller 2007) (See Appendix D for more details on the random replacement).

The Cultural Consensus model was also tested for the effect of coding. We coded the respondents' response to the descriptive LEK questions using three coding schemes with progressively decreasing levels of specificity: hereafter referred to as high, moderate and low specificity answer categories (Table 1, Appendix D). As an example, when classifying species habitat, "coral", "sandy channels" and "octocorals" were categorized individually in the high specificity coding scheme, then two of the responses were clustered together in the moderate scheme (corals and sandy channels), and finally all were grouped into a single category in the low specificity scheme. The coded responses were analyzed using the ANTHROPAC 6.46 software (Borgatti 1996). As expected, the level of specificity of the coding scheme used in the analysis influenced the fit of the data to the model. Lowering the specificity for the classifications generally increased the fit of the CCA model and decreased the number of negative competencies (Table 3 and Appendix D – Table D3).

Relating LEK to perceptions

For the last part of the study, fishers' answers to the questions about knowledge, values and perceptions about the fisheries environment and their management were also coded (Table 1). Knowledge of MPA's or agreement with their establishment responses was binary. Whereas, three categorical responses emerged for the state of the fisheries question, these were "positive", "neutral" and "negative"; this question relates to the fishers' ability to subsist and to provide livelihood for their families. Lastly, for the perceptions on factors affecting their fisheries, multiple responses were given. We tested whether the fishers' responses to these questions correlated with the LEK indicator (competence score) by using two non-parametric procedures: the Spearman's rank order (correlation coefficient), and the Kendall's Tau (coefficient of concordance).

Results

Patterns in Fishers' LEK

We deem 2.75 eigenvalue ratio close to 3, sufficient evidence of conditional independence between factor 1 and 2, evidence of shared knowledge (Borgatti 1996). Using this lower threshold, we found evidence of fit with the CCM for four of the eight key harvested fishes: red snapper, yellow snapper, lobster and shrimp fishers. Details of the analysis of how LEK coding affected the CCA are presented in Appendix D but, in summary, we used the low specificity coding scheme for LEK responses on red snapper, yellowtail snapper and lobster groups, but LEK responses for shrimp better fit the CCM when coded with moderate specificity. We did not find evidence of good fit to the CCM for the remaining four key fish species (yellow jack, kingfish mackerel, white grunt and mahi mahi), so these groups were excluded from further analysis.

A total of 132 fishers targeted the four species that fit the CCM, and 116 fished more than one of those species. The fishers in these four groups had an average age of 45, with a range between 38 – 51 years of age. They had an average of 26 years of fishing experience, with a range between 18 – 33 years. The agreement between fishers of the same group is given by the eigen value ratio (Table 3) the average competence score for a group represents the agreement fishers have on the LEK that they share, this score ranges from 0-1. Fishers targeting lobsters had a higher average competence score than the fishers targeting the other three key species, suggesting that this group perhaps had a more culturally cohesive and greater overall knowledge of their target species than the groups of fishers catching shrimp, red snapper and yellowtail snapper (Table 3).

Based on the level of agreement in response to LEK questions (weighted frequency, Table 4), fishers' level of knowledge was highest when asked about habitat use. This was true for all four key species analyzed. For three of the four groups (red snapper, yellowtail snapper and shrimp), there was also clear consensus about their major predators. Although the lobster fishers' also displayed high agreement in their responses regarding habitat use (33/34), their second highest level of agreement concerned their knowledge of lobster reproduction (29/34) and not their predators (27/34) (Table 4).

Fishers' Perceptions - Knowledge of MPAs and agreement with their establishment

We summarize the perceptions for the analyzed fishers (n = 132) who presented evidence of a shared body of knowledge. In general the majority of the respondents indicated knowing about the MPAs in their region 65% (86/132) knew about the MPAs and 64% (85/132) were in agreement with their establishment. Non-support for MPAs was higher for the red snapper and the yellowtail snapper groups, and some fishers chose not to respond (Table 5).

Perceptions of Factors affecting fisheries and their management

There was consensus among the fishers that gill/seine nets were the factors negatively affecting their fisheries the most. Next, the bottom trawling devices was the second highest negative factor for shrimp group (33%) and weather for the red snapper group (14%); weather was also one of the main factors affecting for the yellowtail snapper (13%) and shrimp (10%) groups. The fishers explained that the gill and seine nets and trawling devices catch fish indiscriminately, targeting juvenile and generating wasteful bycatch; the latter method also destroys bottom substrate that serves as fish habitat. Responses on these perceptions were very diverse, other factors of concern being: the fisheries controlled by overregulation and the presence of compressor divers. In terms of ecological factors affecting fisheries, the fishers mentioned the presence of invasive lion fish as having an impact in their waters (Fig.3).

Perceptions on the State of the Fisheries

The overall consensus on the state of the fisheries was negative, responses ranging from 76% on the Yellowtail Snapper to 52% on the Shrimp group (Fig. 4). The latter group had the highest percentage responding that the state of their fisheries was positive (19%) followed by the Red Snapper (7%). Others responded that the state of the fisheries was in between (23 – 35%), or chose not to respond (Fig.4).

Relationships between LEK and Perceptions of the Fishery

The fishers' perceptions on the management of the fisheries, their knowledge of MPAs and their agreement with their establishment does not correlate with their competence score (Table 6, Fig. 5 & 6). Likewise, their perception on the state of the fisheries and the factors affecting their fisheries does not correlate to their competence score (p-values > 0.05) (Fig.7). Fishers with a high competence score can equally perceive state of the fishery to be distinctively positive (lobster), or negative (shrimp); or fishers with similar competence score are equally likely to respond that the state of their fisheries is "positive", "neutral" or "negative" (Fig.8).

Discussion

Local Ecological Knowledge of Fishers

In our study, half of the studied fisher groups presented a common body of LEK, whereas the other half did not. Groups of fishers with a single shared cultural model of knowledge generally presented a high level of agreement on their responses regarding species habitat. High consensus in knowledge of fish species' habitat is to be expected; as without this knowledge it would be hard to successfully harvest a given species (García-Quijano 2007). Next to habitat, fishers responses to the known fish's predators also presented a high level of agreement (Silvano et al. 2006). An interesting observation was that during the field surveys, the LEK question on the species' main predator in general tended to elicit a visible excitement from the respondents, perhaps a confidence in their knowledge, which could also explain the high agreement on this question. The lobster group, however, second to habitat, had a high level of agreement on the responses about the reproductive period. This is of interest knowing that the lobster fishery is one of the most valued and regulated fisheries in the D.R. (Herrera et al. 2011). The fishers' high level of agreement on lobster reproduction could be associated to their knowledge of the seasonal closure (Jorge 1997), which coincides with the lobsters reproductive period.

Fishers' Perceptions about their fisheries

The fisher's local ecological knowledge does not influence how the fishers perceive the state of their fishery and how it is managed. Already in 1994, thirty one percent of fishers participating in a study in Samaná responded that their fisheries would decline greatly if no changes were made (McCann 1994). Our assumption that fishers who are more conversant with LEK would perceive these negative changes was based on social theories that connect both knowledge, accumulated information, and experiences and social relations that form the people's perceptions (Turner et al. 2014). Alternatively, fishers who are less conversant of knowledge should seek to benefit from social networks, given the uncertainty of the system in which they work (Friket et al. 2000).

In response to the changes that would help the fisheries, in 1994 fishers expressed that having better equipment and prohibiting the use of gillnets would help their fisheries recover (McCann 1994). What is regarded as a recovery preference has been linked to the knowledge of the life history of the fish, that made fishers supportive of MPA (Sawchuk 2012) as well as to the perceived benefits of a protected area, when fishers catch larger fish (Kincaid et al. 2014).

Although most fishers have knowledge of the established MPAs in the region (65%, 86/132), and many are in agreement with their establishment (58%, 76/132), in general, many fishers do not know why MPAs are established (Table 7). Other studies indicate that having knowledge of an MPA, or agreement with their establishment, may be influenced by physical proximity of an MPA to their fishing grounds or their involvement (Scholz et al. 2004, Pollnac and Seara 2011, Kincaid et al. 2014). In the absence of direct knowledge of the purpose of the MPAs, some fishers made the connection between the importance of this area for tourism and for the protection of the Samaná Bay whale sanctuary. They explained their understanding of for the need to conserve and protect these ecosystems. However, some of the fishers responded that they disliked being restricted, explaining that the establishment of the MPAs had negatively impacted them. Others believed that someone gained benefits from the MPAs, and it was not them (Table 7). In contrast, favorable comments of the local fishers regarding the MPAs highlighted the importance of the protected estuaries and their role in increasing the fish productivity in these areas. Like other established coastal programs, lack of inclusion of stakeholders has been associated to programs not being easily accepted by locals (McClanahan et al. 2006). The knowledge of the benefits of an MPA, or efforts to include fishers in local coastal programs, does not change the fact that some of these areas represent traditional fishing grounds and safety nets for the locals. Areas like the inner bays in the National Park of *Los Haitises* represent sheltered areas that are favored for fishing during storms and weather events.

State of the fisheries and factors affecting the fisheries the most

The categorical responses ("positive", "neutral" and "negative") used to describe the state of the fisheries reflects a change from what previously was to the present, as well as to the challenge this entailed for fishers to subsist and to provide for their families. The respondents in our survey explained that in order to fish they required a prior investment for fuel, ice and food; not making a profit, nor breaking even, meant they would go into debt and would have to rely on others. From multiple responses to the descriptive questions on the survey the description of the state of the fisheries varied across the groups when describing the present time (Fig. 5), their response were always "negative" in relation to the past. That is because for the Samaná fishers, fishing in the past was described as having been abundant, close by and taking less time. Positive responses on the present state of the fisheries in our study might be a function of gear type and seasonality. As an example, shrimp fishers responding to the survey in June, after a peak in their rain season, benefitted due to the rich sediment that feeds the bay, whereas line fishers expressed that they were more restricted when it rained and were unable to fish without an exit permit from the Coast Guard during this time.

Fishers expressed that the main factors that have affected their fisheries were the use of gill nets, seine nets and bottom trawling (Fig. 4). They had expressed two decades earlier that their fisheries would recover if gill nets were prohibited (McCann 1994). In recent years, the adoption and deployment of multiple gears –by an individual fisher - is seen as a means to adapt to decreased stocks (Jorge 1997, FAO 2011). For the fishers in Samaná, the majority practiced traditional line fishing (N =109) and near 50% responded that the stated of the fisheries was “negative”; whereas only 28% of fishers that practiced mixed (N = 43) (traditional and destructive fishing) responded with “negative”. The fishers identified gears as destructive if they killed corals, extracted indiscriminately and also affected negatively the traditional practices. Close to half of the line fishers (51/109) believed that nets and trawling devices were negative factors affecting their fisheries, and more than half (26/43) of those who fished using mixed gear (traditional/destructive) agreed. However, in contrast with these responses, other fishers responded that “overregulation” was the factor that affected them the most, or the weather (rain). It is not uncommon for fishers to oppose regulations, especially when this interferes with their obligation to feed their families (Fenner 2012).

Other studies support that the deployment of multiple gear –by an individual fisher - also influences their responses on the state of the fisheries. The use of multiple gear can be seen as an adaptation to decreasing stocks (Chuenpagdee et al. 2003). Access to multiple gears, allows for multiple species to be targeted, in different habitats, allowing for flexibility when one resource becomes scarce (Chuenpagdee et al. 2003).

Some management implications

Understanding the inter-relation and association between LEK and perception can help us understand the knowledge that fishers have (Fig.1), and how they relate to the natural environment. Consensus in our analysis is mainly influenced by the categorical data of habitat and predation; from this we could assume that fishers would perceive conservation of the fish habitats and food webs as being important to sustain their fisheries. Our premises assumed that there would be a direct relationship between people's habitual way of life and their expectations in their societies (Uddin and Foisal 2007) and that fishers who are more conversant in their LEK would have agreement on their perceptions.

The systematic quantification of LEK and coding of categorical responses need to consider the effect of coding and how the specificity level of the data influences the outcome of a cultural consensus analysis. This recording and quantification of LEK brings us closer to the use and integration of fisher's knowledge for management purposes. Unfortunately, not many studies that record LEK are put to use in fisheries sciences (Hind 2015). This omission further challenges the integration of fishers into planning and development efforts needed for effective coastal management programs (Berkes 2009, Raymond et al. 2010a). Active involvement leads to understandings and experiences that shape people's knowledge and perceptions (Kincaid et al. 2014).

The lack of connection between the fishers LEK and their perceptions could be indicative of a divide where the fishers, due to social and political circumstances, operate in different spheres than those that inform the overall population and the management of coastal programs (pers. comm.). It is possible that through shared social and political spheres; and positive experiences in their active participation (Dalton et al. 2012), locals' perceptions of MPAs would result in more congruency. Through stakeholders involvement in the planning of marine protected areas their interest and support is gained (Rodríguez-Martínez 2008). Furthermore, there is an increasing potential for the disassociation of fishers from their social networks. Respondents in our surveys explained that it was difficult to be a member of a fisheries association when you could not be present for the meetings. Fishers are fishing farther out and fishing for a longer period of time. In some cases, fishers also alternated between livelihoods, diversifying their social-networks and decreasing their involvement from one or the other.

To address challenges that limit individuals from accessing social networks and opportunities for knowledge, to engage in experiences, coastal management and extension programs could facilitate process for short-term fishers to learn from long-term fishers, creating forums where groups and individuals interact. Logically, fishers that benefit by catching larger fish after the implementation of a protected area, are likely to agree and support it (Kincaid et al. 2014).

Fisheries and managers could benefit from LEK, learning from local stakeholders the perceptions they have on solutions that can promote recovery of the fisheries. From the earlier assessment in Samaná fishers' already knew that with better equipment their fisheries could be improved (McCann 1994). Improvements at this level could potentially relieve the fishing pressure along the near coast, decrease the amount of fishing time, and serve as an incentive to discontinue the use of destructive fishing gear. Indirectly, reducing time at sea would increase fishers' social network time where perceptions and community cohesion thrives.

Conclusion

We investigated the use of LEK as a tool for understanding the knowledge of the fishers in their communities. Next to demographics, it broadens our description of coastal populations, capturing the diversity of fish that are caught, the gears that are used and the fishing habitats that are targeted; furthermore, we learn of multiple dynamics and adaptations that the fishing communities portray and how people relate to their environment. Next to LEK, perceptions help us understand motivations behind peoples' actions and behaviors; this being essential for sustainable fisheries.

We used the CCA to assess patterns in the cultural models of shared knowledge among the fishers in the Samaná region. With this study we furthered the use of the CCM, by using LEK competence scores as a knowledge indicator to examine possible connections between fishers' local ecological knowledge and their perceptions surrounding the state of their fisheries and their management. Considerations accounted for the effect of coding qualitative data; differences in the CCA were influenced by lowering the specificity of the coding of the responses.

Although groups of fishers share a common body of LEK, the LEK of the fishers is not directly related to how they perceive their fisheries and its management, the presence of cultural shared models of knowledge supports the views that fishers have knowledge about the environments where they fish due to the long-standing relationships they have with the areas that they fish (Silvano et al. 2006, Uddin and Foisal 2007, García-Quijano 2007). Furthermore, the integration of this LEK could help us increase the base of knowledge that is being used in management favoring sustainability (Lubchenco 1998, Ruddle 2008, Silvano and Valbo-Joregnsen 2008), promote the transfer of knowledge (van Kerkhoff and Lebel 2006), and support positive interactions in these processes through the participation of stakeholders (Dalton 2005).

More studies emphasize the need to understand the interactive social – ecological processes that are driving the decline of fisheries (Berkes *et al.* 2000, Frank *et al.* 2005), and the need to consider protected areas as social-ecological systems (Pollnac et al. 2010). Understanding fisher's LEK and testing models that help systematically quantify and analyze qualitative data can strengthen our ability to design and implement more integrated and sustainable coastal management program that take stakeholders into account, conserving the environment within their complex social-ecological context that can benefit the coastal management programs.

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Tables

Table 1.2 Name of the eight species fished in Samaná Bay studied using the CCA and their capture method.

Species Name	**English Common Name**	**Spanish Common Name (in Samaná)**	**Capture Method**
Lutjanus campechanus	red snapper	Chillo, Colorado, Pargo	Line and spear fishing
Carangoides bartholomaei	yellow jack	Jurelete	Line and spear fishing
Ocyurus chrysurus	yellowtail snapper	Colirubia	Line and spear fishing
Scomberomorus maculates	kingfish mackerel	Carite, Guatapanal	Line fishing
Haemulon plumierii	white grunt	Bocayate	Line and spear fishing
Coryphaena hippurus	mahi mahi	Dorado	Line fishing
Panulirus argus	spiny lobster	Langosta	Traps, spear fishing
Penaeus spp.	shrimp	Camarón	Gill net fishing, other nets

Table 2.2 Survey questions used to record fishers' LEK on the species fished and their perceptions on factors affecting their fisheries.

Local Ecological Knowledge (LEK)

1. How would you describe the **habitat** where this species is fished?
2. What are the **depths** or depth ranges where you find this species?
3. During what **time of the year** do you catch this species?
4. During what time of the year would you say this species **reproduces**?
5. Who is the **predator** of this species?

Perceptions	***(Further breakdown)*** ***(Possible Responses)***
1. Do you know of any MPAs in this area?	*(Knowledge)* *(Yes/No)*
2. Do you agree with the establishment of the MPA?	*(Attitude) (Yes/No)*
3. What is the State of the Fisheries where you fish?	*(Perception)* *(Good/In between/bad)*
4. What is the Factor that is affecting the fisheries the most where you fish?	*(Perception)* *(descriptive variables)*

Table 3.2 Demographic information on the fishers represented in the groups found to have measured evidence of shared knowledge, the coding scheme used for the analysis and the cultural consensus analysis results indicating the data's fitness to the model.

	red snapper	***yellowtail snapper***	***lobster***	***shrimp***	***Total Combined***
Fishers	76	53	34	21	116
Average Age	47	51	38	43	45
Average No. of yrs fishing	26	33	18	26	26
CCM Coding level of Specificity	Low	Low	Low	Moderate	◈
No. of Negative Competence score	1	4	0	1	6
Average competency	0.572	0.507	0.605	0.570	0.560
Range in competence	0.07 - 0.88	0.013 - 0.96	0.10 - 0.99	0.13 - 0.95	◈
Eigenvalue ratio	2.752	2.798	3.715	2.776	3

Table 4.2 Local Ecological Knowledge on the four species with fit to the CCM. Responses correspond to the measured shared LEK, or CCM cultural correct responses. The two response categories where fishers had the highest agreement are indicated by the frequency of their responses (or weighted frequencies).

Species	Habitat	Depth	Time of the year caught	Time of the year reproduction	Predators
red snapper (N=76)	Rock bottom with sand, deep channel, corals, mud and soft corals	Wide range from 8-20m, to 66m deep	All Year around	Months from Apr-Dec / Always	barracuda, sharks, kingfish mackerel, yellow jack, barracuda, groupers, manta ray
	2nd/Wtd. Freq. 66				**1st/Wtd.Freq.72**
yellowtail snapper (N=53)	Rock bottom, coral, *Acropora palmata* , soft corals, channels, sand and mud	15-34m deep	All year around / Months mentioned March-Nov.	Cold months: Jan-May / lent	Mix of sharks and fish like: barracuda, kingfish mackerel, red snapper, manta ray
	1st/Wtd.Freq.50				**2nd/Wtd.Freq.48**
lobster (N=34)	Rocks, caves, corals, *Acropora palmata* , seagrass and octocorals	From shallow to great depths / 0.5 - 10m deep	Hot months, from June - Aug	Summer: July-September and May with a thunder	groupers, barracuda, sharks, pufferfish, eels and lion fish
	1st/Wtd.Freq.33			**2nd/Wtd.Freq.29**	
shrimp (N=21)	Soft bottom: mud	From 0-33m deep/ changes: 2-4m (AM) and 24m (PM)	May - August, May is rain season	Warm months, April-Aug / May is the month of the shrimp	yellow jack, barracuda, yellow drum, lady fish, atl. croaker, banana grunt, sea bass and rainbow runner
	2nd/Wtd. Freq. 18				**1st/Wtd.Freq.19**

** All species assessment derive from low specificity coding scheme CCA ouput, with the excetion of Shrimp that had best fit on the moderate specificity coding level.*

Table 5.2 Knowledge of Marine Protected Areas and agreement with their establishment for the 4 groups with shared LEK. Note that a fisher counted within one species group can also fish other species listed, the majority fished more than one species (88%).

	red snapper	***yellowtail snapper***	***lobster***	***shrimp***	***Total Combined***
Fishermen	76	53	34	21	132*
Knowledge of MPAs	53 (70%)	35 (66%)	18 (53%)	13 (62%)	86
Agreement with establishment of MPAs	49 (64%)	30 (57%)	15 (44%)	12 (57%)	76
No Agreement	13 (17%)	11 (21%)	5 (15%)	2 (10%)	21
No response	14 (18%)	12 (23%)	14 (41%)	7 (33%)	35

*The total number of fishers analyzed with the CCA 132, of which 116 fished more than one species

Table 6.2 Correlation Analysis on fishers' perceptions in relation to their LEK and competence score. These represent *Spearman Rho* correlations, *Kendal Tau* coefficient of association values.

Fished Species	*Perception Variable*	***Spearman's rho***	***Kendall's Tau-b***	***Tested pairs***	***p -value***
red snapper (N=76)	Know MPA	0.067	0.056	2701	0.281
	Agree MPA	0.062	0.051	2701	0.298
	State Fisheries	-0.014	-0.012	2701	0.553
	Factors Affecting	0.055	0.028	2701	0.372
yellowtail snapper (N=53)	Know MPA	-0.090	-0.075	1128	0.733
	Agree MPA	-0.206	-0.173	1128	0.923
	State Fisheries	-0.043	-0.034	1128	0.612
	Factors Affecting	-0.112	-0.086	1128	0.785
lobster (N=34)	Know MPA	-0.078	-0.066		0.676
	Agree MPA	-0.043	0.024	561	0.434
	State Fisheries	-0.132	-0.107	561	0.774
	Factors Affecting	-0.176	-0.135	561	0.857
shrimp (N=21)	Know MPA	-0.053	-0.045	190	0.594
	Agree MPA	0.340	0.274	190	0.065*
	State Fisheries	-0.118	-0.083	190	0.687
	Factors Affecting	-0.118	-0.083	190	0.687

* Although non-significant we note that the lowest p-value corresponds to a difference between shrimp fishers agreement or lack of agreement on the establishment of MPAs. Shrimp fishers are generally associated with destructive fishing practices.

Table 7.2 General fishers' understanding of the reasons why Marine Protected Areas are being established. Numbers represent the number of fishers (n = 152) that responded in one way or another.

	#	*Perceptions of why MPAs are established*
First reason	42	Do not know
	29	For conservation and Protection. Protection of Mangroves and historical sites.
	27	To protect fish, fish nurseries, manatee, mammals and to protect the forests.
	25	For tourism.
	14	Protect Whale Sanctuary
	10	For the benefit of someone (Generally refering to the Government)
	1	To restrain poor people.
	4	No response
Second reason	5	To protect the mangroves.
	4	For tourism.
	2	For the finantial benefit of some.
	2	To protect the whales; motor boats disturb them.
	2	For profit; extraction of guano.
	1	For ecosystem services. The value of forests in attracting rainfall.

Figure Legends

Figure 1.2 Representation of the Conceptual Model: Through the understanding of LEK and the perceptions that fishers have, we can understand the connections that exist between knowledge and the perceptions that outline how people relate to their natural environment. Understanding LEK and the connections that exist between knowledge and perceptions can serve for the implementation of effective management programs.

Figure 2.2 Map of the Northeast coast of the DR. Diamond markers indicating the 10 communities visited in 2011: Samaná, Sánchez, Los Cacaos, Las Galeras, Las Terrenas, Miches, Sabana de la Mar, Los Gratinices, Villa Clara and Rincón.

Figure 3.2 Perceptions on the factors that are affecting fishing the most represented by the 4 groups with shared LEK. The main factors are the use of destructive nets and bottom trawling device.

Figure 4.2 Fishers' perceptions on the state of the fisheries for the four groups that fit the CCM and for the total of surveyed fishers. Number '1' in the first two groups, denotes fishers who did not respond in these groups.

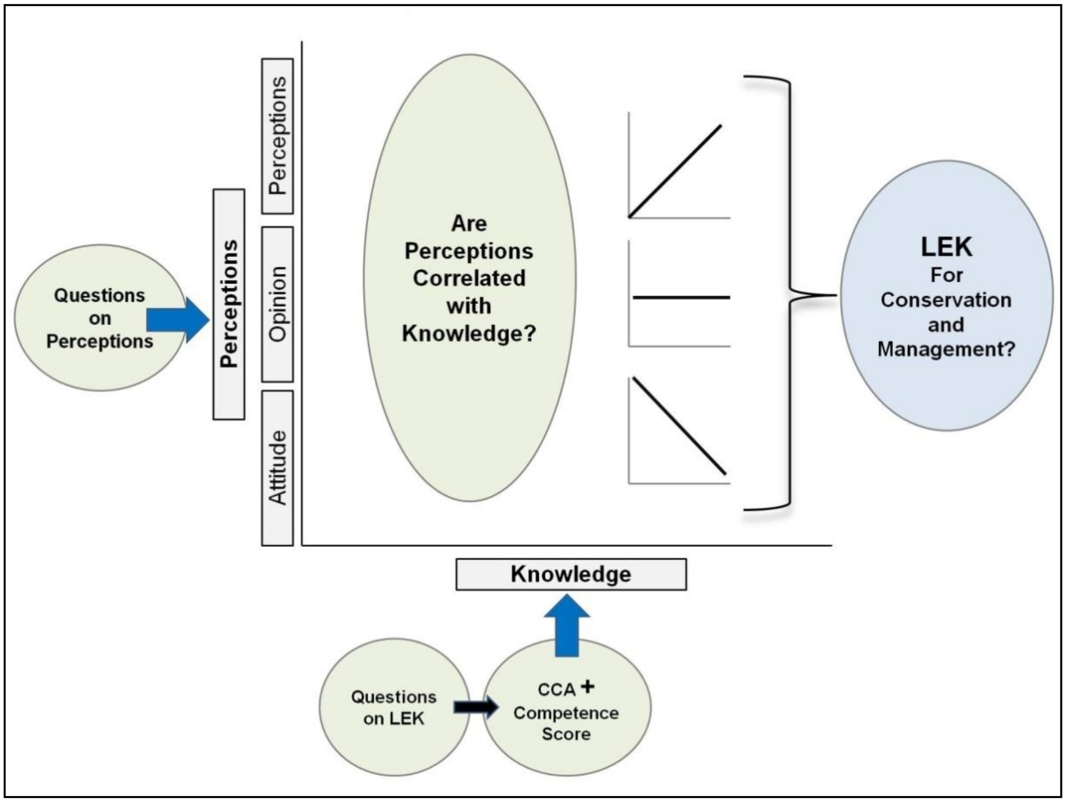
Figure 5.2 Knowledge of the fishers on the MPAs (x-axes) as it relates to their competence score (y-axes). For these binary responses the competence estimates does not influence the fisher's knowledge of MPAs.

Figure 6.2 Fishers' agreement on the establishment of MPAs. Differences are very small, for the snappers fishers with higher competence agreed with the establishment of MPAs, and in the case of lobsters and shrimp, the inverse is observed.

Figure 7.2 Competence score as it relates to the fisher's opinion on the state of the fisheries. Fishers with similar score can invariably respond across all three possible categories, with no distinct pattern (red snapper, yellowtail snapper). Or the high competence score can be associated with perceiving the state of the fisheries to be distinctively positive (lobster) or negative (shrimp).

Figure 8.2 Competence score as it relates to the fisher's perception on the factors that affect their fisheries the most. For the different groups with shared cultural knowledge the factor varies across groups but not always in relation to the competence score. An exception is seen for factors relating to 'contamination', 'divers' being a problem for lobster fishers, or the absence of regulation not affecting the yellowtail snapper fishers.

Figures



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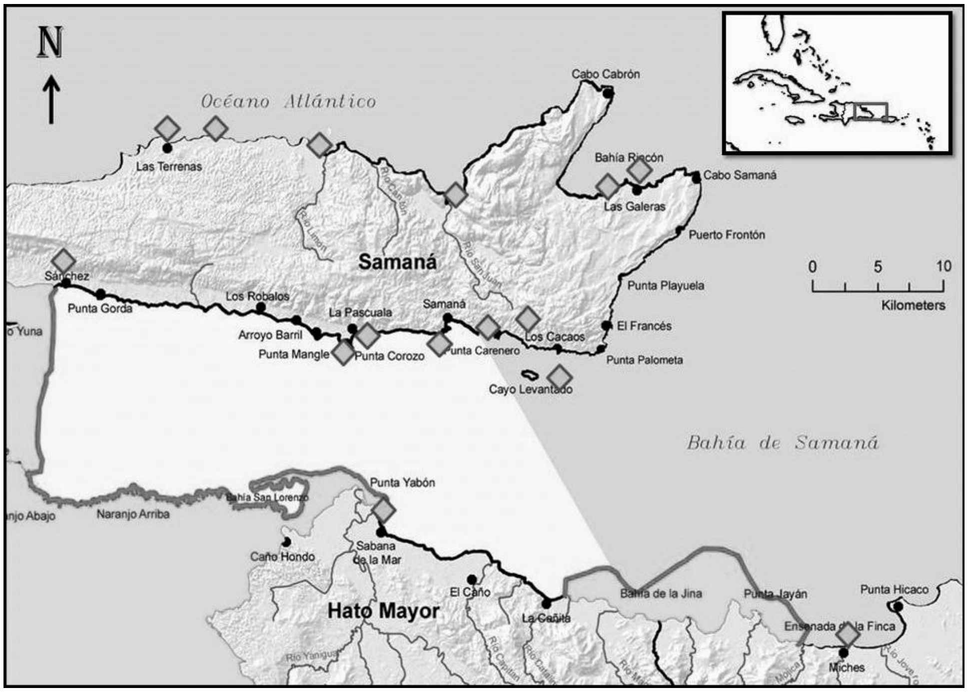

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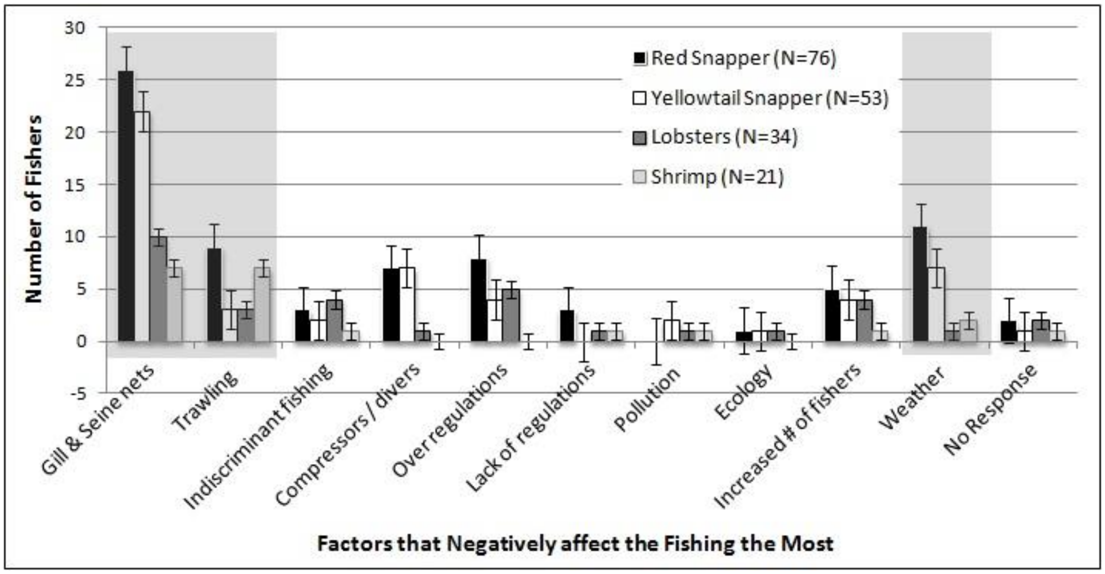

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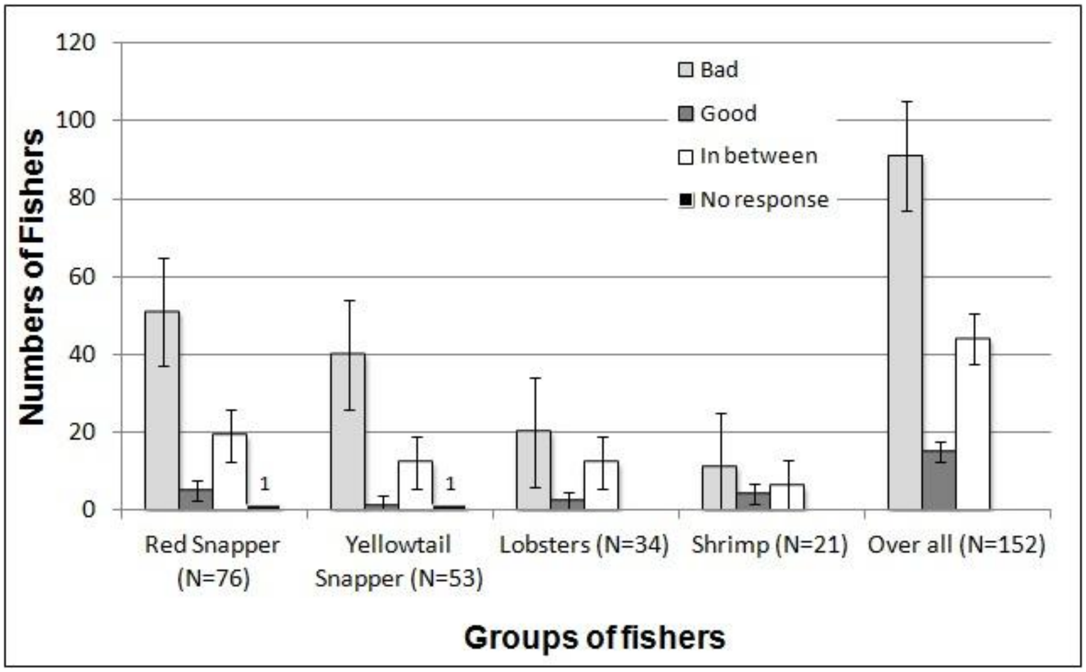

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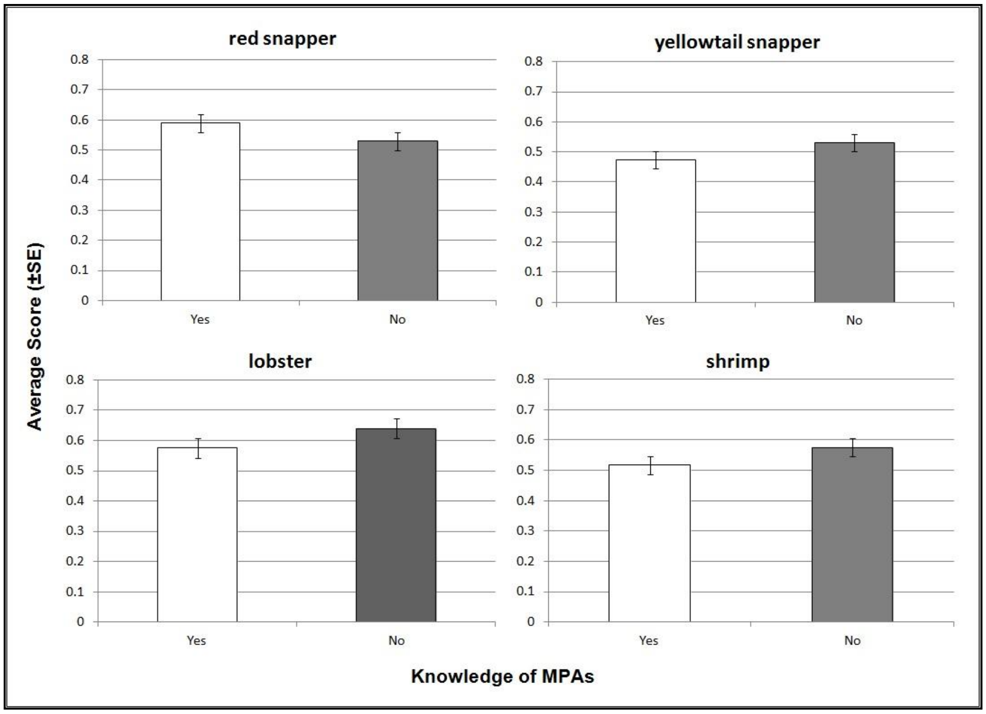

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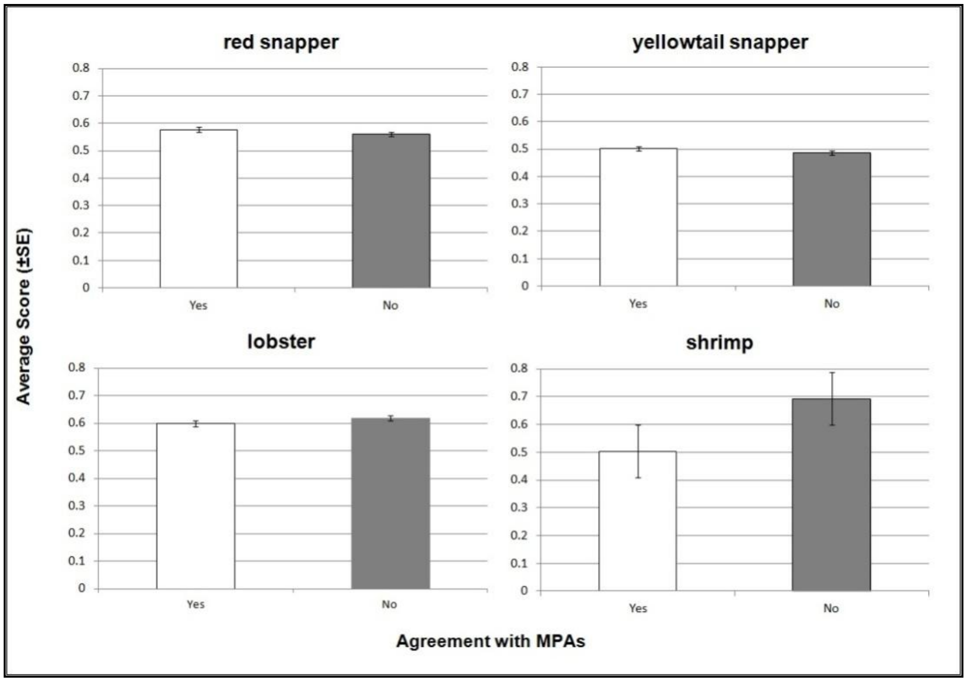

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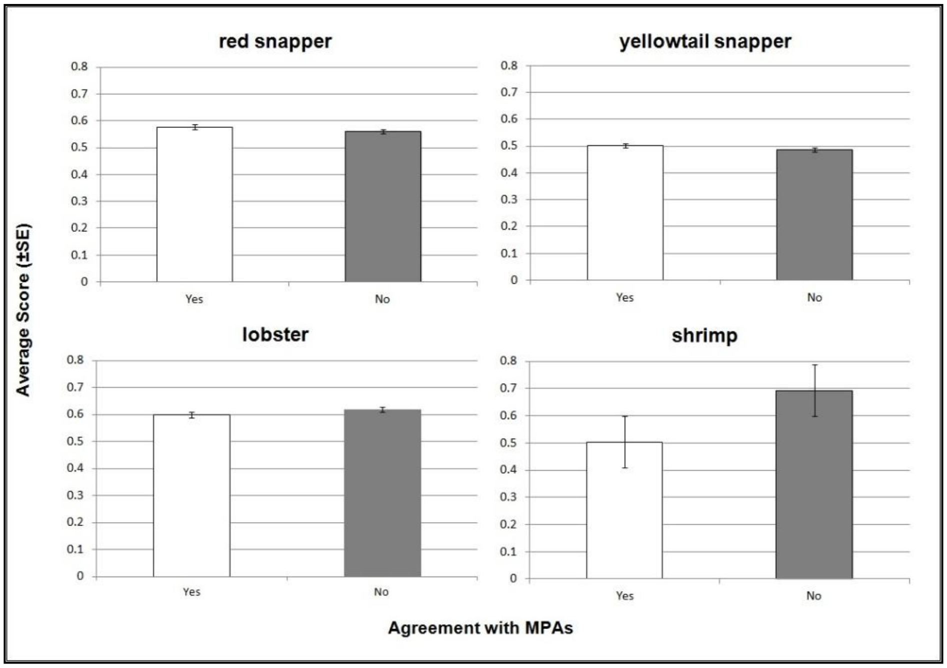

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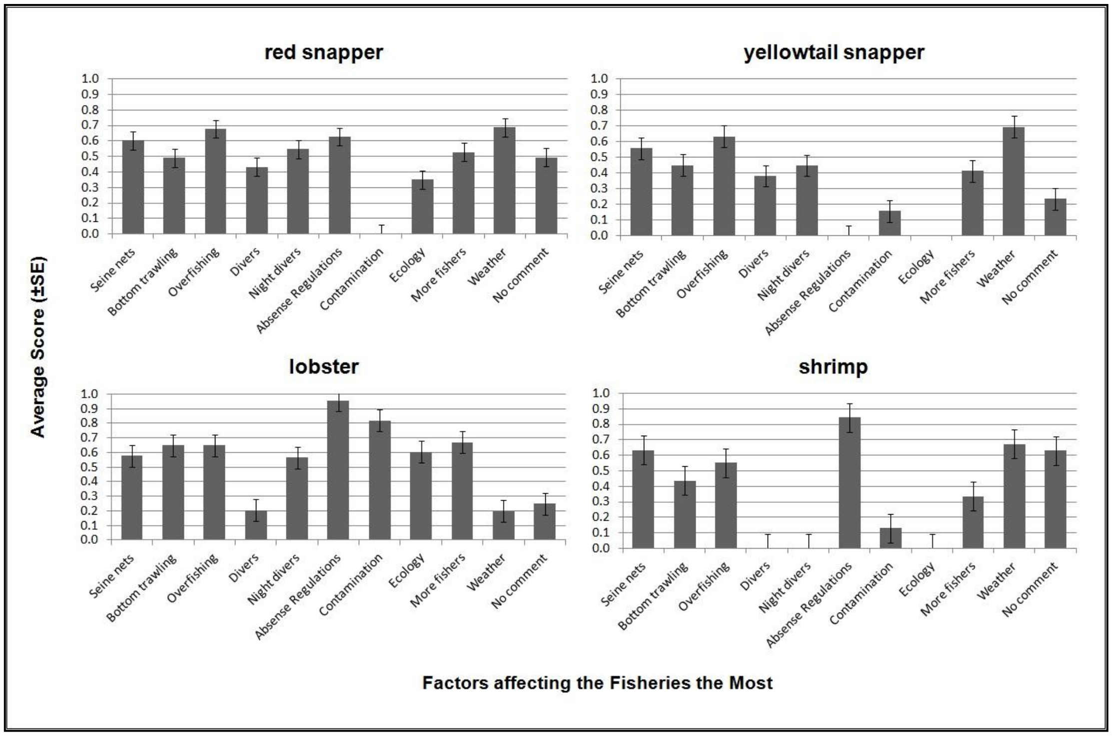

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Appendices

Appendix A.

Table 1. The fisheries in the Samaná region are best described as a multi species fishery. Name and classification of species mentioned during the survey study.

Family	English Common name	Spanish Common name	*Scientific name*
Acanthuridae	surgeonfish	Pez Cirujano	*Acanthurus coeruleus*
Balistidae	queen trigger fish	Peje puerco	*Balistes vetula*
Carangidae	blue runner	Cacona	*Caranx crysos*
			Carangoides bartholomaei
Carangidae	yellow jack	Cojinua	
Carangidae	crevalle jack	Jurel	*Caranx hippos*
Carangidae	skip jack	Jurelete/ Cojinua	*Caranx caballus*
Carangidae	rainbow runner	Macarela / Salmon	*Elagatis bipinnulata*
Carangidae	almaco jack	Medregal	*Seriola rivolaria*
Centropomidae	snook	Espuelu/ Róbalo	*Centropomus undecimalis*
Coryphaenidae	mahi mahi	Dorado	*Coryphaena hippurus*
Elopidae	ladyfish / spanish hogfish	Colvino / Macabi / Boca larga	*Bodianus rufus*
Gerridae	bait fish	Mojarra	*Guerres equulus*
Haemulidae	banana grunt	Banano	*Haemulon striatum*
Haemulidae	white grunt	Bocayate	*Haemulon plumierii*
Holocentridae	squirrel fish	Candil	*Holocentrus adscensionis*
Istiophoridae	blue Marlin	Marlin/ Agujon	*Makaira nigricans*
Lobotidae	atlantic triple tail	Burra	*Lobotes surinamensis*
Lutjanidae	red snapper	Chillo, Colorado	*Lutjanus campechanus*
Lutjanidae	yellowtail snapper	Colirubia	*Ocyurus chrysurus*
Lutjanidae	queen snapper	Chillo doral	*Etelis oculatus*
Lutjanidae	mutton snapper	Sama	*Anoplopoma fimbria*
Lutjanidae	black spot snapper	Pargo, peje de Dios	*Lutjanus ehrenbergii*
Lutjanidae	spotted Rose Snapper	Cojinua rosada	*Lutjanus guttatus*
Megalopidae	tarpon	Sabalo	*Megalops Atlanticus*
Mullidae	white wullet	Lisa , Lebranche	*Mugil curema*
Scaridae	queen parrot	Cotorro, Lora	*Scarus vetula*
Scaridae	guacamallo	Papagallo	*Scarus guacamaia*
Sciaenidae	whitemouth croaker	Dorada	*Micropogonias turnieri*

Table 1 continued

Family	**English Common name**	**Spanish Common name**	***Scientific name***
Serranidae	coney	Mero Arigua	*Cephalopholis fulva*
Serranidae	red hind	Pinto, Cabrilla	*Epinephelus guttatus*
Serranidae	goliath grouper	Cherna	*Epinephelus itajara*
Serranidae	nassau grouper	Mero batata, guasa	*Epinephelus striatus*
Serranidae	dogtooth grouper	Mero gris	*Ephinephelus caninus*
Serranidae	graysby	Mero Criollo	*Cephalopholis cruentata*
Serranidae	yellowfin grouper	Guajil	*Mycteroperca venenosa*
Sparidae	sea bream	Pargo, peje de Dios	*Stenotomus chrysops*
Sparidae	red porgy	Amor de Gallina	*Pagrus pagrus*
Labridae	hogfish	Capitan	*Lachnolaimus maximus*
Sphyraenidae	banded barracuda	Barracuda	*Sphyraena barracuda*
Carcharhinidae	sharks	Tiburon	*(not specified)*
Myliobatidae	spotted eagle ray	Raya	*Aetobatus narinari*
Trichiuridade	atlantic cutlassfish	Machete / Sable	*Lepidopus caudatus*
Sciaenidae	red drum	Corvino	*Sciaenops ocellatus*
Scorpaenidae	red Lion fish	Pez Leon	*Pterois volitans*
Diverse Invertebrates			
Tegulidae	whelk	Burgao	*Cittarium pica*
Strombidae	queen conch	Lambi	*Strombus gigas*
Octopodidae	octopus	Pulpo	*Octopus vulgaris*
Cheloniidae	green sea turtle	Tortuga	*Chelonya mydas*
Thysanoteuthidae	diamond squid	Calamar gigante/diamante	*Thysanoteuthis rhombus*
Loliginidae	squid (normal)	Calamari	*Loligo vulgaris*
Scyllaridae	lobster - slipper	Langosta cucaracha	*Scyllarides latus*
Palinuridae	lobster	Langosta	*Panulirus argus*

Appendix B

Table 1. Names of fish and the localities were the fishers that catch them reside. Surveys conducted during the summers of 2011-2012.

Localities / Year visited

2011

2012

Common name [ENG]	**Miches**	**Villa clara**	**Rincon**	**Gratinices**	**Samana**	**Sabana de la Mar**	**Sanchez**	**Las Terrenas**	**Los Cacaos**	**Las Galeras**	**La Pascuala**	**Aguas Sabrosas**	**El Valle**	**Punta El Corozo**
Surgeonfish												x		
Trigger fish												x		
Blue runner						x	x		x		x		x	x
Yellow Jack				x	x	x	x		x	x				
Crevalle Jack					x		x							
Skip Jack			x	x	x	x	x	x	x		x		x	
Rainbow runner								x						
Almaco Jack					x						x			
Snook							x	x						
Mahi mahi					x	x	x	x	x	x			x	
Ladyfish							x							
Bait fish						x								
Banana grunt						x	x	x	x	x	x	x	x	x
White grunt	x	x	x	x	x	x	x	x	x	x		x		x
Squirrel fish			x	x		x						x		
Blue Marlin			x				x	x	x		x			
Atl. Triple tail						x	x	x	x					
Red Snapper	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Yellowtail Snapper	x	x	x	x	x	x	x	x	x	x	x	x	x	
Queen Snapper					x			x	x		x		x	
Mutton Snapper	x				x	x	x	x		x			x	
Black spot snapper					x									
Spotted Rose Snapper					x						x			
Tarpon							x							
White Mullet						x	x		x					x
Queen parrot	x	x	x		x	x	x	x	x	x		x		
Guacamallo	x							x		x				
Whitemouth croaker					x	x	x	x						x
Kingfish														
Mackerel	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Albacore					x	x	x	x		x	x		x	x
Bluefin tuna					x		x	x	x	x				
Sea bass	x					x	x		x					
Coney					x	x		x	x	x		x	x	
Red hind	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Goliath Grouper					x			x		x	x		x	
Nassau Grouper	x	x	x						x	x				
Dogtooth grouper								x						
grasby					x			x						

Table 1 continued

Common name [ENG]	**Miches**	**Villa clara**	**Rincon**	**Gratinices**	**Samana**	**Sabana de la Mar**	**Sanchez**	**Las Terrenas**	**Los Cacaos**	**Las Galeras**	**La Pascuala**	**Aguas Sabrosas**	**El Valle**	**Punta El Corozo**
Yellowfin grouper								x						
Sea bream	x				x			x						
Red Porgy									x					
Hogfish			x					x		x				
Banded Barracuda			x			x	x			x		x		
Sharks			x			x	x			x				
Spotted Eagle Ray						x	x			x				
Atlantic Cutlassfish		x							x	x				
Red drum		x					x							
Red Lion fish								x						

Appendix C

Table 1. Diversity of fished and collected invertebrates in the Samaná region

Localities / Year visited

	2011													
					2012									
Common name [ENG]	**Miches**	**Villa clara**	**Rincon**	**Gratinices**	**Samana**	**Sabana de la Mar**	**Sanchez**	**Las Terrenas**	**Los Cacaos**	**Las Galeras**	**La Pascuala**	**Aguas Sabrosas**	**El Valle**	**Punta El Corozo**
Whelk						x								
Queen Conch	x	x	x		x	x		x	x	x				x
Octopus	x	x	x					x	x	x				
Green sea turtle							x							
Diamond Squid		x	x						x					
Squid (normal)					x									
Lobster - slipper		x						x						
Lobster	x	x	x		x	x		x	x	x		x	x	x
Crayfish	x					x		x	x					
Shrimp(?)						x	x	x						
Red shrimp						x	x							x
White Shrimp						x	x				x			x
Blue crab						x	x			x				
King crab		x						x		x				
Clams						x	x							
Oyster						x								

Appendix D

Cultural Consensus Model (CCM)

The cultural consensus analysis is a tool used to identify groups with shared knowledge or values (Boster 1984, Romney et al. 1986, Weller 1987). The way in which the CCM works is by determining the Principal Components Analysis of a case-by-case agreement matrix based on answers to a set of related questions, a procedure called Cultural Consensus Analysis (CCA). When the observed clustering of the analyzed data fit the CCM, the factor loadings of individual respondents are considered to be estimates of shared cultural knowledge: this score is the knowledge that a respondent has in relation to the overall responses of the group (Romney et al. 1986). The individual respondents' factor loading scores, are called "competence scores" , these scores explain how close an individual fisher is to the overall "cultural correct" response –this represents the agreement that an individual has with other fishers in the same group (Romney et al. 1986, Weller 2007), in this way the individual fisher's competence score can be related to other social – ecological circumstances (Boster 1984). Under certain assumptions (see García-Quijano 2009), this can safely be understood to represent variation in ecological knowledge of individuals in the population.

For this study, we tested the effects of coding data on the cultural consensus model output. First, the LEK responses were organized and coded using varying coding categorical schemes of progressively higher specificity, from high, moderate to low categories. The categories used to group the informant's responses constitute logical categories, these are explained as follows:

a) High specificity level: categories conserve the diversity of the fishers' responses, the response units are treated as unique with individual categories, and response units are grouped into the same category when they are similar.
b) Moderate specificity level: categories conserve the complexity of the responses while grouping closely related responses into a single category; response units are clustered into logical categories.

Low specificity level: categories cluster possible responses that are scientifically valid keeping distinct responses separately.

The Coding of Local Ecological Knowledge (LEK)

The coding of LEK responses to the questions outlined in Table D1, for the three levels of specificity, or coding schemes, the breakdown into the different categories is explained as follows:

i) Habitat type describes the nature of bottom substrate where given specie is fished. At the high level of specificity these are described as: (1) rocky, coral or hard bottom, (2) mud, (3) sand, (4) mud/sand and rocky, (5) rocky with soft coral presents, (6) soft bottom with sea grass. At the moderate level logical combinations of rocky and other substrate types are combined, and mud and sea grass habitats are kept independent. For the low specificity categories, substrates with rocks and other complexities are grouped together, and the soft bottom (mud/sand) types are kept separate.

ii) Depth categories capture distinct numerical responses of depth (in meters) and also groupings of short ranges of depth, or wide ranges of depth depending on how the fisher responded, noting that some species are equally fished in shallow waters as they are also caught in greater depth.

iii) Time of the year found categories captures the seasonality or non seasonality aspect of when these species are fished, responses can be specific to a month, or groups of months, or in reference to warm/cold times of the years. Some species are caught throughout the entire year, or at varying periods.

iv) Time of the year when species are reproducing categories follows the same logic and sorting as the previous category. In some species the LEK on the time of reproduction is more defined given to either seasonal closures, or time of the year when there is more abundant.

v) Predator categories are done following taxonomical and broader groups, as well as differentiating the main known predators for the different species, the responses are grouped accordingly: a) shark – only, b) shark and fish, c) fish only, d) fish and other taxa (crab, turtle, octopus, etc)

Results on the Effect of Coding

Preceding the CCA, data values with no responses from the fishers were considered. We completed random replacement substitution of “I do not know” in order to generate and use the value corresponding to the average of the total replacements. This step was done in order to optimize the random replacement. Using R-programming software, the code recognized the ‘n/a’ values for the missing responses and randomly inserts one value of the total possible valid responses (Table D2). Next the code allows for a matrix of a 100 worksheets to simultaneously repeat this step, recognizing and replacing the ‘n/a’ and creating an overlay where the known responses are never modified. The stacked worksheets are referred to as a cube. Finally, the code generates a final output that represents the mean values of the cube. The resulting table for each species represented the averaged values for the random substitutions the error and confidence interval 96% were calculated for these tables (Figure D1). The mean and their errors are higher for the two species that had the highest number of respondents, red snapper (76) and yellowtail snapper (53) (Table D3). The initial substitution table corresponded to the high specificity coding table, once the averaged substitution table was obtained; it was coded for both moderate and low specificity schemes respectively.

Different coded levels of specificity influence the output of the CCA. In general, the analyses from high level of specificity had more negative competencies and smaller eigenvalues, and their ratios than the low level and moderate level. And the inverse is seen for the low level of specificity where the eigenvalues and their ratios increased, and the value of some of the negative competencies were reduced. For example, the red Snapper group high level of specificity scheme had nine negative competencies and the largest eigenvalue of 13.0, then for the low coding scheme it only had 1 negative competence and 28.25. The ratio of the eigenvalue increased from 1.75 to 2.75. Higher consensus corresponds mainly for the low specificity coded schemes, with the exception of the shrimp group were the moderate coded scheme fits the model and the low specificity scheme does not. Shared cultural model applied to four groups and were absent in four (Table D4).

Table D1. Collapsing of the coded categorical responses for the Red Snapper species, *Lutjanus campechanus*, responses correspond to the LEK of fishers (see questions outlined in the main paper - Table 1). The coding of the responses is from high specificity to progressively broader and less specific categories.

Specificity Level	***High***	***Moderate***	***Low***
No. Category		***Habitat***	
1	Rocks, corals, channels & pestiles	Rocks, corals, channels, pestiles & sofcorals	Rocks, corals, channels, pestiles, sofcorals & sand
2	Mud / silt / mud holes	Mud / silt / mud holes	Mud / silt / mud holes
3	Sand and sandy channels	Sand and sandy channels	Rocks, mud & seagrass
4	Rocks, mud / corals & sand/ rock channels and mud	Rocks, mud & seagrass	
5	Rocky / Soft corals		
6	Rocks, mud & seagrass		
#		***Depth***	
1	5-10 meters / shallow	5-10 meters / shallow	5-10 meters / shallow
2	13-24 meters	13-24 meters	13-24 m, 2-30 m, 25-66 m, 40-50 m, 50-167 m
3	(Wide ranges) 2-30 meters, 25-66 meters	(Wide ranges) 2-30 m, 25-66 m, 40-50 m, 50-167 m	>167, 668 / open water
4	(Wide ranges) 40-50 meters, 50-167 meters	>167, 668 / open water	
5	>167, 668 / open water		
#		***Time of the year when they are found***	
1	Hot months	Hot months	Hot months
2	Cold months	Cold months	Cold months
3	All the time	All the time	All the time / Variable times
4	Variable times	Variable times / Mar-May	
5	Specific time: Mar-May		

Table D1 continued

Specificity Level	*High*	*Moderate*	*Low*
No. Category	***Time of the year when they reproduce***		
1	Hot months	Hot months	Hot months
2	Cold months	Cold months	Cold months
3	All the time	All the time	All the time / Variable times
4	Variable times	Variable times / Apr-May	
5	Specific time: Apr-May		
#	***Predator***		
1	Sharks	Sharks and elasmobranchs	Sharks, elasmobranchs, mixed predatory fish
2	Sharks and elasmobranchs	Mixed predatory fish, including sharks	Only fish mentioned
3	Mixed predatory fish, including sharks	Groupers	
4	Groupers	Specific fish species	
5	Specific fish species		

Table D2. R-code used for on the red snapper species, random replacement of ‘I do not know’ First code generates a cube array of random replacement 100 times, and second code averages the cube of possible replacements into a single matrix.

Cube array for the random replacement of ‘I do not know’ values

```
n.samples = 100
cube = array(0, dim=c(dim(red2)[1], dim(red2)[2], n.samples))

for(j in 1:n.samples){
red2=redsnapper
n.rep = c(5,4,5,5,6)
for(i in 2:6){
ind= which(is.na(red2[,i])==TRUE)
red2[ind,i] = sample(seq(1,n.rep[i-1]), size=length(ind), replace=T)
 }
cube[,,j] = as.matrix(red2)
}
cube[,,30]
```

Code to average the values of the cube into one single Matrix

```
cube.mean = matrix(0,dim(redsnapper)[1],dim(redsnapper)[2])
for(i in 1:n.samples) cube.mean= cube.mean + cube[,,j]
  cube.mean = cube.mean/n.samples
```

Table D3. Effect of categorical coding scheme of the LEK responses, and the cultural consensus analysis for the eight groups of fished species. As the coded categories become broader the negative competencies decrease and the eigenvalues and their ratio increases. The CCA results for the red snapper, Yellowtail Snapper, Lobster and Shrimp groups are chosen for further analysis.

	banana grunt	**kingfish mackerel**	**red snapper**	**lobster**	**mahi mahi**	**shrimp**	**yellowtail snapper**	**yellow jack**
Mean of cube.mean	4.061	4.525	8.660	5.025	4.174	3.810	6.472	4.405
Error	0.769	0.955	2.825	1.226	0.846	0.750	1.956	1.000
Left	3.292	3.570	5.835	3.798	3.328	3.060	4.516	3.405
Right	4.829	5.480	11.485	6.251	5.020	4.559	8.428	5.405

Table D4. Cultural Consensus Analysis for the groups of fishers in Samaná found to have shared cultural knowledge. Eigenvalue ratio accepted for all ratio's above 2.75.

		Coding Specificity level		
Species Fished	***CCM output***	High	Moderate	Low
white grunt (N=22)	No. neg.comp	4	3	3
	Largest eigenvalue	3.590	4.852	5.613
	2nd eigenvalue	2.732	3.318	3.846
	eigenvalue Ratio	1.314	1.463	1.459
kingsfish mackerel (N=27)	No. neg.comp	10	7	3
	Largest eigenvalue	3.812	4.647	6.872
	2nd eigenvalue	3.053	4.105	5.263
	eigenvalue Ratio	1.249	1.132	1.306
red snapper (N=76)	No. neg.comp	9	2	**1**
	Largest eigenvalue	13.009	17.34	**28.261**
	2nd eigenvalue	7.394	9.927	**10.271**
	eigenvalue Ratio	1.759	1.747	**2.752**
lobster (N=34)	No. neg.comp	3	3	**0**
	Largest eigenvalue	8.501	9.173	**14.691**
	2nd eigenvalue	3.776	4.390	**3.954**
	eigenvalue Ratio	2.251	2.090	**3.715**
mahi mahi (N=24)	No. neg.comp	1	2	0
	Largest eigenvalue	7.343	7.643	9.611
	2nd eigenvalue	3.414	3.755	4.867
	eigenvalue Ratio	2.151	2.035	1.975
shrimp (N= 21)	No. neg.comp	1	**1**	0
	Largest eigenvalue	5.167	**7.535**	8.711
	2nd eigenvalue	2.463	**2.714**	3.630
	eigenvalue Ratio	2.097	**2.776**	2.400
yellowtail snapper (N=53)	No. neg.comp	5	4	**4**
	Largest eigenvalue	11.896	13.612	**19.401**
	2nd eigenvalue	5.932	6.367	**6.935**
	eigenvalue Ratio	2.005	2.138	**2.798**
yellow jack (N=28)	No. neg.comp	8	4	0
	Largest eigenvalue	4.315	5.788	8.094
	2nd eigenvalue	3.15	3.684	3.703
	eigenvalue Ratio	1.37	1.571	2.186

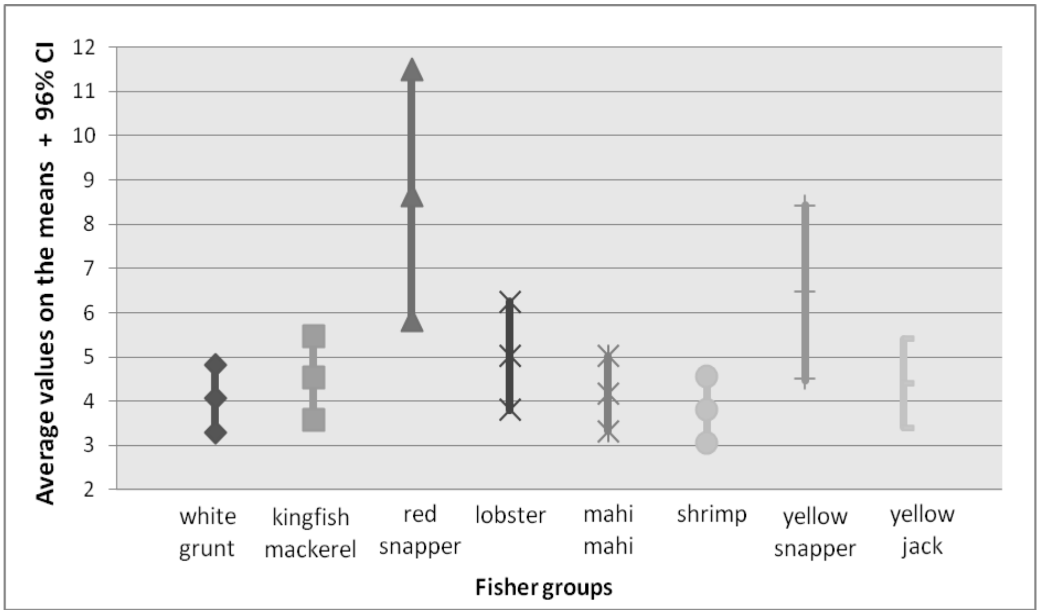

Figure D1. Mean values estimates and 96% confidence intervals for coded random replacement of “I do not know” values for the small categorical scheme. Values were randomly replaced 100 times. Higher values for the red snapper and yellowtail snapper species represent the difference in the ecological knowledge at a multispecies level.

MANUSCRIPT 3

Comparing estimates of size-at-maturity and maximum body size made by fishers and scientists as indicators of potential overfishing

by

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III. Comparing estimates of size-at-maturity and maximum body size made by fishers and scientists as indicators of potential overfishing

Abstract

Coastal artisanal fisheries around the world are reported as exploited and fished unsustainably. As a consequence the need to understand what influences the current fishing patterns is essential. This paper proposes that studying the fishers' local ecological knowledge (FEK) on the size of maturity relative to the size-at-capture, and the maximum body size can be useful as an indicator for overfishing. The fishers' perceptions can also be used to assess the extent to which the fisher's know that they are harvesting sustainably or not. We designed a survey to compile the FEK, and the perceptions on their fisheries. Comparisons on the estimates between size-at-capture and size-at-maturity informed whether the fishers perceived to be catching adults and juveniles; comparisons between the FEK and the science based knowledge (SEK) informed on whether there was agreement between the fishers and the scientist and comparisons on the maximum size known for a given species compared to the maximum body size harvested (FEK) relative to the known maximum size known to scientist informed on whether large fish specimens in a population had declined. Results from the surveys indicate that for 15 species studied, there was relatively little congruence in fishers' and scientists' estimates of SAM, however for the maximum body size there was a consistent pattern of disagreement. Fishers perceived that their catch was comprised of juvenile and adults, when in fact the scientist would have them catching mostly adults. For almost half of the harvested species their perceptions of the catch was that it approached their maximum known body size when scientist would have them catching primarily individuals much smaller than the maximum possible body size (13/15). No relationship was found between fishers' perceptions on the state of the fishery, nor the changes in the fisheries, and the fish size estimates they gave. The majority of the fishers believed their fisheries to be bad and agreed that their fisheries had changed for the worst. These results suggest that the potential for overfishing can be estimated from these comparisons. However, dissimilarities across both forms of knowledge, cautions the use of FEK in the absence of SEK.

Key words: fishers, local ecological knowledge, size-at-maturity, size-at-capture, overfishing, maximum size.

INTRODUCTION

Fishers' knowledge of harvested species can expand the base of knowledge for management

Increased exploitation and ineffective management of some fisheries has resulted in the depletion of fish stocks, and overfishing threatens our ability to sustain fisheries (Hughes 1994, Jorge 1997). The global problem of overfishing requires fishery scientists to expand the approaches they use to advise policymakers (Jackson et al. 2001, Pauly et al. 2002, Worm et al. 2006). Overfishing takes place when the fish recruitment capacity is reduced and when they are caught before they attain their full growth potential (Froese 2004). Incorporating fishers' ecological knowledge (hereafter FEK) into fisheries' science and management is a growing trend that can complement scientific ecological knowledge (hereafter SEK) and diversify the information used to understand a fishery (Johannes 1991; Friket, et al. 2000; Wilson et al 2006; Johannes 2007; Gerhardinger et al 2009; Daw et al. 2011). The scientific community generally views FEK as epistemologically different from Western scientific knowledge; so different that it may not always be comparable to the factual or numerical information typical of Western science (Berkes 1999; Neis et al. 1999; Johannes et al. 2000). Nonetheless, researchers have argued that there are situations in which FEK and SEK can be framed in similar terms for more direct comparison (Neis et al. 1999, Grant et al. 2008, Davis and Ruddle 2010, Le Fur et al. 2011, Duggan et al. 2014). Past studies that incorporated FEK measured several aspects of the ecology of harvested species, including population trends

(Castello et al. 2009, Azurro et al. 2011, Bender et al. 2013) and whether stocks are in decline (Davis et al. 2004, Kay et al. 2012, Katikiro 2014), habitat use and diet (García-Quijano 2009, Boudreau and Worm 2010, Rasalato et al. 2010, de Magalhães et al. 2012), the timing and location of reproduction (Johannes and Hviding 2000; Aswani and Lauer 2006; Fraser et al. 2006; Griffith et al 2013) and migration patterns (Silvano et al. 2006, Grant et al. 2008).

Size-at-capture and size-at maturity as indicators of potential overfishing

Scientists typically use the demography of harvested fishes to assess the current level of fishing (Getz and Haight 1989), to predict future responses to harvesting (Ratner and Lande 2001, Reeves and Pastoors 2007), and to provide advice aimed at preventing overfishing (Hilborn and Stokes 2010). Size-at reproductive maturity (SAM) is a key demographic variable for fisheries scientists because it is used to help predict spawning biomass and recruitment potential of harvested stocks (Cole 1954). In simple terms, harvesting fish before they are mature is also a common indicator of overfishing because it removes individuals before they can make any contribution to future population growth (Salas et al. 2007). Because most fisheries selectively remove large-bodied individuals, the size of fish captured relative to the maximum body size attainable by a species (MS) is also a possible indicator of whether large size-classes have been depleted. Fishers' knowledge of size-at-maturity and maximum body size of harvested species have rarely been assessed (Mackinson 2001). However, collecting such knowledge provides an opportunity to assess fishers' perceptions about the extent to which they are harvesting fish that are juveniles, or are much smaller than the potential size reached by that species. This information may influence whether the fishers themselves judge the fishery to be sustainable, and may provide a valuable addition to the base of knowledge that informs fisheries management.

Objectives

We studied a small-scale artisanal fishery to look closely at the relationships between FEK and SEK, in order to understand if, and why, they produced similar conclusions about the potential for overfishing. We examined relationships between the following variables: (1) fishers' statements about the typical size-at-capture of targeted species (SAC), (2) fishers' estimates of size-at-maturity for the species they harvested (FEK-SAM), (3) scientific estimates of size-at-maturity for the same species (SEK-SAM), (4) fishers' estimates of the maximum possible body size of targeted species (FEK-MS), (5) scientific estimates of the maximum possible body size of the same species (SEK-MS).

Comparing fishers' (2) and scientific (3) estimates of size-at-maturity is a direct comparison of whether the two sources of knowledge are congruent and also a test for whether the two groups might agree on the potential for overfishing. Comparing fisher's estimates of size-at-capture (1) and size-at-maturity (2) can clarify fishers' perceptions about whether they are catching mostly juvenile or adult fishes. If fishers are catching mostly juveniles and believe that fishing juveniles is unsustainable, this may shed light on whether fishers perceive the species as overfished. Using similar logic, comparing scientific estimates of size-at-maturity (3) and size-at-capture (1) is test of whether scientists would conclude that fishers are catching mostly juvenile or adult fishes, with corresponding implications for sustainability.

We applied similar logic to comparisons of fishers' (4) and scientific (5) estimates of maximum body size. Comparing estimates of typical size-at-capture (1) to estimates of maximum body size (4 and 5) is a second indicator that fishers and scientists may use to judge the potential for overfishing. If fishers are harvesting individuals much smaller than the estimated maximum possible body size for that species, this is a potential indication that the fishery is depleted.

Characteristics of the fishery

We studied the fishery in Samaná Bay, on the North East Coast of the Dominican Republic. This small-scale artisanal fishery, like many tropical coastal fisheries, is decentralized and fishers in the region reside in many small communities spread along the coastline (See Map - Appendix A). The local ecological knowledge of the fishers is transmitted across generations, and also acquired directly through years of observation and experience. Fishers' local knowledge is not limited to fisheries alone because the majority of Dominican fishers also engage in activities other than fishing to generate income (Herrera et al. 2011). Other important livelihoods are agriculture, cattle ranching, mining and tourism (McCann 1994).

Fishers in this region, like those in many tropical coastal fisheries, now catch multiple species and may use several fishing methods (Jorge 1997, Sang et al. 1997). Diverse new gear types have been adopted over the past 40 years (FAO 2001; Herrera et al. 2011), possibly as a response to the growth of the fishery and depletion of stocks (Colom et al.1994; SERCM 2004; Herrera et al. 2011). Most fishers accumulate knowledge of several harvested species, but the particular species with which they become familiar varies depending on where they live, the gear type(s) they use and habitat(s) where they fish. This is a valuable case study for comparing FEK and SEK, and its implications for management, because fishers live in close connection with their environment and their experiences builds on a diverse body of FEK. At the same time, resources to collect SEK and develop scientifically based management plans are limited (Herrera et al. 2011).

METHODS

Surveying fishers ecological knowledge and perceptions

Fishers' knowledge and perceptions were studied during a one-month trip to the Samaná region in the summer of 2012. We interviewed a total of 82 fishers who resided in 10 coastal communities (Appendix A & B). In each community, we first went to beaches, docks and landing stations, and fishers were approached as they were encountered. Further respondents were identified using snowball sampling by asking initial respondents to recommend other fishers in their community for interview (Johnson 1990, Babbie 2010). Additional observations and informal conversations took place at fishers' association meetings, capacity-building workshops organized by local institutions and at a regional council meeting. Only fishers that were 18 years or older were interviewed.

We completed a structured interview with each respondent, during which we asked a mix of direct questions designed to yield factual responses, plus descriptive questions designed to allow respondents to articulate their perceptions more freely. Data collected using structured interviews are useful to assess trends (Neis et al. 1999) ensuring that the responses can be aggregated. In combination, the questions were designed to capture the fisher's ecological knowledge (FEK), perceptions about the past and present state of the fishery, and about how the fishery is managed. To put these data in context, we also asked fishers about the history of their involvement in the fishery, when and where they fished, and what gear types they used.

Classifying fisher's ecological knowledge

Each fisher was asked to list the species they commonly harvested, and what fraction of their total catch each represented. For each common species, fishers were then asked the size of the fish they typically captured. Some fishers reported the typical size-at-capture as a range of sizes, in which case we analyzed the mean for the given range, whereas others gave a single number. Next, respondents were asked if they knew the size at which the fish reached maturity, and the maximum body size it reached. Fishers reported all sizes as body mass in pounds, which were transformed into grams for analysis.

Classifying fishers perceptions on the state of the fishery

To assess their perception of the status of the fishery, fishers were asked to rate their agreement with each of the following statements using a five-point likert-type scale (1 = strongly disagree, 5 = strongly agree): (1) the present state of the fisheries in my community is bad, (2) the present state of the fisheries in my community is good, (3) the present state of the fisheries in my community is neither good nor bad. Fishers were asked to score their response to all three questions to ensure consistency and symmetry in their responses (i.e. if they strongly-disagreed that state of the fishery was good, we expected them to strongly agree that its state was bad. There was almost perfect symmetry in responses, so answers were coded as good, bad, or neutral.

To assess their perception about change in the fishery, and to separate perceptions on long-term changes from those regarding seasonality, each fisher was asked to rate their agreement with the following statements using the same five-point likert-type scale: (1) the state of the fishery has not changed; (2) changes in the state of the fishery are only seasonal. Fishers were then given the opportunity to explain the reasons for their perceptions of the state of the fishery and why it had changed, from which we created a new variable coded as either changed for the worse, no change, or changed for the better.

Scientific estimates of size-at-maturity and maximum body size

Scientific estimates of size-at-maturity (Lm) and maximum body size were compiled from the online database FishBase (Froese and Pauly 2015) with the occasional addition of data from the primary (Randall 1963) or grey literature (Mancini and Marie-Jeanne 2009). The scientific estimates were all given in body lengths (either fork length or total length in cm), so they were converted to body mass in grams using length-mass regressions in FishBase or published studies (Randall 1963, Froese and Pauly 2015).

Analyses

We are interested in characterizing the responses of fishers' as a group, rather than studying differences among individuals, so we calculated the mean and 95% confidence interval (CI) of the fisher's responses about SAC, SAM and MS for each species. Two estimates were judged to be similar if the 95% CIs for the means overlapped, and different if the 95% CIs did not overlap. The scientific estimates of SAM and MS were single values, so congruence between FEK and SEK was assessed based on whether the SEK value fell within 95% CI of the FEK estimate.

Because sample sizes were small for some fish species, we wished to check whether means and 95% CIs were reasonable measures of central tendency and dispersion of the samples respectively. We therefore also calculated the median and 95% CI the fisher's responses about typical size-at-capture, size-at-maturity and maximum body size for each species. Medians and CIs for FEK estimates were compared to SEK estimates as a simple empirical check of whether the patterns of results were similar to those based on means. Apart from subtle differences in the results for a few species (Appendix C), the pattern of results was similar for means and medians, so we report only the means.

To determine whether FEK was associated with perceptions on the state of the fishery, we used one-way analyses of variance (ANOVA) to test whether estimates of size-at-capture, size-at- maturity and maximum body size (three separate dependent variables) differed among fishers who perceived the state of the fishery as good, bad or neutral (the categorical independent variable). This gave a total of 45 one-way ANOVA tests (15 species x 3 dependent variables). We also tested whether the same three FEK size estimates (SAC, SAM, and MS) differed according to whether fishers perceived that the fishery had changed for the worse, not changed, or changed for the better (the independent variable). This gave another 45 one-way ANOVA tests (15 species x 3 dependent variables). To account for multiple tests, we used the Bonferroni correction to keep the family-wise error rate at 0.05 (tests were judged significant if $p < 0.05/90 = 0.0005$).

RESULTS

Characterizing the fishery

The fishers in the Samaná region belong to a long-standing traditional fishery that has endured decades of changes. Most of the surveyed fishers began fishing at a young age (14 years). Their average age at the time of survey was 48 [range 24 – 76 years], and they reported an average of 35 years fishing experience (Appendix B). Multiple gear types were in use. Line fishing, skin diving, long lining, the use of traps, and the collection of invertebrates represent traditional artisanal fishing methods. Newer gear types included compressors, gill nets, and bottom trawling devices, and the fishers generally characterized these gears as being more destructive than traditional methods (Appendix D). The traditional line fishing was the most common gear type used by 30% (N = 25) of the surveyed fishers, followed by the combined use of line and nets by 23% (N =19), and other combinations that included fishing lines and compressor diving by 12% (N = 11), or fishing lines and long lining by 11% of the fishers (Appendix D).

The majority of the respondents (59% N = 48) were characterized as specialist fishers who relied only on fishing for their livelihood, whereas 41% (N = 34) were part time fishers who also had other sources of food or income. Seventy two respondents (88%) fished commercially and reported making an average of 86% of their total livelihood from fishing (Appendix B). All of the fishers provided FEK for multiple target species [mean = 5 species, range 2-10 species caught]. FEK was provided for 52 species, but we used only the 15 most commonly harvested species in the comparisons of FEK and SEK (Table 1).

Comparing fishers' and scientists' estimates of size-at-maturity

Across the 15 species studied, there was relatively little congruence in fishers' and scientists' estimates of SAM (Table 2). For four species, the 95% CI for the mean FEK estimate fell below the SEK estimate, for six species the 95% CI for the mean FEK estimate was above the SEK estimate, and for the remaining five species the 95% CI overlapped the SEK estimate (Table 2).

Comparing fishers' and scientists estimates of maximum body size

Maximum body size estimates showed a more consistent pattern of disagreement between fishers and scientists (Table 2). For nine of the 15 fish species, the 95% CI for the mean FEK estimate fell below the SEK estimate, indicating that fishers' estimate of the maximum attainable size for most species was substantially below that reported by scientists. For three species, however, the fishers' estimate of MS was significantly greater than the scientific estimate, and for three species the two MS estimates overlapped (Table 2).

Size-at-capture relative to size-at-maturity: comparing fishers and scientists estimates

We used size-at-capture relative to size-at-maturity as an index of whether the catch is dominated by juvenile fishes, by adults, or by a mixture of the two. Because fishers and scientists often had different estimates of size-at-maturity for a given species, comparing these estimates to SAC often produced differing estimates of the representation of juveniles and adult fish in the catch. For almost all target species (13 of the 15), comparing fishers estimates of SAC to SAM yielded the perception that the catch was comprised of both adults and juveniles because the 95% CIs for estimates of SAC and SAM overlapped (Table 3). Comparing SAC to scientific estimates of SAM yielded a very different general pattern. For most species (11 of the 15 species), the 95% CI for estimated SAC was greater than the scientific estimate of SAM, yielding the conclusion that the catch was comprised primarily of adults (Table 3).

For individual single species, fishers and scientists would come to the same conclusion about the composition of the catch for only 5 of the 15 species (Table 3). For three of those species (blue Runner, albacore, and yellow Jack) an overlap between the SAC and both estimates of SAM would lead both groups to conclude that the catch was comprised of adults and juveniles (Table 3). For the other two species (whitemouth croaker and mahi mahi), SAC was greater than both estimates of SAM, suggesting that adults dominated the catch (Table 3). For the remaining ten species, fishers and scientists would come to a different conclusion about the composition of the catch by comparing SAC to their estimate of SAM. For virtually all of those species (9 of 10), fishers' estimates of SAM suggest a catch comprised of both adults and juveniles (95% CI for SAC and SAM overlap), whereas scientific estimates of

SAM suggest a catch dominated by adults (95% CI for SAC less than SAM estimate) (Table 3 & Fig. 1).

Size-at-capture relative to maximum size: comparing fishers and scientists estimates

We used size-at-capture relative to maximum body size as an index of the extent to which fishers are catching individuals much smaller than the potential maximum for that species. Because fishers tended to report lower MS estimates than scientists for most species (9 of 15 species), this sometimes led to differing estimates of size-at-capture relative to maximum size (Table 4). For roughly half of the target species (7 of 15), comparing fishers' estimates of SAC to MS yielded the perception that the catch was comprised of individuals approaching the maximum body size for that species because the 95% CIs for estimates of SAC and MS overlapped (Table 4). For the remaining eight species, fishers reported catching fish well below the maximum size for the species (95% CI for SAC below 95% CI for MS; Table 4). Comparing SAC to scientific estimates of MS yielded a very different general pattern. For most species (13 of 15 species), the 95% CI for estimated SAC was less than the scientific estimate of MS, yielding the conclusion that the catch was comprised primarily of individuals much smaller than the maximum possible body size (Table 4). The two exceptions to this pattern were the banana grunt and coney, for which fishers reported typical SAC significantly greater than the scientific estimates of MS (Table 4).

For individual species, fishers and scientists would come to the same conclusion about the size-composition of the catch for roughly half of the 15 species (8 of 15 species). For those eight species, SAC was less than both estimates of MS, suggesting that most fish caught were significantly smaller than the maximum possible for that species (Table 4). For the remaining seven species, fishers and scientists would come to a different conclusion about the composition of the catch by comparing SAC to their estimate of MS. For all seven species, fishers' estimates of MS suggest that individuals close to the maximum possible size are well-represented in the catch (95% CI for SAC and MS overlap), whereas scientific estimates of MS suggest a catch dominated individuals far smaller than the maximum potential size for the species (95% CI for SAC less than MS estimate) (Table 4 & Fig.1).

Fisher's perceptions of state of the fisheries and changes in the fisheries

Direct questions regarding the state of their fishery, resulted in the vast majority responding that the state of the fishery was bad (73%, 60/82). Most (70%, 57/82) fishers also perceived that there had been a change in the fishery, and 86% (49/57) responded that the change had been for the worst.

Relationships between fishers' perceptions about the fishery and their estimates of SAC, SAM and MS

For virtually all of the studied fish species, no relationship was found between fishers' perceptions on the state of the fishery and the three fish size estimates they gave (SAC, SAM, MS)(Appendices E & F). Of the 45 one-way ANOVAs performed, only one yielded a significant result (Fishers' estimates of albacore maximum size differed according to the perception of the state of the fishery). We found a similar absence of relationships between fishers' views on change in the fishery and the three fish size estimates. Of the 45 one-way ANOVAs, again only one yielded a significant result (Fishers' estimates of mahi mahi size-at-maturity differed according to the perception of change in the fishery) (Appendix F).

<u>*DISCUSSION*</u>

Lack of agreement between FEK-SAM and SEK-SAM

One reason to compare FEK & SEK was to test if FEK could be substituted for SEK. In species-rich, data- poor tropical fisheries, estimates of parameters like SAM are often lacking and expensive to obtain. Congruence between FEK and SEK would suggest the possibility of using fisher's estimates as a cost effective alternative. The lack of agreement suggests this is not possible (Table 2, Fig.1). A consistent pattern of differences between SEK and FEK might suggest a simple general hypothesis for the differences. For example, consistently lower SAM estimates by fishers relative to scientific estimates could reflect a life-history shift to smaller SAM in response to overfishing (Trippel 1995, Hutchings and Jones 1998). However, SEK and FEK might differ for many reasons and the lack of a consistent pattern makes it hard to explain the differences between SEK and FEK. Lack of agreement about SAM may reflect different methods to assess SAM. Scientists use systematic collections, coupled with dissections of histological analysis of gonads (Bonar et al. 1989, Kjesbu 1991, Froese and Binohlan 2000, Swenson et al. 2007). Fishers appear to make their judgments from assessments of gonadal appearance and content as the fish are being gutted and prepared, sometimes while still out at sea.

Lack of agreement between FEK-MS- and SEK-MS

The lack of agreement was also the case for the compared FEK & SEK on the maximum body size; the lower FEK-MS was the predominant pattern, only three exceptions were observed where the values overlapped with SEK-MS (albacore tuna, queen parrot and white mullet) that presented overlapping values (Table 2). A simple hypothesis for the lower size estimates would be consistent with the global decline of large size fish in the reef systems (Pandolfi et al. 2003a). The lower FEK-MS can also be explained by the proximity to shore where the fishers fish. We could also infer that only fishers that fish in deeper water or in the out-shore banks would see larger fish, and that coastal and bay fishers that are limited to the near-shore are not seeing the larger fish of the fished species. The over estimation of a fish MS could be explained by different reasons. For example, the stoplight parrotfish, *Sparisoma viride*, that grows more, could be mistaken to be the queen parrot fish, *Scarus vetula*, adult counterpart. In order to address the potential for identification biases while in the field, a photo-ID book was used to validate the fishers' responses for each species. However, morphological similarities more than color distinction can dictate whether the fisher categorizes these differently. Scientists use a systematic classification and validation to guide the ID of one species from the other.

Differing estimates reveal a difference in the perceived composition of the catch

Once more we compare FEK & SEK, looking at how the size estimates define the composition of the catch, so as to determine if FEK can be substituted for SEK. Congruency in the catch composition would suggest that the fisher's size estimates could be used as an index for overfishing; thereby cutting the need and the cost to do extensive field work. The lack of congruency on these comparisons is predicted by the previous differing estimates on the estimates on SAM. Although fishers perceived that their catch was comprised of both juvenile and adults, for the majority of the comparisons the scientists would conclude that the catch was composed of adults (Table 3).

Congruence on the composition of the catch was only found for three species. Generally the MS estimates relative to SAC indicated a decline of the larger size specimens(60%), because the reported sizes at capture were substantially below that reported by scientists (Table 3 & 4, Fig. 1). The exceptions to the observed pattern is seen as an overestimation on the maximum body size by the fishers observed for the banana grunt (*Haemulon striatum*) and the coney species (*Cephalopholis fulvus*). For the coney species, overestimation could be explained by fishers believing the larger species of the goliath (*Epinephelus itajara*) or the nassau groupers (*Epinephelus striatus*) to be the coney's adult counterpart. Similar to the queen parrot, a photo-ID book was used to validate the fishers' responses for each species. These results are in agreement with the science literature that covers the decline of large size fish in the fisheries (Christensen and Guenette 2003, Myers and Worm 2003, Coleman et al. 2004) as well as trends on the catch of juvenile fish in coastal waters. These practices are attributed to fishers targeting nursery areas, or to the use of small mesh size nets (FAO 2011).

Another possible explanation for the reduction of large size fish is the market preference for the "plate size" fish; several fishers explained this common practice was common for red snapper, yellowtail snappers, and other fish. This is documented in the literature as market-driven size selectivity (Reddy et al. 2013) that encourages fishers to catch fish before they grow larger. We care about the composition of the catch because fish that mature can contribute to future population growth (Salas et al. 2007) and the large fish within a population are important from an ecosystem services point of view (Worm et al 2006).

In the Dominican Republic, in response to the decline in the fisheries, and the negative impacts on the populations, closures and regulations are being established. In the US in response to the goliath grouper depletion, a closure was established for the US region in the 1990s (NOAA 1991). Similarly, the goliath grouper fishing was closed and prohibited in the Caribbean starting in 1993 (NOAA 2012). However, enforcement in the D.R. is scarce and our observations confirmed that this grouper continues to be overfished.

Lack of correlation between fisher's size estimates and their perceptions about their fisheries

One of the premises for our study states that a positive relationship between the fisher's size estimates and the perceptions fishers have of their fisheries would indicate that the fishers see the decline in the fisheries, and that they potentially overfish knowingly. With an average of 35 years fishing experience, the majority of the fishers would have stood witness to a time – in their own words – when "fish were bigger, abundant" and they took less effort to catch because they were near. However, out of a total of 90 one-way ANOVA tests only the mahi mahi presented a significant difference observed for the size-at-maturity and the perceptions on the state of the fisheries; fishers who responded that the changes had been for the better estimated the size of maturity to be two times larger than those who responded to the state of the fisheries having changed for the worst (Appendix G). Although, in size estimate comparisons the perceptions may not be associated, other studies on knowledge and perceptions of commercial fishermen that have been looked at in the context of recovery preferences (Sawchuk 2012), or to quantify population abundances (Gandiwa 2012, Beaudreau and Levin 2014), have been successful to complement scientific knowledge.

Perhaps a clearer signal on the state of the fisheries, rather than the association between fisher's size estimates and their perceptions, would be the general responses of the fishers. When responding to the survey, the majority perceived the state of the fisheries to be bad (73%), that their fisheries have changed (70%), and that the changes have been for the worst (86%). These perceptions are in agreement with general decline of fish (Myers and Worm 2003; Pauly et al. 1998; Sala et al. 2004) in coastal areas of the Caribbean where parallel to population growth, resources are becoming more limited (NOAA 2012).

CONCLUSION

In the absence of agreement between FEK and SEK using fish size estimates to (1) determine catch composition, and (2) as an index for the potential for overfishing, so as to reduce the costs of extensive research, would not be possible. At the management level, the differences do outline the need for informing, educating and communicating to the fishers the basic base for the size-at-maturity of the fish they catch, how big they grow, as well as the role that the larger fish play in the ecosystems. However, these efforts would also need to address regulations and the importance of closures and the protection of nursery habitats; enforcement and alternatives that solve for the essential needs of a growing population where anything caught has the potential of being food for someone (McCann 1994). Therefore the common conservation practice of 'throwing the small one back in [the water]' is no longer sustained.

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TABLES

Table 1.3 A list of the 15 harvested species used for the analysis, with the number of fishers reporting FEK about each species (n).

English common name(s)	Spanish common name(s)	Family	Scientific Name	*n*
kingfish mackerel	carite	Scombridae	*Scomberomorus regalis*	54
red snapper	chillo, colorado	Lutjanidae	*Lutjanus campechanus*	46
banana grunt	banano	Haemulidae	*Haemulon striatum*	29
yellowtail snapper	colirubia	Lutjanidae	*Ocyurus chrysurus*	28
mahi mahi	dorado	Coryphaenidae	*Coryphaena hippurus*	17
blue runner	cacona	Carangidae	*Caranx crysos*	17
coney	mero arigua	Epinephelidae	*Cephalopholis fulvus*	10
queen parrot	cotorro, lora	Scaridae	*Scarus vetula*	12
albacore	bonito, bacora	Scombridae	*Thunus alalunga*	11
red hind	pinto, cabrilla	Epinephelidae	*Epinephelus guttatus*	9
goliath grouper	mero batata, guasa	Epinephelidae	*Epinephelus itajara*	7
whitemouth croaker	dorada	Sciaenidae	*Micropogonias turnieri*	8
white mullet	lisa	Mugilidae	*Mugil curema*	6
white grunt	bocayate	Haemulidae	*Haemulon plumierii*	5
yellow jack	cojinua	Carangidae	*Carangoides bartholomaei*	5

Table 2.3 A summary of comparisons between fishers (FEK) and scientists (SEK) estimates of size-at-maturity and maximum body size for each target species. Comparisons indicate whether the 95% CIs overlapped (FEK = SEK) or did not overlap (FEK < SEK and FEK > SEK).

	Comparison of estimates by fishers (FEK) and scientists (SEK)	
Species	**Size-at-maturity estimate (SAM)**	**Maximum size estimate (MS)**
goliath grouper	FEK < SEK	FEK < SEK
whitemouth croaker	FEK < SEK	FEK < SEK
blue runner	FEK < SEK	FEK < SEK
albacore	FEK < SEK	FEK = SEK
red snapper	FEK = SEK	FEK < SEK
mahi mahi	FEK = SEK	FEK < SEK
yellow jack	FEK = SEK	FEK < SEK
queen parrot	FEK = SEK	FEK = SEK
banana grunt	FEK = SEK	FEK > SEK
red hind	FEK = SEK	FEK > SEK
kingfish mackerel	FEK > SEK	FEK < SEK
yellowtail snapper	FEK > SEK	FEK < SEK
white grunt	FEK > SEK	FEK < SEK
white mullet	FEK > SEK	FEK = SEK
coney	FEK > SEK	FEK > SEK

Table 3.3 A summary of comparisons between estimates of size-at-capture (SAC) and size-at-maturity (SAM) as an index of catch composition. For each species, we show the comparison between SAC and fisher's estimate of SAM, and between SAC and the scientific estimate of SAM. Comparisons indicate whether the 95% CIs overlapped (SAC = SAM) or did not overlap (SAC > SAM and SAC < SAM). Comparisons are underlined when SAM estimates by fishers and scientists produce the same outcome.

	Size-at-capture (SAC) relative to size-at-maturity (SAM)	
Species	**Fishers estimate of SAM**	**Scientific estimate of SAM**
goliath grouper	SAC = SAM	SAC < SAM
blue runner	SAC = SAM	SAC = SAM
albacore	SAC = SAM	SAC = SAM
yellow jack	SAC = SAM	SAC = SAM
queen Parrot	SAC = SAM	SAC > SAM
banana grunt	SAC = SAM	SAC > SAM
red hind	SAC = SAM	SAC > SAM
kingfish mackerel	SAC = SAM	SAC > SAM
yellowtail snapper	SAC = SAM	SAC > SAM
white grunt	SAC = SAM	SAC > SAM
white mullet	SAC = SAM	SAC > SAM
coney	SAC = SAM	SAC > SAM
red snapper	SAC = SAM	SAC > SAM
whitemouth croaker	SAC > SAM	SAC > SAM
mahi mahi	SAC > SAM	SAC > SAM

Table 4.3 A summary of comparisons between estimates of size-at-capture (SAC) and maximum body size (MS) as an index of catch composition. For each species, we show the comparison between SAC and fisher's estimate of MS, and between SAC and the scientific estimate of MS. Comparisons indicate whether the 95% CIs overlapped (SAC = MS) or did not overlap (SAC > MS and SAC < MS). Comparisons are underlined when MS estimates by fishers and scientists produce the same outcome.

	Size-at-capture (SAC) relative to maximum size (MS)	
Species	**Fishers estimate of MS**	**Scientific estimate of MS**
blue runner	SAC < MS	SAC < MS
yellow jack	SAC < MS	SAC < MS
red hind	SAC < MS	SAC < MS
kingfish mackerel	SAC < MS	SAC < MS
yellowtail snapper	SAC < MS	SAC < MS
red snapper	SAC < MS	SAC < MS
whitemouth croaker	SAC < MS	SAC < MS
mahi mahi	SAC < MS	SAC < MS
goliath grouper	SAC = MS	SAC < MS
albacore	SAC = MS	SAC < MS
queen parrot	SAC = MS	SAC < MS
white grunt	SAC = MS	SAC < MS
white mullet	SAC = MS	SAC < MS
banana grunt	SAC = MS	SAC > MS
coney	SAC = MS	SAC > MS

Figure Legends

Figure 1. For each species, we plot the fishers' estimate of size-at-capture (FEK-SAC), fishers' estimate of size-at-maturity (SAM-FEK), the scientific estimates of size-at-maturity (SAM-SEK), the fishers' estimates of the maximum possible body size (MS-FEK), and the scientific estimate of maximum body size (MS-SEK). Fishers' estimates are means (± 95% CI).

FIGURES

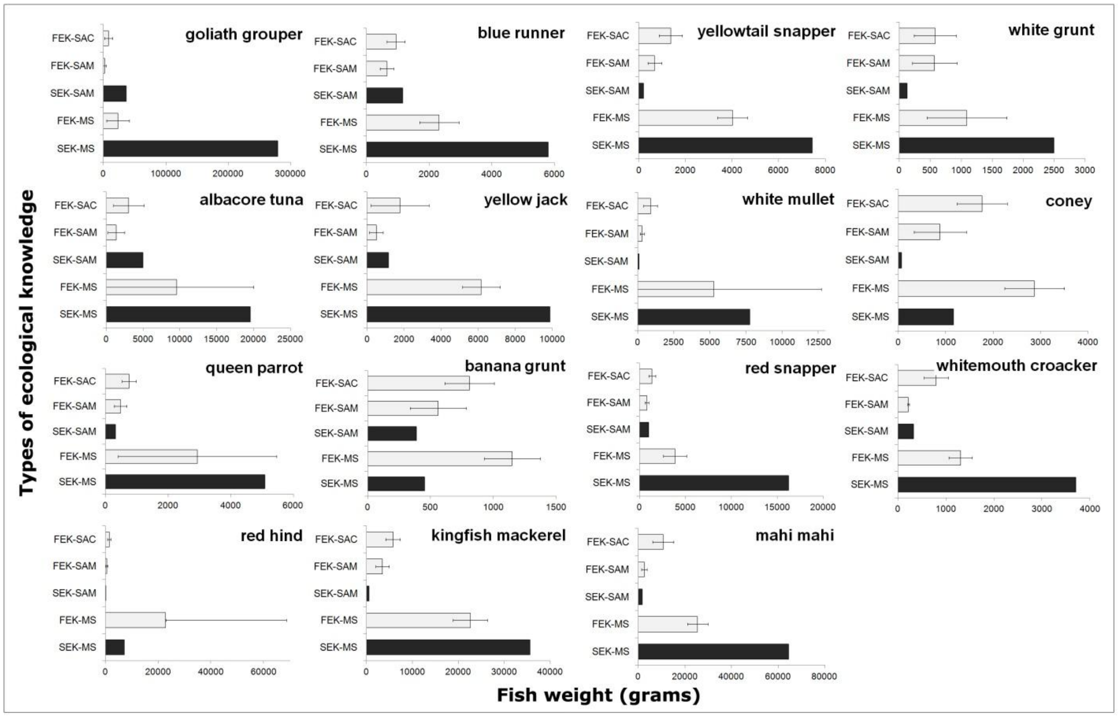

Figure 1.3 For each species, we plot the fishers' estimate of size-at-capture (FEK-SAC), fishers' estimate of size-at-maturity (FEK-SAM), the scientific estimates of size-at-maturity (SEK-SAM), the fishers' estimates of the maximum possible body size (FEK-MS) and the scientific estimate of maximum body size (SEK-MS). Fishers' estimates are means (± 95% CI).

APPENDICES

Appendix A. Map of study area.

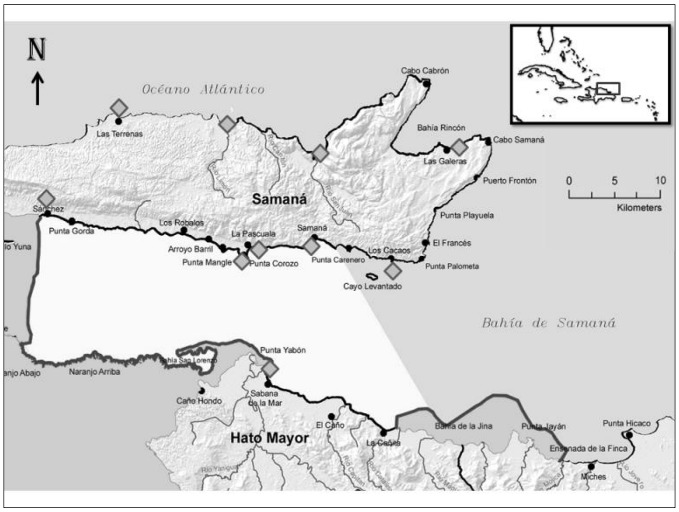

Figure 1. Map of the North East region of the Dominican Republic comprising the Samaná Peninsula. The ten communities surveyed are indicated with the diamond.

Appendix B. Table1. Characteristics of the 82 fishers interviewed in the 10 localities visited.

Locality	N	Mean Age	SE Mean	StDev	Range	No. Commercial fishers	Mean Age Start Fishing	Ave No. Yrs. Fishing	Ave. % Income from Fish.	Ave. % Income other than	Ave. No. hrs fish/wk
Aguas Sabrosas	6	45.5	4.17	10.21	[33 - 59]	6	15.17	30.3	85	30	45.8
El Valle	10	48.6	2.45	7.75	[34 - 60]	10	13.3	35.3	96.7	12.5	37.7
La Pascuala	7	53.29	6.32	16.73	[24 - 76]	7	12.71	40.6	80	40	31
Las Galeras	8	41.38	2.02	5.71	[32 - 50]	7*	13.38	28.0	70.3	47.6	26.5
Las Terrenas	9	56.56	2.51	7.54	[47 - 69]	8*	11.44	45.1	89.4	80	37.7
Los Cacaos	8	46.88	4.57	12.93	[37 - 77]	8	10.13	36.8	71.8	41.3	55.1
Punta Corozo	10	41.7	3.72	11.77	[24 - 62]	10	12.2	29.5	90	45	43.3
Sabana de la Mar	6	46.5	6	14.71	[29 -72]	5*	17.5	29.0	100	*	46.2
Samana	8	52	4.2	11.87	[27 - 63]	5*	15.5	36.5	95	17.5	98
Sanchez	10	49.4	2.47	7.82	[38 - 62]	6*	14.6	34.8	83	16.67	63.3
Total	**82**	**48**	**38.4**	**10.7**	*****	**72**	**13.6**	**34.6**	**86.1**	**36.7**	**48.5**

* Some fishers indicated fishing only for personal consumption

Appendix C. Sample size (means and medians)

Solving for sample size, comparing the size estimates with the means and the medians

In order to remove potential sorting errors due to small group sample size biases, our data summary compared the fisher groups' fishing patterns according to both the mean and the median values of the data and their 95% CI. Fish groups whose patterns changed when comparing the mean sorting with the median are denoted with an asterix (*) (Table 1, 2, 3).

The advantage of using the means is that it uses every value in the calculation, however because it is susceptible to the influence of outliers, we considered the median values. Medians represent the middle score of a set of values arranged in order of their magnitude, because of this it is less affected by skewed data.

Table 1. A summary of the comparisons between fishers (FEK) and scientists (SEK) estimates for size-at-maturity and maximum body size for each target species. Comparisons indicate whether the 95% CIs overlapped (FEK = SEK) or did not overlap (FEK < SEK and FEK > SEK).

	Comparison of estimates by fishers (FEK) and scientists (SEK)			
Species	**Mean size at maturity estimate (SAM)**	**Mean maximum size estimate (MS)**	**Median size at maturity estimate (SAM)**	**Median Maximum size estimate (MS)**
goliath grouper	FEK < SEK	FEK < SEK	FEK < SEK	FEK < SEK
whitemouth croaker	FEK < SEK	FEK < SEK	FEK < SEK	FEK < SEK
blue runner	FEK < SEK	FEK < SEK	FEK < SEK	FEK < SEK
albacore	FEK < SEK	FEK = SEK	FEK < SEK	FEK <SEK*
yellow jack	FEK = SEK	FEK < SEK	FEK < SEK*	FEK < SEK
red snapper	FEK = SEK	FEK < SEK	FEK < SEK**	FEK < SEK
mahi mahi	FEK = SEK	FEK < SEK	FEK = SEK	FEK < SEK
queen parrot	FEK = SEK	FEK = SEK	FEK = SEK	FEK < SEK*
banana grunt	FEK = SEK	FEK > SEK	FEK = SEK	FEK > SEK
red hind	FEK = SEK	FEK > SEK	FEK = SEK	FEK = SEK*
kingfish mackerel	FEK > SEK	FEK < SEK	FEK > SEK	FEK < SEK
yellowtail snapper	FEK > SEK	FEK < SEK	FEK > SEK	FEK < SEK
white grunt	FEK > SEK	FEK < SEK	FEK > SEK	FEK < SEK
white mullet	FEK > SEK	FEK = SEK	FEK > SEK	FEK = SEK
coney	FEK > SEK	FEK > SEK	FEK > SEK	FEK > SEK

*Median patter differs from the mean pattern

** Differences are small

Table 2. A summary of comparisons between estimates of size-at-capture (SAC) and size-at-maturity (SAM) as an index of catch composition. For each species, we show the comparison between SAC and fisher's estimate of SAM, and between SAC and the scientific estimate of SAM. Comparisons indicate whether the 95% CIs overlapped (SAC = SAM) or did not overlap (SAC > SAM and SAC < SAM). Comparisons are underlined when SAM estimates by fishers and scientists produce the same outcome.

	Size at capture (SAC) relative to size at maturity (SAM)			
Species	**Fishers mean estimate of SAM**	**Scientific mean estimate of SAM**	**Fishers median estimate of SAM**	**Scientific median estimate of SAM**
red snapper	SAC = SAM	SAC > SAM	SAC = SAM	SAC = SAM*
blue runner	SAC = SAM	SAC = SAM	SAC = SAM	SAC = SAM
albacore	SAC = SAM	SAC = SAM	SAC = SAM	SAC = SAM
yellow jack	SAC = SAM	SAC = SAM	SAC = SAM	SAC = SAM
queen parrot	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
banana grunt	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
red hind	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
kingfish mackerel	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
yellowtail snapper	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
white grunt	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
white mullet	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
coney	SAC = SAM	SAC > SAM	SAC = SAM	SAC > SAM
goliath grouper	SAC = SAM	SAC < SAM	SAC = SAM	SAC < SAM
whitemouth croaker	SAC > SAM	SAC > SAM	SAC > SAM	SAC > SAM
mahi mahi	SAC > SAM	SAC > SAM	SAC > SAM	SAC = SAM*

* Median pattern differs from the mean pattern

Table 3. A summary of comparisons between estimates of size-at-capture (SAC) and maximum body size (MS) as an index of catch composition. For each species, we show the comparison between SAC and fisher's estimate of MS, and between SAC and the scientific estimate of MS. Comparisons indicate whether the 95% CIs overlapped (SAC = MS) or did not overlap (SAC > MS and SAC < MS). Comparisons are underlined when MS estimates by fishers and scientists produce the same outcome.

	Size-at-capture (SAC) relative to maximum size (MS)			
Species	**Fishers mean estimate of MS**	**Scientific mean estimate of MS**	**Fishers median estimate of MS**	**Scientific median estimate of MS**
yellow jack	SAC < MS	SAC < MS	SAC < MS	SAC < MS
kingfish mackerel	SAC < MS	SAC < MS	SAC < MS	SAC < MS
yellowtail snapper	SAC < MS	SAC < MS	SAC < MS	SAC < MS
red snapper	SAC < MS	SAC < MS	SAC < MS	SAC < MS
mahi mahi	SAC < MS	SAC < MS	SAC < MS	SAC < MS
red hind	SAC < MS	SAC < MS	SAC = MS*	SAC < MS
blue runner	SAC < MS	SAC < MS	SAC = MS*	SAC < MS
whitemouth croacker	SAC < MS	SAC < MS	SAC = MS*	SAC < MS
goliath grouper	SAC = MS	SAC < MS	SAC = MS	SAC < MS
albacore	SAC = MS	SAC < MS	SAC = MS	SAC < MS
queen parrot	SAC = MS	SAC < MS	SAC = MS	SAC < MS
white grunt	SAC = MS	SAC < MS	SAC = MS	SAC < MS
white mullet	SAC = MS	SAC < MS	SAC = MS	SAC = MS*
banana grunt	SAC = MS	SAC > MS	SAC = MS	SAC > MS
coney	SAC = MS	SAC > MS	SAC = MS	SAC > MS

* Median pattern differs from the mean pattern

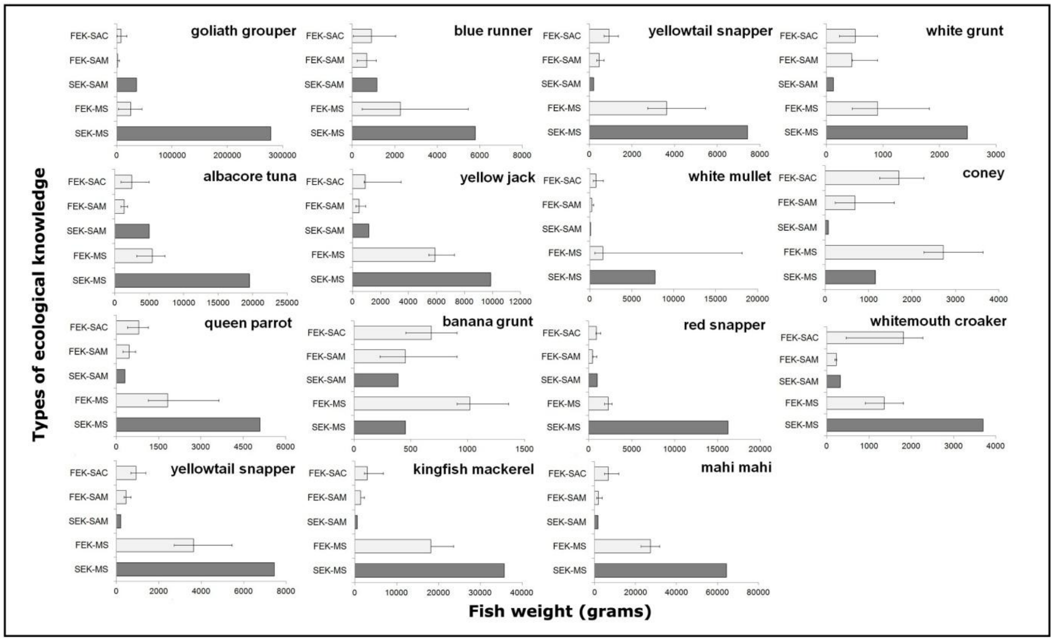

Figure 1. For each species, we plot the fishers' estimate of size-at-capture (FEK - SAC), fishers' estimate of size-at-maturity (SAM-FEK), the scientific estimates of size-at-maturity (SEK-SAM), the fishers' estimates of the maximum possible body size (FEK-MS), and the scientific estimate of maximum body size (SEK-MS). Fishers' estimates are medians (± 95% CI).

Appendix D. Types of gears used by the Samaná Fishers.

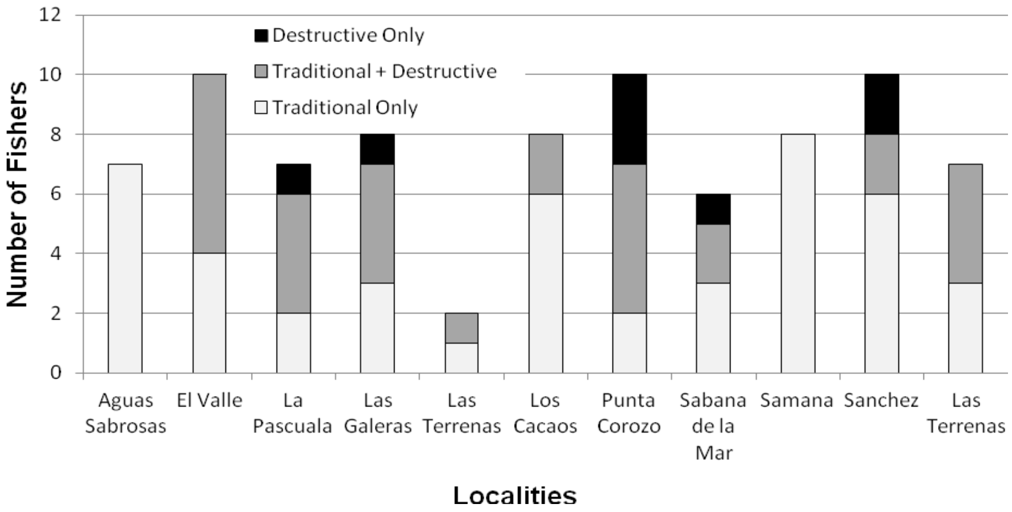

Figure 1. Types of gears used by the surveyed fishers in the 10 localities. Fishers use either traditional or destructive gear or a combination of both.

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Table 1. Characterization of the types of gear used by the localities and characterized by being traditional (non destructive), destructive or a mix of both.

	Traditional Only						***Traditional + Destructive***		***Destructive Only***				
	Line	**Line + Long lining**	**Line + Skin diving**	**Line + traps**	**Traps**	**Other**	**Line + Compres**	**Line + Compressor + Net**	**Line + Net**	**Net**	**Compressor**	**Net + trawling**	**Trawling**
Aguas Sabrosas	4			1	1								
El Valle	3		1				1		5				
La Pascuala	2								4	1			
Las Galeras		2	1				4				1		
Las Terrenas			1						1				
Los Cacaos	2	3	1				2						
Punta Corozo			1			1			5	3			
Sabana de la Mar	2			1					2			1	
Samana	3	4	1										
Sanchez	6						1		1			1	1
Las Terrenas	3						2	1	1				
Total	**25**	**9**	**6**	**2**	**1**	**1**	**10**	**1**	**19**	**4**	**1**	**2**	**1**

Appendix E. State of the fisheries.

Table 1. Comparisons between groups and within groups ANOVA on FEK fish size responses for perceptions on state of the fisheries.

	Sizes	Analysis	Sum of Squares	df	Mean Square	F	Sig.
Kingfish	**SAM**	Between Groups	13385881.19	2	6692940.597	0.296	0.745
		Within Groups	904194496.4	40	22604862.41		
		Total	917580377.5	42			
	SAC	Between Groups	28628967.87	2	14314483.93	0.415	0.663
		Within Groups	1794565375	52	34510872.6		
		Total	1823194343	54			
	MS	Between Groups	306469484.2	2	153234742.1	0.788	0.46
		Within Groups	10108131080	52	194387136.1		
		Total	10414600564	54			
Red Snapper	**SAM**	Between Groups	74895.332	2	37447.666	0.087	0.917
		Within Groups	15122595.23	35	432074.149		
		Total	15197490.56	37			
	SAC	Between Groups	6169562.67	2	3084781.335	1.894	0.163
		Within Groups	68391778.74	42	1628375.684		
		Total	74561341.41	44			
	MS	Between Groups	5651814.634	2	2825907.317	0.157	0.856
		Within Groups	739685538.5	41	18041110.7		
		Total	745337353.2	43			
Banana Grunt	**SAM**	Between Groups	140646.476	2	70323.238	0.366	0.7
		Within Groups	2494666.642	13	191897.434		
		Total	2635313.118	15			
	SAC	Between Groups	1954395.855	2	977197.928	4.547	0.02*
		Within Groups	5587103.965	26	214888.614		
		Total	7541499.82	28			
	MS	Between Groups	63683.194	2	31841.597	0.09	0.915
		Within Groups	8878906.803	25	355156.272		
		Total	8942589.997	27			
Yellowtail Snapper	**SAM**	Between Groups	3717511.831	2	1858755.915	4.043	0.03*
		Within Groups	11494351.79	25	459774.072		
		Total	15211863.62	27			
	SAC	Between Groups	3893140.361	2	1946570.181	1.219	0.313
		Within Groups	39928271.52	25	1597130.861		
		Total	43821411.88	27			
	MS	Between Groups	453691.622	2	226845.811	0.073	0.929
		Within Groups	80396867.81	26	3092187.223		
		Total	80850559.43	28			

Table 1. continued

	Sizes	Analysis	Sum of Squares	df	Mean Square	F	Sig.
Mahi Mahi	**SAM**	Between Groups	23052662.93	2	11526331.47	3.178	0.078
		Within Groups	43526646.39	12	3627220.532		
		Total	66579309.32	14			
	SAC	Between Groups	234644509.1	2	117322254.6	1.642	0.229
		Within Groups	1000220138	14	71444295.6		
		Total	1234864648	16			
	MS	Between Groups	108192716.3	2	54096358.14	0.699	0.514
		Within Groups	1083534803	14	77395343.08		
		Total	1191727519	16			
Coney	**SAM**	Between Groups	1310200.064	2	655100.032	1.379	0.322
		Within Groups	2850435.253	6	475072.542		
		Total	4160635.317	8			
	SAC	Between Groups	212603.893	2	106301.946	0.157	0.857
		Within Groups	4730436.609	7	675776.658		
		Total	4943040.502	9			
	MS	Between Groups	3730855.405	2	1865427.702	6.915	0.028*
		Within Groups	1618532.859	6	269755.477		
		Total	5349388.264	8			
Queen Parrot	**SAM**	Between Groups	45721.267	1	45721.267	0.622	0.456
		Within Groups	514364.256	7	73480.608		
		Total	560085.523	8			
	SAC	Between Groups	426753.476	2	213376.738	2.361	0.156
		Within Groups	722967.538	8	90370.942		
		Total	1149721.013	10			
	MS	Between Groups	6001955.442	2	3000977.721	0.177	0.841
		Within Groups	136009339.6	8	17001167.46		
		Total	142011295.1	10			
Tuna	**SAM**	Between Groups	308618.554	1	308618.554	3	0.333
		Within Groups	102872.851	1	102872.851		
		Total	411491.405	2			
	SAC	Between Groups	41098418.46	2	20549209.23	6.915	0.021*
		Within Groups	15733116.69	6	2622186.114		
		Total	56831535.15	8			
	MS	Between Groups	1443283242	2	721641621.1	228.746	0*
		Within Groups	18928604.63	6	3154767.438		
		Total	1462211847	8			

Table 1. continued

	Sizes	Analysis	Sum of Squares	df	Mean Square	F	Sig.
Red Hind	**SAM**	Between Groups	726539.512	2	363269.756	2.047	0.224
		Within Groups	887278.342	5	177455.668		
		Total	1613817.854	7			
	SAC	Between Groups	884063.565	2	442031.783	0.494	0.633
		Within Groups	5365462.147	6	894243.691		
		Total	6249525.712	8			
	MS	Between Groups	6835500903	2	3417750452	0.954	0.437
		Within Groups	21484617779	6	3580769630		
		Total	28320118683	8			
Goliath Grouper	**SAM**	Between Groups	7361195.461	1	7361195.461	3.236	0.17
		Within Groups	6824970.724	3	2274990.241		
		Total	14186166.19	4			
	SAC	Between Groups	97519348.05	2	48759674.03	0.949	0.46
		Within Groups	205581105.9	4	51395276.48		
		Total	303100454	6			
	MS	Between Groups	526297506.9	2	263148753.5	0.788	0.531
		Within Groups	1002393062	3	334131020.8		
		Total	1528690569	5			
Whitemouth Croaker	**SAM**	Between Groups	639.363	2	319.682	1	0.465
		Within Groups	959.045	3	319.682		
		Total	1598.408	5			
	SAC	Between Groups	39071.109	2	19535.554	0.155	0.86
		Within Groups	630754.6	5	126150.92		
		Total	669825.709	7			
	MS	Between Groups	282900.341	2	141450.17	2.292	0.197
		Within Groups	308618.554	5	61723.711		
		Total	591518.895	7			
Queen Snapper	**SAM**	Between Groups	857273.76	1	857273.76	0.926	0.512
		Within Groups	925855.661	1	925855.661		
		Total	1783129.421	2			
	SAC	Between Groups	7248861.981	2	3624430.991	2.035	0.246
		Within Groups	7123944.948	4	1780986.237		
		Total	14372806.93	6			
	MS	Between Groups	9309993.036	2	4654996.518	4.827	0.086
		Within Groups	3857731.921	4	964432.98		
		Total	13167724.96	6			

Table1. continued

	Sizes	Analysis	Sum of Squares	df	Mean Square	F	Sig.
White Mullet	SAM	Between Groups	4286.369	1	4286.369	0.267	0.633
		Within Groups	64295.532	4	16073.883		
		Total	68581.901	5			
	SAC	Between Groups	107159.22	1	107159.22	0.463	0.534
		Within Groups	925855.661	4	231463.915		
		Total	1033014.881	5			
	MS	Between Groups	48617066.54	1	48617066.54	0.963	0.382
		Within Groups	201974769.5	4	50493692.38		
		Total	250591836	5			
Blue Runner	SAM	Between Groups	73154.028	2	36577.014	0.372	0.704
		Within Groups	589804.347	6	98300.725		
		Total	662958.375	8			
	SAC	Between Groups	229576.022	2	114788.011	0.339	0.718
		Within Groups	4733554.942	14	338111.067		
		Total	4963130.964	16			
	MS	Between Groups	4392267.325	2	2196133.662	1.542	0.248
		Within Groups	19940187.66	14	1424299.119		
		Total	24332454.99	16			
Yellow Jack	SAM	Between Groups	92585.566	1	92585.566	1.08	0.375
		Within Groups	257182.128	3	85727.376		
		Total	349767.694	4			
	SAC	Between Groups	1211044.923	1	1211044.923	0.702	0.464
		Within Groups	5177976.376	3	1725992.125		
		Total	6389021.299	4			
	MS	Between Groups	504076.971	1	504076.971	0.684	0.469
		Within Groups	2211766.301	3	737255.434		
		Total	2715843.273	4			

Table 2 .Post Hoc Multiple Comparisons test - State of the fisheries of the means in the FEK fish sizes.

Fished Species	Variables	A	B	Mean Difference (A-B)	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
banana grunt	SAM	Bad	Good	-113.40	285.33	0.917	-866.78	639.99
		Bad	Neutral	226.80	336.74	0.783	-662.35	1115.94
		Good	Neutral	340.19	399.89	0.679	-715.70	1396.09
	SAC	Bad	Good	-713.69*	251.97	0.023*	-1339.81	-87.56
		Bad	Neutral	182.91	285.30	0.799	-526.03	891.86
		Good	Neutral	896.60*	354.05	0.045	16.82	1776.38
	MS	Bad	Good	-102.60	325.12	0.947	-912.41	707.21
		Bad	Neutral	86.40	367.83	0.97	-829.80	1002.60
		Good	Neutral	189.00	455.16	0.91	-944.74	1322.73
Yellowtail snapper	SAM	Bad	Good	82.71	344.96	0.969	-776.53	941.96
		Bad	Neutral	866.05*	321.99	0.032*	-1668.06	-64.04
		Good	Neutral	-948.76	410.59	0.073	-1971.47	73.95
	SAC	Bad	Good	925.83	642.94	0.336	-675.63	2527.30
		Bad	Neutral	-140.75	600.11	0.97	-1635.53	1354.04
		Good	Neutral	-1066.58	765.25	0.359	-2972.70	839.54
	MS	Bad	Good	-115.92	888.95	0.991	-2324.86	2093.02
		Bad	Neutral	265.13	828.95	0.945	-1794.71	2324.98
		Good	Neutral	381.05	1064.80	0.932	-2264.87	3026.97

Notes mean size differences: banana grunt: SAC – 'bad' (731), neutral (548) good (1444.6) yellow snapper SAM – 'bad' (513), 'neutral' (1379). For the overall 82 surveyed fishers: Of 60 that indicate that the state of the fisheries is bad; 57 say that the fisheries have changed; of these 49 indicate that fisheries have changed for the worst.

Appendix G. Changes in the fisheries.

Table. Between groups and within groups ANOVA on FEK fish size responses for perceptions on changes in the fisheries.

	Sizes	**Analysis**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
kingfish	**SAM**	Between Groups	17651184.06	1	17651184.06	0.804	0.375
		Within Groups	899929193.5	41	21949492.52		
		Total	917580377.5	42			
	SAC	Between Groups	199440282.7	1	199440282.7	6.51	0.014*
		Within Groups	1623754060	53	30636869.06		
		Total	1823194343	54			
	MS	Between Groups	47296499.34	1	47296499.34	0.242	0.625
		Within Groups	10367304065	53	195609510.7		
		Total	10414600564	54			
red snapper	**SAM**	Between Groups	13080.828	1	13080.828	0.031	0.861
		Within Groups	15184409.73	36	421789.159		
		Total	15197490.56	37			
	SAC	Between Groups	45563.70	1	45563.70	0.026	0.872
		Within Groups	74515777.71	43	1732925.06		
		Total	74561341.41	44			
	MS	Between Groups	4319792.87	1	4319792.87	0.245	0.623
		Within Groups	741017560.3	42	17643275.25		
		Total	745337353.2	43			
banana grunt	**SAM**	Between Groups	25833.03	1	25833.03	0.139	0.715
		Within Groups	2609480.09	14	186391.44		
		Total	2635313.12	15			
	SAC	Between Groups	350091.65	1	350091.65	1.314	0.262
		Within Groups	7191408.17	27	266348.45		
		Total	7541499.82	28			
	MS	Between Groups	439805.93	1	439805.93	1.345	0.257
		Within Groups	8502784.06	26	327030.16		
		Total	8942590.00	27			
yellowtail snapper	**SAM**	Between Groups	176353.46	1	176353.46	0.305	0.586
		Within Groups	15035510.16	26	578288.85		
		Total	15211863.62	27			
	SAC	Between Groups	367741.06	1	367741.06	0.22	0.643
		Within Groups	43453670.82	26	1671295.03		
		Total	43821411.88	27			
	MS	Between Groups	2497905.05	1	2497905.051	0.861	0.362
		Within Groups	78352654.38	27	2901950.162		
		Total	80850559.43	28			
mahi mahi	**SAM**	Between Groups	46989379.22	1	46989379.22	31.182	0*
		Within Groups	19589930.1	13	1506917.7		
		Total	66579309.32	14			
	SAC	Between Groups	217072676.6	1	217072676.6	3.199	0.094
		Within Groups	1017791971	15	67852798.06		
		Total	1234864648	16			
	MS	Between Groups	205934.807	1	205934.807	0.003	0.96
		Within Groups	1191521585	15	79434772.31		
		Total	1191727519	16			

Table 1. continued

	Sizes	Analysis	Sum of Squares	df	Mean Square	F	Sig.
coney	**SAM**	Between Groups	20003.054	1	20003.054	0.034	0.859
		Within Groups	4140632.262	7	591518.895		
		Total	4160635.316	8			
	SAC	Between Groups	11573.196	1	11573.196	0.019	0.894
		Within Groups	4931467.306	8	616433.413		
		Total	4943040.502	9			
	MS	Between Groups	1469612.16	1	1469612.16	2.652	0.147
		Within Groups	3879776.10	7	554253.73		
		Total	5349388.26	8			
queen snapper	**SAM**	Between Groups	206460.10	1	206460.10	4.087	0.083
		Within Groups	353625.43	7	50517.92		
		Total	560085.52	8			
	SAC	Between Groups	164391.99	1	164391.99	1.502	0.252
		Within Groups	985329.03	9	109481.00		
		Total	1149721.01	10			
	MS	Between Groups	46760.39	1	46760.39	0.003	0.958
		Within Groups	141964534.7	9	15773837.19		
		Total	142011295.1	10			
albacore tuna	**SAM**	Between Groups	0	1	0	0	1
		Within Groups	411491.41	1	411491.41		
		Total	411491.41	2			
	SAC	Between Groups	3159232.41	1	3159232.41	0.412	0.541
		Within Groups	53672302.74	7	7667471.82		
		Total	56831535.15	8			
	MS	Between Groups	19214362.55	1	19214362.55	0.093	0.769
		Within Groups	1442997484	7	206142497.7		
		Total	1462211847	8			
queen snapper	**SAM**	Between Groups	857273.76	1	857273.76	0.926	0.512
		Within Groups	925855.66	1	925855.66		
		Total	1783129.42	2			
	SAC	Between Groups	5174259.48	1	5174259.48	2.813	0.154
		Within Groups	9198547.45	5	1839709.49		
		Total	14372806.93	6			
	MS	Between Groups	240036.653	1	240036.653	0.093	0.773
		Within Groups	12927688.31	5	2585537.661		
		Total	13167724.96	6			
	SAC	Between Groups	96160.11	1	96160.114	0.296	0.594
		Within Groups	4866970.85	15	324464.723		
		Total	4963130.96	16			
	MS	Between Groups	572041.13	1	572041.13	0.361	0.557
		Within Groups	23760413.86	15	1584027.591		
		Total	24332454.99	16			

Table 2. Post Hoc Multiple Comparisons test on the perceptions on the changes in the fisheries for the FEK mean body size estimates.

	Sizes	Analysis	Sum of Squares	df	Mean Square	F	Sig.
Kingfish	**SAC**	Between Groups	199440282.7	1	199440282.7	6.51	0.014*
		Within Groups	1623754060	53	30636869.06		
		Total	1823194343	54			
Mahi Mahi	**SAM**	Between Groups	46989379.22	1	46989379.22	31.182	0*
		Within Groups	19589930.1	13	1506917.7		
		Total	66579309.32	14			

Note 1: Mean size differences for Kingfish (SAC) “yes” (5197.63 gr.) “no” (12530.48 gr.) mahi mahi SAM: yes (1976.37) no (9071.84).

Note 2: the mean size estimates for those that say there have been “no” changes are catching larger fish and estimating larger size of maturity.

Appendix G. Summary of primary and secondary sources of livelihoods for the surveyed part time fishers in the Samaná region.

Number whose single livelihood is fishing (N = 48)

primary sources of livelihood	***No.***	***%***
Agriculture	28	34
Construction	14	17
Carpentry	3	4
Other	23	28
Other secondary sources of livelihood		
Agriculture	11	13
Coconut plantations	4	5
Tourism	3	4
Other	19	23