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The disconnect between knowledge and perceptions: A study of fishermen's local ecological knowledge and their perception of the state of fisheries and how these are managed in the Dominican Republic

by

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Abstract

Understanding what fishers know about the ecology of the fish they catch, and how they perceive the state and management of their fisheries can guide efforts towards more sustainable fishing practices. We tested relationships between fishers' local ecological knowledge (LEK) and their perceptions of their fisheries and of marine protected areas in the Dominican Republic. A qualitative-quantitative methodological sequence using data from interviews with 152 multi-species fishers revealed variable, but generally high levels of LEK, particularly of habitat use and predator-prey interactions. The majority reported negative perceptions of the state of their fishery and were aware of local management actions. Contrary to study expectations, we found that fishers' LEK, measured by Cultural Consensus Analysis, did not significantly co-vary with their perceptions of the state of fisheries or with their awareness of, and support for, marine protected areas. These results highlight the need to identify and understand barriers to information flow and communication in local fisheries' social/political networks.

Key words: fishers ⋆ local ecological knowledge ⋆ coastal fisheries ⋆ cultural consensus ⋆ perceptions Dominican Republic

Introduction

The widespread failure to sustain fisheries has been attributed to simultaneous effects of overfishing and natural disturbances on fish habitats (Hughes 1994; Pandolfi et al. 2003). Others also cite overlooked social factors surrounding fisheries (McGoodwin 1990; Mascia 2004). These pressures are increasing with a growing dependence on coastal resources (Salas et al. 2007) and mounting uncertainty around subsistence strategies (Hilborn and Walters 2013). In the tropics, a scarcity of scientific data on fish populations and fishing practices renders the current state of fisheries and their management uncertain and fishers' knowledge and perceptions on the state of the fisheries can expand the available data enabling the implementation of strategies to sustain fisheries and conserve ecosystems.

Fishers in coastal communities possess a wealth of local ecological knowledge (LEK) (Johannes et al. 2000). The study of LEK may integrate diverse forms of information including scientific knowledge, beliefs, and lived experiences (Berkes 1999). These are understandings held by a given group of people regarding local ecosystems (Olsson and Folke 2001) that are passed from generation to generation influencing the nature, timing, and location of fishing practices (Johannes and Hviding 2000). The study of traditional ecological knowledge emphasizes attributes of history and cultural continuity, but we consider LEK to also include knowledge related to the exploration and development of new fishing practices as fishers adapt to changing conditions and exploit new opportunities. Our specific focus is knowledge of the ecology of harvested species.

Historically, fishers' knowledge was often ignored (Johannes et al. 2000) and rarely integrated into fisheries science (Hind 2015). The scientific community regarded LEK as less precise and differing from Western scientific knowledge used in fisheries management (Raymond et al. 2010). By ignoring fishers' views, fishery managers risked "missing the boat" (Johannes et al. 2000). Today, LEK serves as a powerful tool to understand coastal communities as social-ecological systems (Salpeteur et al. 2017) to complement scientific research (Paterson 2010; Bender et al. 2014; Turner et al. 2015), and inform management (Haggan et al. 2007; Charlotte et al. 2021; Sjostrom et al. 2021). Other studies addressed the benefits of LEK for conservation and marine protected areas (MPAs) (Lundquist and Granek 2005; Gerhardinger et al. 2009), the importance of fisher's perceptions (Carothers et al. 2014), and understanding levels of agreement amongst fishers (Figus et al. 2017), as well as how participatory approaches are important for fisheries management (Johannes 1991; Sánchez-Jiménez et al. 2019). The benefits of using LEK go beyond understanding the social and social-ecological challenges that small-scale fishing communities face; in some cases, LEK is more cost-effective to obtain (Aswani and Lauer 2006; Macusi et al. 2017) than scientific data, and also increases trust among stakeholders and managers (Wilson 2003).

Although the study of LEK is expanding (Hind 2015) and its value increasingly recognized (Sutherland et al. 2014), its quantification and interpretation remain a challenge. To describe variation (intra- or intercultural) in knowledge, some scientists have employed cultural consensus analysis (CCA), based on the cultural consensus model (CCM) (Romney et al. 1987). Treating culture as a cognitive phenomenon consisting of learned and shared information and behavior, CCA provides a robust and replicable way to test patterns of shared knowledge (Romney et al. 1987; Weller 2007). CCM assumes that knowledge is transmitted socially and intra-culturally distributed to varying degrees in a population based on social, individual, and stochastic factors (Romney et al. 1996, Borgatti and Halgin 2011). Thus, fishers can be assumed to share knowledge based on 1) their common experiences of harvesting and observing local resources, and 2) intracultural and intergenerational communication, both formally (e.g., apprenticeships and socialization as members of a fishing culture) and informally (while fishing) (García-Quijano 2009).

Knowledge and perceptions gained through cognitive and social networks (Olsson et al. 2004; Turner et al. 2014) may also help to explain fishers' behaviors and their decision-making. Perceptions reflect people's understanding of the social and physical world around them and their expectations in their society (Uddin and Foisal 2007). Perceptions — together with beliefs — refer to position-limited information about the state of things or what processes are happening. The understanding of different perceptions and values can both improve management efforts and help solve existing social-environmental conflicts. These values are linked to fishers' understanding of ecosystem services and their support for protecting species habitats (Garcia-Quijano and Valdez-Pizzini 2015).

Study Area

We studied local fishers in Samaná Bay, on the northeast coast of the Dominican Republic (D.R.) (**Error! Reference source not found.**), which supports one of the most important fisheries of the D.R. (Herrera et al. 2011; Ministerio de Economía 2019). Small-scale artisanal fisheries here, like many tropical coastal fisheries, are decentralized and fishers live in small communities along the coastline that rely on coastal resources for both income and food security. Historically, many fishers alternated their livelihood between farming and fishing, but increasing reliance on coastal resources has intensified pressure on fisheries (Partelow et al. 2020). During the mid-1990s, this region experienced an expansion of the fisheries sector, with the adoption of different types of gear and the targeting of multiple species (Herrera et al. 2011). Local fishers' concerns about declining fisheries was documented during this period of expansion (McCann 1994) and continue to the present day (Eastwood et al. 2017).

FIG 1. Map of the Northeast coast of the D.R. 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. The colors representing: ocean (blue), estuarine zone (white), protected national park (orange, and indigo outline), physical landscape with rivers (grey).

In response to overfishing, the national government established MPAs and fishing regulations in the region. The MPAs are managed by the Ministry of the Environment and Natural resources and the National Office for Protected Areas (Herrera et al. 2011; Ministerio de Medio Ambiente y Recursos Naturales 2013). In Samaná, the National Park of Los Haitises was established in 1976, but enforcement of park regulations was implemented only in the 1990s (McCann 1994).

Objectives and Hypothesis

We studied the LEK of fishers in Samaná Bay and how they perceive the state of their fisheries. Specifically, we report on the connections between fishers' LEK and their knowledge and perceptions regarding MPAs, the state of the fishery, and the factors that affect the fisheries. Our goal was to address the following areas:

(1) The nature and content of fishers' knowledge about multiple important fishery species;
(2) How LEK varies intra-culturally among fishers;
(3) How fishers vary in their knowledge and perceptions concerning the establishment of MPAs, the changes in their fishery, and factors affecting their fishery;
(4) Whether fishers' LEK is linked to their perceptions of the state of their fishery and of how the fishery is managed.

Methodology and Research design

Field interviews

We visited 10 different communities recommended by local scientists and fishers as key fishery-dependent communities in the region (**Error! Reference source not found.**). We conducted structured interviews with 152 fishers during summer of 2011. In each community, fishers were approached as they were encountered at the docks and landing stations. The sample of local fishers was enhanced using snowball sampling (Bernard 2006): once an interview was completed, the fishers were thanked and asked if they knew of other fishers to interview.

At the start of each interview, anonymity and privacy statements were explained, and the respondents learned about the purpose of the study. Each respondent received a copy of the informed consent form. Permission was usually obtained verbally (in accord with the University of Rhode Island Institutional Research Board). Each fisher was interviewed separately so that their responses would be independent.

Measuring Local ecological knowledge and Marine Protected Area knowledge

Elicitation and coding

We asked fishers about the ecology of species they commonly harvested (Table 1) and most fishers volunteered responses for several species (mean = 4.5 species per fisher), in total 66 species of fish (Appendix A and B) and invertebrates (Appendix C) from multiple habitats. We selected eight key species for detailed analysis (Table 2) because they were of high value economically and/or for food security. The fishers' responses were tabulated separately for each species, so sample sizes for the eight key species varied depending on the number of fishers who offered information on that species (Table 3). We also asked fishers about their knowledge and perceptions of the establishment of MPAs, the changes in their fishery, and factors affecting their fishery (Table 1). The MPAs in this region are associated to protected national parks (Fig. 1), as well as seasonal whale visits inside the bay.

Fishers used their own words when answering questions about LEK, enhancing access to their cultural insider perspectives (e.g., Goodenough 1970) as expert fishers, rather than selected pre-determined answers, with the tradeoff that coding became necessary for standardizing the responses for CCA. The research team discussed the ecological validity of alternative coding schemes for each question and arrived at a consensus for each (Appendix D, Table D1). "I do not know" answers to the LEK questions were assigned a random answer drawn from the set of responses given by the other fishers, which simulates a guess by the respondent. This approach is consistent with the CCM assumption that less knowledgeable individuals will give a wide range of answers, whereas knowledgeable individuals will converge around "correct" answers (Weller 2007; García-Quijano 2009).

Assessing Local Ecological Knowledge – Cultural Consensus Analysis

We coded the categorical LEK responses numerically and analyzed them using A*NTHROPAC 6.46* software (Borgatti 1996). We used CCA to assess the degree to which fishers shared a common pool of LEK and to quantify variation in LEK among fishers (Romney et al. 1986; Weller 2007). For analytical purposes, we considered the ecology of each harvested species as a separate cultural domain (Weller 2007; García-Quijano 2009). A cultural domain is an area of conceptualization, knowledge, or belief that is culturally shared as a coherent field of thought by a group of people (Weller and Romney 1988; Dressler et al. 2018). The CCA assumes that: 1) respondents collectively share a cultural model regarding the cultural domain under examination, even if they vary in their individual competences, and 2) more knowledgeable individuals will agree more with each other than less knowledgeable individuals (Romney et al. 1986; Weller 2007). For each harvested species, we used the ratio of the largest eigenvalue (the principal vector) and the second largest eigenvalue to test whether the data met these assumptions (ibid.). We deemed eigenvalue ratios above 2.75:1 as providing sufficient evidence of a shared cultural model (see Lacy and Snodgrass 2016) and indicative of conditional independence between factor 1 and 2 (Borgatti 1996).

CCA uses factor analysis to estimate the culturally correct response to each question asked based on the frequency of shared answers. The factor loading score for each respondent (hereafter their competence score) quantifies how closely their answers converge on the culturally correct set of answers and so is considered an indicator of their LEK (Romney et al. 1986; Weller 2007).

Relationship between LEK and perceptions about fishery management

For each harvested species, we coded fishers' answers to questions about their knowledge of MPAs and management into simple categories (Table 1). Responses about knowledge of MPA's and agreement with their establishment were given binary (yes/no) codes, which reflects fishers' understanding of these management initiatives and of whether their values and beliefs result in support (e.g. Stoffle and Minnis, 2007). Responses to questions about the perceived status of the fishery were also simplified to three categories for analysis (positive, neutral, and negative, Table 1). Responses about factors affecting the fisheries were coded into 10 categories corresponding to negative fishing practices, regulations and enforcement, weather related impacts, or negative impacts caused by an invasive species.

For each harvested fish species, we tested statistically whether the fishers' coded responses to questions about MPAs, factors affecting the fisheries, and changes in the fisheries were related to their LEK (competence score). For each question (Table 1), the coded responses were treated as a categorical independent variable (e.g., knowledge of MPAs = yes versus no) and we tested the null hypothesis that mean competence scores were identical among groups using a t-test for binary categories (yes versus no) or one-way ANOVAs for questions with multiple responses (e.g., positive, negative, neutral).

Results

Patterns in Fishers' LEK

We found sufficient evidence of a single shared cultural model for four of the eight key species: red snapper, yellow snapper, lobster, and shrimp (Table 4). Lack of fit to the CCM for the remaining four key species (yellow jack, kingfish mackerel, white grunt, and mahi mahi) led us to exclude these groups from further analysis. A total of 132 fishers targeted the four species that fit the CCM, and 116 fishers reported LEK for more than one of those species. The fishers in these four groups had an average age of 45 (range = 38 – 51) and averaged 26 years of fishing experience (range = 18 – 33).

Competence scores for individual fishers (our proxy for an individual's LEK) ranged from 0 to 1 and average competence scores differed among the four key species analyzed. Fishers targeting shrimp (0.68) and lobster (0.61) had higher average scores than those targeting red snapper (0.57) and yellowtail snapper (0.51), suggesting that knowledge of these two invertebrates was more culturally cohesive than knowledge of red snapper and yellowtail snapper (Table 3). This may be because LEK was reported for many ecologically similar finfish (58 species), but far fewer relatively ecologically distinct invertebrates (8 species) (Table A1).

Based on the level of agreement in response to LEK questions (weighted frequency, Table 4) fishers' level of knowledge was consistently high when asked about habitat use. This was true for all four key species analyzed (red snapper = 59/76, yellowtail snapper = 51/53, lobster = 33/34, shrimp = 21/21). For three of the four groups there was also clear consensus about their major predators (red snapper = 71/76, yellowtail snapper = 49/53, shrimp = 20/21). Lobsters were an exception because although there was good consensus on habitat use (33/34), the second highest level of agreement was about lobster reproduction (29/34) rather than predators (27/34) (Table 4).

Fishers' Perceptions — Knowledge of Marine Protected Areas and agreement with their establishment

The majority of the fishers who presented evidence of a shared cultural model in the CCA (n = 132) indicated knowing about the MPAs (65%). Independent of their prior knowledge of MPAs, most fishers were supportive of MPAs in the area (76%) or had no response (35%), and relatively few disagreed with their establishment (21%). Non-support for MPAs was slightly higher for the red snapper and the yellowtail snapper fishers than those responding about lobster and shrimp (Table 5). This may be related to MPAs imposing a direct geographical constraint on traditional red and yellowtail snapper fishing practices, in contrast to known and well-established closures related to lobster fisheries, as well as easier access to shrimp fishing outside of MPAs. The fishers' perceptions on why MPAs had been established also varied. The most frequent response was no knowledge of why they had been established (28%). Most fishers who stated a reason for MPAs mentioned the protection of fish, nursery habitats, mammals, mangroves and forestland, and historical sites (19%). In the absence of specific knowledge of the purpose of the MPAs, some fishers made the connection between the importance of the area for tourism and for the protection of the Samaná Bay whale sanctuary. Others stated that the MPAs were established to benefit people, but that they were not beneficiaries themselves (Table 7).

Perceptions of factors affecting fisheries and their management

Fishers described multiple factors that they believed were influencing their fishery (FIG 2), but most (69%) mentioned factors related to fishing activity. The use of gill/seine nets was most frequently mentioned as having a negative effect on the fishery (35% of respondents), and trawling (15%) and compressors/diving (7%) were also described as harmful. Fishers explained that gill/seine nets and trawling devices catch fish indiscriminately, targeting juveniles. Trawling was said to damage seabed habitats upon which fish depend. Other fishers (6%) viewed indiscriminate fishing as a problem, without linking it to any one method, whereas others (6%) mentioned an increase in the number of fishers as a problem. Governance factors of concern were the over-regulation of fishing (11%), which affected red snapper, yellowtail snapper, and lobster fishers, or the lack of effective fisheries regulation (2%), which affected red snapper, lobster, and shrimp fishers. Factors unrelated to fishing activity were mentioned less infrequently and included the weather (10%), pollution (3%), and ecological changes resulting from the presence of invasive lionfish (1%) (FIG 2).

FIG 2. Perceptions of the factors that are affecting fishing the most (right) represented by the four groups with shared local ecological knowledge (left). The main factors are the use of destructive nets and bottom trawling.

Perceptions of the State of the Fisheries

The fishers' responses on the state of the fisheries varied across the groups, but all groups tended to describe the past state as "abundant," being able to fish "close by," and taking less time. Hence, in relation to the state of the fisheries in the past, the fishers generally stated negative views on the current state of their fisheries. The percentage of fishers reporting negative responses ranged from 76% by the yellowtail snapper fishers to 52% by the shrimp fishers (FIG 3). Shrimp fishers had the highest percentage of responses that the state of their fisheries was positive (19%), followed by red snapper fishers (7%). Others responded that the state of the fisheries was in-between (23 – 35%) or chose not to respond (FIG 3).

FIG 3. Fishers' perceptions of the state of the fisheries (right) for the four groups that fit the CCM (left). The majority of the fishers responded that the state of the fisheries is "bad".

Relations between LEK and perceptions about fishery management

In general, fishers' responses to questions about their knowledge of MPAs, agreement with MPAs, perceptions of the state of the fisheries, or the factors affecting their fisheries were not related to their competence score (Table 6, Table 8, FIG 4, FIG **5**). Fishers who knew of MPAs showed no tendency to differ in competence scores from those who were unaware of MPAs (Table 6). Similarly, fishers who supported MPAs were similar in mean competence to those who did not support MPAs (Table 6). There was variation among harvested species in how fishers perceived the state of the fishery, e.g., shrimp was generally perceived as being in a "positive" or "neutral" state while red snapper was considered by most to be in a "negative" state, but fishers who perceived their fishery to be negative had similar competence scores to those who perceived their fishery as positive (Fig. 4, Table 8). Finally, there were no detectable differences in LEK (mean competence) among fishers who reported differing perceptions on the key factors affecting their fishery (FIG 5, Table 8).

FIG 4. Mean competence scores of fishers with differing perceptions of the state of the fisheries. There was no systematic pattern for higher competence to be associated with a negative or positive perception.

FIG 5. Mean competence scores of fishers reporting different perceptions of the factors that affect their fisheries the most. For the different groups with shared cultural knowledge, there was no systematic pattern for higher competence to be associated with specific patterns of perception.

Discussion

Local Ecological Knowledge of Fishers

For the four important harvested species with evidence of a shared cultural model of LEK, we found the highest levels of consensus in responses about species' habitat and predators. LEK of target species matched to its habitat is of obvious practical value for successful fishing in a multispecies, small-scale fishery (García-Quijano 2009; Silvano and Begossi 2012). Many Samaná fishers were visibly excited when discussing predators and displayed confidence in their answers, which for us indicates that fishers think this is an important topic and are in a good position to provide insights. Expert fishers in a small-scale multi-species fishery In Puerto Rico were also knowledgeable about trophic interactions and habitat use (e.g., Garcia-Quijano and Valdez-Pizzini 2015), which suggests that fishers are well-versed in the type of LEK needed to integrate this information into management.

The lobster fishers also possessed high levels of LEK about the lobster's reproductive period, which may be because lobster eggs are generally visible externally. In contrast, reliably judging the reproductive status of teleosts may depend on inspection of the gonads when the fish are cleaned. The lobster fishery is also one of the most valued and regulated fisheries in the D.R., hence fishers' understanding of reproduction and its timing may also be linked to the seasonal closure of the lobster fishery that coincides with its reproductive season (Herrera et al. 2011).

Fishers' Perceptions about marine protected areas

Where most fishers know about, or participated in coastal fishery management, we might expect LEK to covary positively with knowledge of management measures like local MPAs, especially since the greatest consensus in LEK was about species habitats.

This was not the case in Samaná, which may indicate that, in this region, fisheries-related LEK and understanding of management and conservation constitute two separate cultural domains of knowledge. In other study areas, fishers' knowledge of an MPA, or agreement with their establishment, is influenced by their involvement in associated political or management processes and their placement in social networks of fishery management (Scholz et al. 2004; Kincaid et al. 2014). Fishers with the most LEK may, therefore, not be the ones with most access to information about management and conservation initiatives, perhaps because other sociocultural characteristics such as literacy, education level, or political or civic participation, mediate fishers' access to this information.

While our data indicate that many fishers consider MPAs to be ecologically important, several fishers were also not in favor of restrictions to their fishery or did not support local MPAs because the benefits were unequally distributed (Table 7). A lack of inclusion of stakeholders in coastal management has been associated with programs not being easily accepted or supported by locals (McClanahan et al. 2006; Mellado et al. 2014). But whether local fishers fully understand why the MPAs were set up, or whether they have knowledge of MPA benefits, does not change the fact that, for some, these areas represent traditional fishing grounds, safety nets where they fish especially during storms or unfavorable weather events. One way to overcome these constraints is by improving coastal fisheries management through participatory approaches (e.g., Sánchez-

Jiménez et al. 2019) or facilitating ecosystem-based fisheries management (Gaspare et al. 2015) that integrates socioeconomic factors affecting these communities. Despite a broadened understanding of local people's knowledge and how they relate to their environment (e.g., Coelho-Junior et al. 2021), we are still learning how to translate and apply LEK into management strategies (Garcia-Quijano 2007).

State of the fisheries and factors affecting the fisheries the most

In the 1990s, 31% of fishers surveyed in Samaná stated that their fisheries would decline greatly if no changes were made, and that banning gill nets would allow recovery (McCann 1994). Two decades later, fishers still identified gill nets as a cause of decline, although they also perceived seine nets and trawling as damaging (FIG 2). Conversely, the use of gill nets, together with the adoption and deployment of multiple gears by individual fishers is also seen as a means to adapt and maintain incomes despite decreasing stocks (Herrera et al. 2011), a persistent challenge for fisheries throughout Latin American and the Caribbean (Chuenpagdee et al. 2003). Hence, the lack of fisheries management constraints and regulations promotes a sense of sustainability (Farr et al. 2018). Increased engagement with fishers is a possible way to address this challenge, however, it is not uncommon for fishers to oppose regulations, especially when these interfere with their obligation to feed their families (Fenner 2012).

Some management implications

Understanding the association between LEK and perceptions can help us understand how fishers relate to and value their natural environment (Coelho-Junior et al. 2021). Because fishers are knowledgeable about habitats and predator-prey interactions, it is possible that they perceive conservation of fish habitat and food webs as being important to sustaining their fisheries. For this reason, we expected a relationship between fishers' perceptions and their LEK. A plausible explanation of the observed disconnect between LEK and perceptions of the state of the fisheries could be a 'shifting baseline.' Perhaps older fishers having experienced different states of fishery health (higher catches, larger size fish) than their younger counterparts (Bender et al. 2013). We can, however, reject this explanation in Samaná because there were no significant relationships between fisher's response patterns and their age or experience.

In most communities in Samaná, fishers are organized in cooperatives and organizations. Participating in these forums gives fishers access to support and information (Turner et al. 2014). Active participation in MPA planning and management has been found to increase stakeholder agreement in management goals, positive perceptions of MPAs and their benefits, and acceptance of future management (Mellado et al. 2014). In Samaná, however, many fishers said it was difficult for them to attend and participate in management meetings because they now fished farther out and for longer periods of time. In the 1990s, Samaná fishers believed that with better equipment their fisheries sustainability could be improved (McCann, 1994). Changes that make it quicker for fishers to travel to fishing grounds might relieve fishing pressure near the coast 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

Various studies have looked at the value of understanding fishers LEK to inform effective management programs. By quantifying LEK using the CCA, we were able to explore the distribution of LEK among fishers and assess whether their LEK correlates with their perceptions. Although most fishers agreed in their perceptions of the state of fisheries and their awareness of and support for MPAs, our prediction that local ecological knowledge would correlate with their perceptions was not supported. An important limitation of our analysis, however, that CCA is limited to singular knowledge domains, which in this case consisted of group of fishers that targeted a single species. In reality, fishers use different gear types and target different subsets of the harvestable species in the area, while residing in different communities. Thus, each fisher possesses LEK across multiple domains of knowledge that overlap to varying degrees with the knowledge domains of their peers. For multi-species small-scale fisheries, new analytical methods that could quantify LEK across the entire set of species caught by each fisher would allow a more powerful test of links between LEK and perceptions.

The observed disconnect between fishers' LEK and fishery management perceptions also raises the important question of the role that other social differences or barriers in the social/political networks play in driving fisher's perceptions. Some benefits of this study regard the direct engagement with the fishers, addressing their concerns regarding their reported changes, distributing educational resources, and exploring pathways for better fisheries management. Although nine years have passed since the field studies, continuing declines in the fisheries (FAO 2020) and scarcity of data (Partelow et al. 2020) for this region suggest this study still has relevance for local leaders and decision makers. In our opinion, our results underline the need to further understand both universal and locally specific practical and social barriers to participation in management and to address challenges that limit individuals from access to management networks. Addressing these factors could contribute to ameliorating inequalities in the knowledge sharing process, which is crucial to facilitate ecological knowledge sharing between fishers, biological scientists, and resource managers (e.g. Garcia-Quijano and Valdez-Pizzini 2015).

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• **Conflict of Interest:** The authors have no conflicts of interest to declare.

• **Informed consent:** The study was done in compliance with Institutional Review Board (IRB) - Guidelines for studies of human subjects (See Appendix E).

• **Authors Contribution:** This study constitutes Mclean's doctoral research work. All authors contributed to the study conception, design, and to the analysis of the data. Material preparation and data collection were performed by Mclean. The first draft of the manuscript was written by Mclean and all authors contributed to subsequent versions. All authors read and approved the final manuscript.

• **Data Availability Statemnet:** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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TABLES

Table 1. Survey questions used to record fishers' LEK on the species fished and their perceptions of 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 are the **predators** 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 2. The eight species of fish harvested in Samaná Bay that were analyzed using the CCA, and methods used to capture them.

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 3. Summary of CCA model output. 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	Low	
No. of negative competence score	1	4	0	0	6
Average competency	0.572	0.507	0.605	0.684	0.592
Range in competence	0.07 - 0.88	0.013 - 0.96	0.10 - 0.99	0.25 - 0.97	
Eigenvalue ratio	2.752	2.798	3.715	2.81	3

Table 4. Culturally correct responses based on the local ecological knowledge responses for the four species. The response categories with the two highest agreement (level) are indicated for each species. The level of agreement is the weighted frequencies, number of fishers responding similarly (n) relative to the total number of fishers (N).

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 2nd Wtd. Freq. 66	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 1st Wtd.Freq.72
yellowtail snapper (N=53)	Rock bottom, coral, *Acropora palmata*, soft corals, channels, sand and mud 1st Wtd.Freq. 50	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 2nd Wtd.Freq. 48
lobster (N=34)	Rocks, caves, corals, *Acropora palmata*, seagrass and octocorals *1st/Wtd.Freq.33*	From shallow to great depths / 0.5 - 10m deep	Hot months, from June - Aug	Summer: July-September and May with a thunder *2nd Wtd.Freq. 29*	groupers, barracuda, sharks, pufferfish, eels and lionfish
shrimp (N=21)	Soft bottom: mud 2nd Wtd. Freq. 18	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 1st Wtd.Freq. 19

Table 5. 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***
Fishers	76	53	34	21	132*
Fishers that have knowledge of MPAs	53 (70%)	35 (66%)	18 (53%)	13 (62%)	86
'YES' Agreement with the establishment of MPAs	49 (64%)	30 (57%)	15 (44%)	12 (57%)	76
'NO' Do not agree with the establishment of MPAs	13 (17%)	11 (21%)	5 (15%)	2 (10%)	21
No response	14 (18%)	12 (23%)	14	7 (33%)	35

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

Table 6. Results of t-tests assessing whether fishers' perceptions and knowledge of management were associated with their LEK (mean competence score).

Knowledge of Marine Protected Areas								
Fished Species		**Response**	**N**	**Mean competence**	**SE Mean**	**t**	**df**	**p-value**
red snapper (N=76)		Knows	54	0.578	0.028	-0.360	35	0.723
		Does not know	22	0.558	0.049			
yellowtail snapper (N=53)		Knows	33	0.530	0.047	0.690	47	0.494
		Does not know	16	0.588	0.072			
lobster (N=34)		Knows	18	0.575	0.072	0.72	32	0.476
		Does not know	16	0.640	0.050			
shrimp (N=21)		Knows	13	0.622	0.074	1.44	19	0.165
		Does not know	8	0.786	0.080			
Agreement with the establishment of MPAs								
Fished Species		**Response**	**N**	**Mean competence**	**SE Mean**	**t**	**df**	**p-value**
red snapper (N=76)		Agrees	58	0.565	0.028	0.510	74	0.610
		Does not agree	18	0.595	0.049			
yellowtail snapper (N=53)		Agrees	34	0.534	0.045	0.55	47	0.586
		Does not agree	15	0.582	0.082			
lobster (N=34)		Agrees	19	0.567	0.068	0.960	32	0.343
		Does not agree	15	0.654	0.053			
shrimp (N=21)		Agrees	16	0.663	0.067	0.67	19	0.512
		Does not agree	5	0.753	0.110			

Table 7. General fishers' understanding of the reasons why Marine Protected Areas are being established. Numbers (#) represent the number of fishers (out of n = 152) that responded presenting one reason or another.

	#	Reason Explained
Fishers view on not being affected by the establishment of the MPA, N = 55 (36%)	10	The MPA is a nursery, it is where we go to catch bait fish
	4	MPAs favor fish productivity
	3	There are restrictions. Fishers are kept from using their boats to take my family to see whales
	3	The presence of whales favors tourism in our area, we grew up with the whales
	2	Enforcement is present to protect natural resources
	1	Our only problem here are the seine fishers
	1	I am not affected because rules are never enforced
	1	I am allowed to see the whales on my boat
Fishers views on being negatively affected, N = 39 (26%)	7	Regulations do not allow us to go to certain areas, or we need permission in order to go.
	5	Farmers were excluded from the Park. 'Roots' production was high in the National Park
	4	Regulations do not allow us to use our boats to see the whales
	4	Affected because the whales in the Sanctuary scare fish, or whales get in the way of divers
	4	No reason explained
	2	When the weather was unfavorable, the 'Ensenada' was a sheltered place to go fish
	1	I used to live there
	1	Recognizes that the forests were being destroyed
	1	Disagrees because only a few people in power benefit from the MPA
	1	In January whales release "green dots" that causes one to itch

Table 8. Perceptions categorical testing of fishers' responses. Their perceptions do not relate to their LEK (competence score).

Fished Species	Perception Variable	T-value	F-Stat	p -value
red snapper (N=76)	Know MPA	-0.36		0.712
	Agree MPA	0.51		0.610
	State Fisheries		0.087	0.917
	Factors Affecting		1.356	0.226
yellowtail snapper (N=53)	Know MPA	0.69		0.494
	Agree MPA	0.55		0.586
	State Fisheries		1.083	0.347
	Factors Affecting		1.459	0.209
lobster (N=34)	Know MPA	0.72		0.476
	Agree MPA	0.96		0.343
	State Fisheries		2.477	0.100
	Factors Affecting		1.933	0.093
shrimp (N=21)	Know MPA	1.44		0.165
	Agree MPA	0.67		0.512
	State Fisheries		0.541	0.592
	Factors Affecting		0.763	0.627

*t-test used for perceptions with binary response

ANOVA used for perceptions with 3 or more response categories

Figure Legends

FIG 1. Map of the Northeast coast of the D.R. 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. The colors representing: ocean (blue), estuarine zone (white), protected national park (orange, and indigo outline), physical landscape with rivers (grey).

FIG 2. Perceptions of the factors that are affecting fishing the most (right) represented by the four groups with shared local ecological knowledge (left). The main factors are the use of destructive nets and bottom trawling.

FIG 3. Fishers' perceptions of the state of the fisheries (right) for the four groups that fit the CCM (left). The majority of the fishers responded that the state of the fisheries is "bad".

FIG 4. Mean competence scores of fishers with differing perceptions of the state of the fisheries. There was no systematic pattern for higher competence to be associated with a negative or positive perception.

FIG 5. Mean competence scores of fishers reporting different perceptions of the factors that affect their fisheries the most. For the different groups with shared cultural knowledge, there was no systematic pattern for higher competence to be associated with specific patterns of perception.

Appendices

Appendix A. Multi-species fishery.

Table A1. The fisheries in the Samaná region are best described as a multi-species fishery. Names 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 A1. 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*
Other Vertebrates (Reptile)			
Cheloniidae	Green sea turtle	Tortuga	*Chelonya mydas*
Diverse Invertebrates			
Tegulidae	Whelk	Burgao	*Cittarium pica*
Strombidae	Queen Conch	Lambi	*Strombus gigas*
Octopodidae	Octopus	Pulpo	*Octopus vulgaris*
Thysanoteuthidae	Diamond Squid	Calamar gigante	*Thysanoteuthis rhombus*
Loliginidae	Squid (normal)	Calamari	*Loligo vulgaris*
Scyllaridae	Lobster - slipper	Langosta cucaracha	*Scyllarides latus*
Palinuridae	Lobster	Langosta	*Panulirus argus*

Appendix B. Fish and the localities where they are caught.

Table B1. Names of fish and the localities where the fishers that catch them reside. Surveys were conducted during the summers of 2011. Fishers in Sanchez also mentioned catching green sea turtles and manatees.

	LOCALITIES									
Common [ENG] Name	**Samaná**	**Los Cacaos**	**Las Galeras**	**Villa Clara**	**Gratinices**	**Sanchez**	**Rincon**	**Miches**	**Sabana de la mar**	**Las Terrenas**
blue runner		x				x			x	
yellow jack	x	x	x		x	x	x		x	x
crevalle jack	x					x				
skip jack	x	x			x	x	x		x	x
rainbow runner	x					x			x	x
almaco jack/bonito	x		x					x	x	
snook						x				x
mahi mahi	x	x	x			x			x	x
white bait fish	x									
banana grunt	x	x	x			x	x		x	x
white grunt	x	x	x	x	x	x	x	x	x	x
squirrel					x		x		x	
blue marlin		x	x				x			x
Atl. Triple tail		x	x			x	x			x
red snapper	x	x	x	x	x	x	x	x	x	x
yellowtail snapper	x	x	x	x	x	x	x	x	x	x
queen snapper	x	x								x
mutton snapper	x		x					x	x	x
black spot snapper	x									

Table B1. Continued –

	LOCALITIES									
Common [ENG] Name	**Samaná**	**Los Cacaos**	**Las Galeras**	**Villa Clara**	**Gratinices**	**Sanchez**	**Rincon**	**Miches**	**Sabana de la mar**	**Las Terrenas**
spotted rose snapper	x									
tarpon						x				
white mullet		x				x			x	
queen parrot	x	x	x	x		x	x	x	x	x
guacamallo			x					x		x
white mouth croacker	x					x			x	x
kingfish mackerel	x	x	x	x	x	x	x	x	x	x
albacore	x		x			x			x	x
bluefin tuna	x	x	x			x				x
sea bass	x	x				x			x	
coney	x	x	x						x	x
red hind	x	x	x	x	x	x	x	x	x	x
goliath grouper	x		x							x
nassau grouper		x	x	x			x	x		
dog tooth grouper			x							
grasby	x									x
yellowfin grouper										x
sea bream	x							x		x
red porgy		x								
hogfish			x				x			x
banded barracuda			x			x	x		x	
great barracuda						x	x			
sharks			x			x	x		x	
spotted eagle ray			x			x			x	

Table B1. Continued –

Common [ENG] Name	LOCALITIES Samaná	Los Cacaos	Las Galeras	Villa Clara	Gratinices	Sanchez	Rincon	Miches	Sabana de la mar	Las Terrenas
Atlantic cutlass fish		x	x	x						
red drum				x		x				
red lionfish										x
ray fish			x			x			x	
threadfin butterflyfish	x			x						x
sablefish		x		x						
cornet fish		x								
pampano/ permit								x		

Appendix C. Diverse invertebrates and the localities where they are caught.

Table C1. Diversity of fished and collected invertebrates in the Samaná region.

	LOCALITIES									
Common [ENG] Name	**Samaná**	**Los Cacaos**	**Las Galeras**	**Villa Clara**	**Gratinices**	**Sanchez**	**Rincon**	**Miches**	**Sabana de la mar**	**Las Terrenas**
diamond calamari		x		x			x			
squid/calamari	x									
whelk									x	
queen conch	x	x	x	x				x	x	
octopus		x	x	x				x		x
lobster (slipper)				x						x
lobster (spiny)	x	x	x	x			x	x	x	x
crayfish		x							x	x
shrimp						x			x	x
red shrimp						x			x	
white shrimp						x			x	
blue crabs			x			x			x	x
king crabs			x	x						x
clam						x			x	
oysters									x	

Appendix D. List of categories used in the analysis by species.

The coding of LEK responses to the questions outlined in Table 1, for the different categories is explained as follows:

i) Habitat type describes the nature of bottom substrate where given specie is fished. These are described as: rocky, coral or hard bottom; mud, sand; a mix of mud/sand and rocky; rocky with soft coral presents, or soft bottom with sea grass.

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 time of the year when they are found 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 / elasmobranch – only, b) Mixed shark and fish, c) fish only, d) fish and other taxa (crab, turtle, octopus, etc.)

Table D1. Summary of the coded categorical responses for the red snapper, yellowtail snapper, lobster and shrimp species. Responses correspond to the LEK of fishers' questions outlined in the Table 1.

Species	***Category (#)***	***Habitat***	***Depth***	***Time of the year caught***	***Time of the year reproduction***	***Predators***
red snapper (N=76)	**1**	Rock, corals, deep channels, soft corals and sand	Shallow 5-10 meters (<11m)	Warmer months	Warmer months	Sharks, elasmobranchs
	2	Mud, silt, mud holes	Varying depth (13-50, 50-167m)	Colder months	Colder months	Non-shark, mixed of fish mentioned
	3	Rock, mud and grasses	Open water, >167m	All year around	All year around	
yellowtail snapper (N=53)	**1**	Rock, corals, deep channels, soft corals, shallow waters & sand	Shallow 3-7m (<8m)	Warmer months	Warmer months	Large pelagic predators
	2	Seagrass	Depth over 10m to 50m	Colder months	Colder months	Mixed predators (includes lionfish)
	3	Deep water	Variable depth from 2m - 40m	All year around	All year around	Diff. descriptive response (i.e., bigger fish)
	4			It varies (warm & cold months included)	It varies	
lobster (N=34)	1	Rocks, caves, corals, seagrass, octocorals, etc.)	Under 6m	Warmer months	Warmer months	Mixed elasmobranchs (sharks), larger fish and lionfish
	2	Habitat not specified	6-33m	Colder months	Colder months	Octopus, Green eel
	3		Deep 80-90m, >150	All year around	Not specified	Does not know
shrimp (N=21)	1	Mud, sand, silty habitats in the bay	Shallow (0.5-2m)	Rainy season (month of May)	Rainy season (Month of May)	All fish (including sharks)
	2	Not specified	between 25-40m	Colder months (Sep-Dec)	Colder months (Sep-Dec)	All fish + crabs
	3		Variable depth from 2-4m; 16-30; 4-60m	All year around	All year around	All fish (excluding sharks, including dolphins)
	4			It varies	It varies	

Appendix E. 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