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Comparing fishers' and scientists' estimates of size-at-maturity and maximum body size as indicators of overfishing

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Abstract. Coastal artisanal fisheries are reported as fished unsustainably, so understanding what influences current fishing patterns is important. We studied fishers' local ecological knowledge (FEK) about the size-at-capture (SAC) relative to the size of maturity (SAM), and relative to the maximum body size (MS), of the fishes they harvest as potential indicators for overfishing. We surveyed 82 fishers from a small-scale fishery in Samaná Bay, Dominican Republic, using a quantitative and qualitative approach to document their FEK of 52 harvested species and their perceptions of the fishery. For the 15 most frequently mentioned fishes, SAM estimates derived from FEK and SEK overlapped for only 5 of 15 species and, when estimates differed, there was no consistent tendency for FEK to generate estimates higher or lower than SEK. In contrast, fishers' MS estimates were usually lower than (9 species), or overlapped with (3 of 15 species) scientific estimates. Fishers' judgements of catch composition indicate greater potential for overfishing than judgements based on SEK. Fishers believe they routinely catch juveniles (13 of 15 species), whereas SEK estimates suggest they catch mostly adults (11 of 15 species). Fishers perceive harvested fish to be far smaller than MS for about half of the species (8 of 15), whereas SEK estimates support this view for almost all species (13 of 15). Most Samaná fishers (73%) were concerned about the state of their fishery, many (60%) perceived decline over time and their comments suggest these perceptions were linked to overfishing. Our results suggest fishers may use their judgements about SAC-SAM and SAC-MS as potential indicators for overfishing, but future work should test this hypothesis explicitly. Although fishers' and scientists' estimates of these parameters often differed, the fact that fishers make routine informal assessments of maturity and body size suggests potential for future collaborative monitoring efforts to generate estimates usable by scientists and meaningful to fishers.

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). To address overfishing, fisheries scientists are expanding the approaches they use to advise policymakers (Jackson et al. 2001; Pauly et al. 2002; Worm et al. 2006). 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 local fishing patterns (Johannes 1991; Friket et al. 2000; Wilson et al. 2006; Johannes 2007; Gerhardinger et al. 2009; Daw et al. 2011; Beaudreau & Levin 2014). Incorporating FEK has been slow, in part because the scientific community has viewed FEK as epistemologically different from SEK; so different that it may not always be comparable to the factual or numerical information that is characteristic of Western research

(Berkes 1999; Neis et al. 1999; Johannes et al. 2000). Nonetheless, researchers have argued that there are situations when FEK and SEK can be framed in similar terms for comparison (Neis et al. 1999; Grant et al. 2008; Davis & Ruddle 2010; Le Fur et al. 2011; Duggan et al. 2014). Some past examples include the use of FEK to measure population trends (Castello et al. 2009; Azurro et al. 2011; Bender et al. 2013; Beaudreau & Levin 2014) and declines (Davis et al. 2004; Katikiro 2014; Kay et al. 2012), define fish habitat use and diet (García-Quijano 2009; Rasalato et al. 2010; Boudreau & Worm 2010; de Magalhães et al. 2012), pinpoint the timing and location of reproduction (Johannes and Hviding 2000; Aswani and Lauer 2006; Fraser et al. 2006; Griffith et al 2013), reconstruct historical baselines (Ainsworth et al. 2008; Ainsworth 2011) and identify 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 a harvested species to assess fishing pressure (Getz & Haight 1989). In this way, future responses to harvesting are predicted (Ratner & Lande 2001; Reeves & Pastoors 2007) in order to prevent overfishing (Hilborn & Stokes 2010). Size-at reproductive maturity (SAM) is a key demographic variable for fisheries scientists because it helps predict spawning biomass and recruitment potential of harvested stocks (Cole 1954). In simple terms, harvesting fish before they mature is a common indicator of overfishing because it removes individuals before they can contribute 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 common 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), but collecting this knowledge provides an opportunity to assess fishers' perceptions about the extent to which they believe they are harvesting juvenile fish, or fish much smaller than the potential size reached by that species. This information may signal whether the fishers themselves judge their present fishing pattern 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, looking closely at the relationships between FEK and SEK, to understand if 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 the targeted species (FEK-MS), (5) scientific estimates of the maximum possible body size of the same species (SEK-MS).

Comparing fishers' (2) and scientists' (3) estimates of size-at-maturity is a direct indicator of whether the two sources of knowledge are congruent, and testing whether the two groups might agree on the potential for overfishing. Comparing fishers' 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 (Appendix S1: FIG. S1). The local ecological knowledge of the fishers is transmitted across generations, and acquired directly through years of observation and experiences. It is thus subject to the "shifting baseline syndrome", in the sense that a fisher's knowledge is influenced by when they entered the fishery (Pauly 1995; Ainsworth et al. 2008; Katikiro 2014). Furthermore, most fishers' local knowledge is not limited to fisheries alone because the most of them also engage in other activities to generate income, such as agriculture, cattle ranching, mining and tourism (McCann 1994; Herrera et al. 2011).

Fishers in this region, like those in many tropical coastal fisheries, typically catch multiple species and many also use several fishing methods (Sang et al. 1997; Jorge 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. Because resources to collect SEK in this region and develop scientifically based management plans are limited (Herrera et al. 2011), this is a valuable time to study FEK and its use for understanding and managing environmental changes in this coastal ecosystem (Johannes 1998; Huntington et al. 2004; Moller et al. 2004).

METHODS

Surveying fisher's 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 residing in 10 coastal communities (Appendix S1: Table S1 & S2: Table S2). In each community, fishers were approached first in beaches, docks and landing stations, 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 fact-based responses, plus descriptive questions designed to allow respondents to articulate their perceptions more freely. Data collected using structured interviews are useful to assess trends when the responses can be aggregated (Neis et al. 1999). 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.

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 caught, 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 were negative, (2) the present state of the fisheries in my community was positive, (3) the present state of the fisheries in my community was neither positive nor negative. 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 positive, we expected them to strongly agree that its state was negative. There was almost perfect symmetry in responses, so answers were coded as positive, negative, or neutral. Further explanations regarding the descriptors of positive and negative related to the size of their catch and to the fisher's ability to make a living, and provide for their families.

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 (L_m) and maximum body size (L_{max}) were compiled from the online database *FishBase* (Froese & Pauly 2015) with the occasional addition of data from the primary (Randall 1963) or grey literature (Mancini & 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 & Pauly 2015).

Analyses

We were 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 they did not. 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 also calculated the median and 95% CI for fishers' SAC, SAM and MS estimates to check whether means and 95% CIs were reasonable measures of central tendency and dispersion of the samples respectively. 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. We found the pattern of results to be similar for means and medians, (Appendix S3: Table S1), 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 positive, negative or neutral (the categorical independent variable). This gave a total of 45 one-way ANOVA tests (15 species x three 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 and most were very experienced. Their average age at the time of survey was 48 [range 24 – 76 years], and most reported beginning to fish when young (14 years), so they averaged 35 years fishing experience

(Appendix S2: Table S2). 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 S4: Table S1). The traditional line fishing was the most common gear type used by 30% (N = 25) 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 12% (N = 11), or fishing lines and long lining by 11% of the fishers (Appendix S4: Table S2).

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 S2: Table S1). All of the fishers provided FEK for multiple target species [mean = 5 species, range 2-10 species caught]. FEK was provided for 52 fish 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 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 the FEK and SEK 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 nearly 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 size 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 suggest a catch dominated individuals far smaller than MS (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 majority responding that the state of the fishery was negative (73%, 60/82). Most (70%, 57/82) fishers also perceived that there had been a change in the fishery, and 86% of those (49/57) responded that the change had been for the worst. Comments by several fishers, such as "we are killing the goose that lays golden eggs" and "we are fishing like out-laws", suggest these perceptions were linked to overfishing.

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

For nearly all of the studied fish species, no relationship was found between individual fishers' perceptions on the state of the fishery and their estimates of SAC, SAM and MS (Appendices S6 & S7). 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 S7: FIG.1).

DISCUSSION

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 absent and expensive to obtain. Congruence between FEK and SEK would serve to corroborate SEK estimates (Huntington et al. 2004; Thornton & Scheer 2012) , or suggest the possibility of using fisher's estimates as a cost-effective alternative. Although we believe fishers understood the basic concept of size-at maturity, the lack of agreement between SEK and FEK estimates suggests collaboration between scientists and fishers would be essential to produce FEK estimates usable by scientists. A consistent pattern of differences between SEK and FEK could 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 & Jones 1998). However, the lack of a consistent pattern makes it harder to explain the differences between SEK and FEK. Lack of agreement may reflect complexities associated with spawning seasonality, sequential hermaphroditism in some fish species, or differences in the specific methods used to assess SAM. Scientists use systematic collections, followed by dissections, histological analysis and/or weighing of gonads and employ statistical conventions to make their estimates (e.g. minimal size attained at maturity from a sample of fish, or the size at which 50% of sampled fish are mature) (Bonar et al. 1989; Kjesbu 1991; Froese & Binohlan 2000; Swenson et al. 2007) whereas fishers appear to make informal 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

We also found general lack of agreement between fishers' and scientists estimates of maximum body size, but for this parameter there was a consistent pattern to the disagreement - with fishers typically reporting lower MS estimates. The simplest explanation for this pattern is that SEK estimates draw from many sources that span a long time-period and encompass the entire geographic range of the species (for most studied species, this is the entire Caribbean), whereas the FEK estimates are based on the fishers' direct experiences. For most fishers, this experience was limited to coastal and bay areas in Samaná, though some had fished in deeper water or on off-shore banks. Most Samaná fishers were experienced enough to have witnessed a time when, in their own words, "fish were bigger", but their experience is nonetheless much more restricted than that of the broader scientific community, and it is further possible that very large fish in Samaná were already depleted 30-40 years ago when most began fishing (Pandolfi et al. 2003; Katikiro 2014).

The fewer cases where fisher's report larger MS estimates than scientists may have other explanations. For example, using a photo-ID book during interviews suggested that, for the coney, overestimation of MS could be explained by some fishers believing that two larger species of grouper, the goliath grouper (*Epinephelus itajara*) or nassau grouper (*Epinephelus* *striatus*), are the coney's adult counterpart. Reasons for overestimation by the fishers of the MS for the banana grunt (*Haemulon striatum*) are less clear, but there may be occasional pooling of this species with larger-bodied *Haemulon spp*. (e.g. white or bluestriped grunt).

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

A striking feature of our results was that, if scientists and fishers used their size estimates as indicators of the composition of the catch, the two groups would rarely agree on the potential for overfishing. For the majority of species, scientific estimates of SAC-SAM indicate a catch composed primarily of adults, whereas fishers commonly judged their catch was comprised of both juvenile and adult fishes – so fisher's estimates indicate a greater potential for overfishing. Conversely, scientific estimates of SAC-MS suggested that the catch of virtually all species was dominated by individuals far smaller than the maximum potential body size – an indicator that large size-classes may have been depleted - whereas fishers' estimates would lead to this conclusion for only half of the species studied and so indicate less potential overfishing.

Associations between fisher's size estimates and their perceptions about the state of the fishery?

Depletion of larger individuals and capture of juveniles are widely reported by scientists as symptoms of overfishing (Christensen & Guenette 2003; Myers & Worm 2003; Coleman et al. 2004) and, although the Samaná fisheries are poorly studied, scientists in this region have reported them as symptoms of concern (Herrera et al. 2011). Closures and regulations have been established in the Dominican Republic in response to this perceived overharvesting.

It was clear from our results that most Samaná fishers also perceived their fishery as having declined and were concerned about its current state. It is, however, not always clear what information fishers use to judge deterioration of a fishery (Gilchrist et al. 2005; Wilson et al.

2006). Fishers perceptions of population decline have been linked to decreasing catch for a given amount of fishing effort (Stevenson et al. 2011), or a need to travel further or fish longer to maintain catches, or a shift in the species composition of catches . The Samaná fishers appear to use these 'indicators' because they frequently described the past as a time when "there was more", "they were near", and "we only had to fish for a while". Although indvidual fishers' size-estimates were not correlated with their perceptions about the state of the fishery, collectively the Samaná fishers think they are routinely harvesting jveniles of most species they catch, and are harvesting fish well below the maximum possible body size for about half their target species. Our results are thus consistent with the hypothesis that incorporate these size-based 'indicators' into their assessment that the bay is overfished.

Circumstantial evidence supporting the notion that fishers use size estimates to inform their views on overfishing is that, when discussing how fisheries were protected, several responded with comments like "by throwing the small ones back in [the water]". Possible reasons for the apparent decline in this practice include the growth of the fishery in the past 30 years, the roughly twofold increase in the fraction of specialist fishers (from 27% to 59%), and the adoption of new gear types (CEBSE 1994; Colom et al. 1994; SERCM/SEMARN 2004; Herrera et al. 2011). Another contributing factor is increasing market-driven size-selectivity (Reddy et al. 2013) for "plate-sized" fish for sale in restaurants. Several fishers mentioned this demand for smaller fish was particularly common for red snapper, yellowtail snappers, and other demersal species.

Conclusion

Our results suggest that fishers may use their judgements about the size of the fish they catch relative to the size of maturity, and relative to the maximum body size, of the fishes they harvest as potential indicators for overfishing – but future work should test this hypothesis explicitly. Although fishers' and scientists' estimates of these parameters commonly differed, the fact that fishers make routine informal assessments of maturity and body size suggests high potential to involve fishers in future collaborative monitoring efforts to generate estimates usable by scientists and meaningful to fishers.

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TABLES

Table 1. 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. 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. 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. 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

FIG. 1. 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).

FIGURES

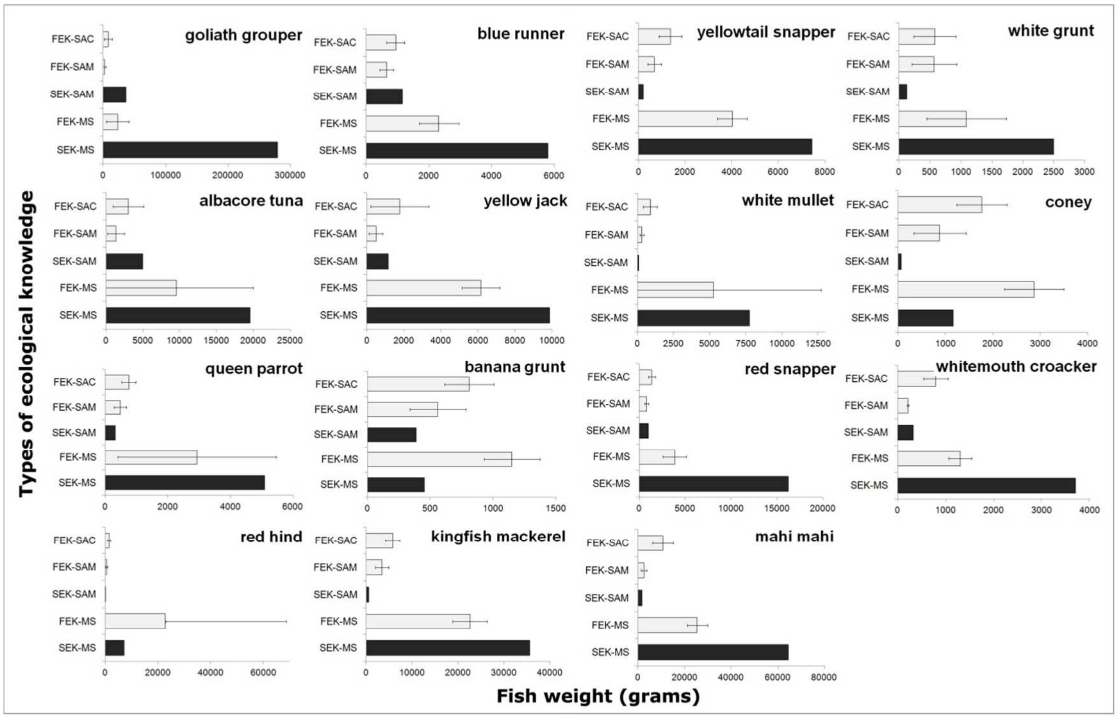
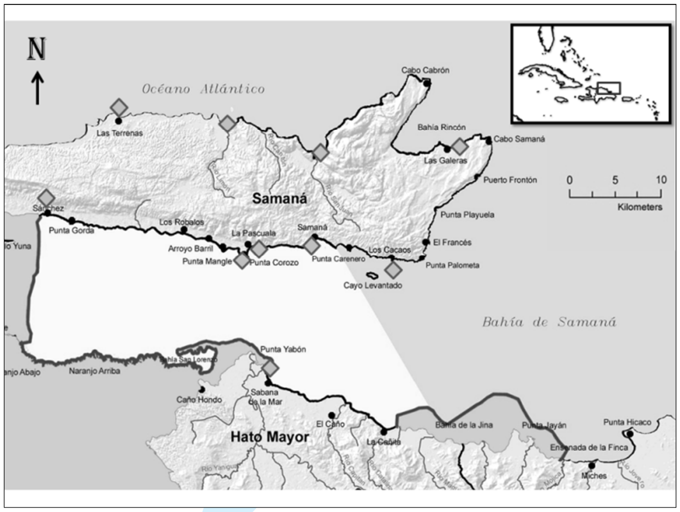


FIG. 1. For each species, we plot the fishers' estimate of size-at-capture (FEK-SAC), fishers' estimate of size-at-maturity (FEK-SAM), the scientific estimates of size-at-maturity (SEK-SAM), the fishers' estimates of the maximum possible body size (FEK-MS), and the scientific estimate of maximum body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

Mclean & Forrester 2017- Comparing fishers' and scientists' estimates of size-at-maturity and maximum body size as indicators of overfishing

APPENDICES

Appendix S1. *Map of study area.*



S1: FIG.1. Map of the North-East region of the Dominican Republic comprising the Samaná Peninsula. The ten communities surveyed are indicated with the diamond.

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Appendix S2: Table 1. 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 S3. *Sample size (means and medians)*

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

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 (*) (S3: Table S1, S2, S3).

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.

S3: Table S1. 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

S3: Table S2. 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*

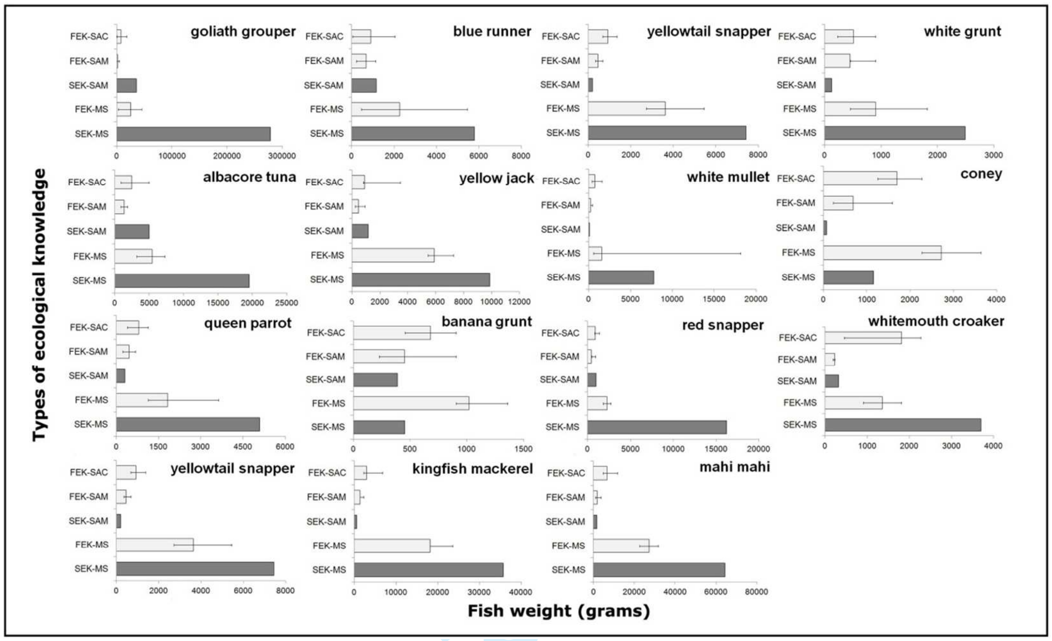
* Median pattern differs from the mean pattern

S3: Table S3. 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

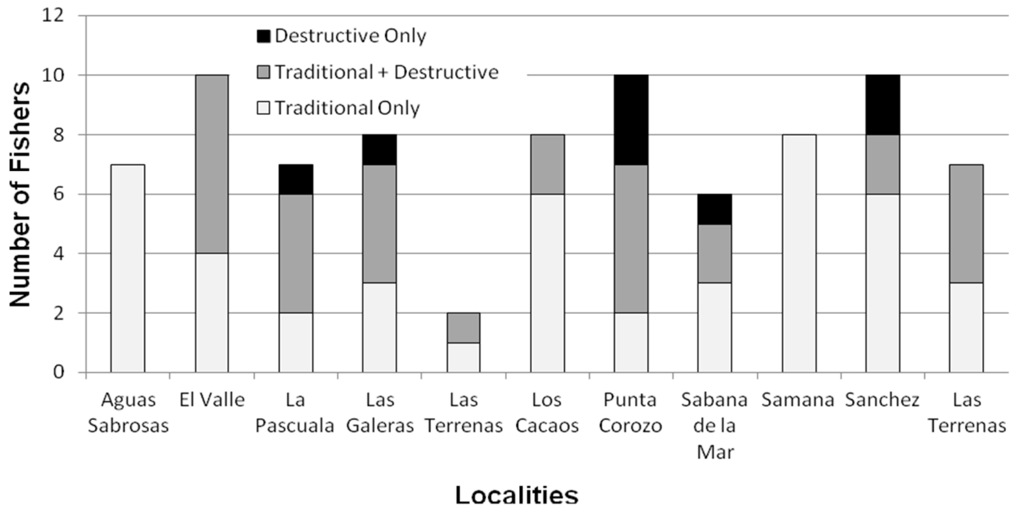
* Median pattern differs from the mean pattern

Mclean & Forrester 2017- Comparing fishers' and scientists' estimates of size-at-maturity and maximum body size as indicators of overfishing



S3: FIG. S1. 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 S4. Types of gears used by the Samaná Fishers.



S4: FIG. S1. 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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S4: Table S1. 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 + Compres sor + Net**	**Line + Net**	**Net**	**Compres sor**	**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 S5. State of the fisheries.

S5: Table S1. 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			

S5: Table S1. 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			

S5: Table S1. 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			

S5: Table S1. 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			

S5 Table S2. 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	Negative	Positive	-113.40	285.33	0.917	-866.78	639.99
		Negative	Neutral	226.80	336.74	0.783	-662.35	1115.94
		Positive	Neutral	340.19	399.89	0.679	-715.70	1396.09
	SAC	Negative	Positive	-713.69*	251.97	0.023*	-1339.81	-87.56
		Negative	Neutral	182.91	285.3	0.799	-526.03	891.86
		Positive	Neutral	896.60*	354.05	0.045*	16.82	1776.38
	MS	Negative	Positive	-102.60	325.12	0.947	-912.41	707.21
		Negative	Neutral	86.40	367.83	0.97	-829.80	1002.60
		Positive	Neutral	189.00	455.16	0.91	-944.74	1322.73
yellowtail snapper	SAM	Negative	Positive	82.71	344.96	0.969	-776.53	941.96
		Negative	Neutral	866.05*	321.99	0.032*	-1668.06	-64.04
		Positive	Neutral	-948.76	410.59	0.073	-1971.47	73.95
	SAC	Negative	Positive	925.83	642.94	0.336	-675.63	2527.30
		Negative	Neutral	-140.75	600.11	0.97	-1635.53	1354.04
		Positive	Neutral	-1066.58	765.25	0.359	-2972.7	839.54
	MS	Negative	Positive	-115.92	888.95	0.991	-2324.86	2093.02
		Negative	Neutral	265.13	828.95	0.945	-1794.71	2324.98
		Positive	Neutral	381.05	1064.8	0.932	-2264.87	3026.97

Notes mean size differences: banana grunt: SAC – ‘negative’ (731), neutral (548) ‘positive’ (1444.6) yellow snapper SAM – ‘negative’ (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 S6. Changes in the fisheries.

S6: Table S1. 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			

S6: Table S1. 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			

S6: Table S2. 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).

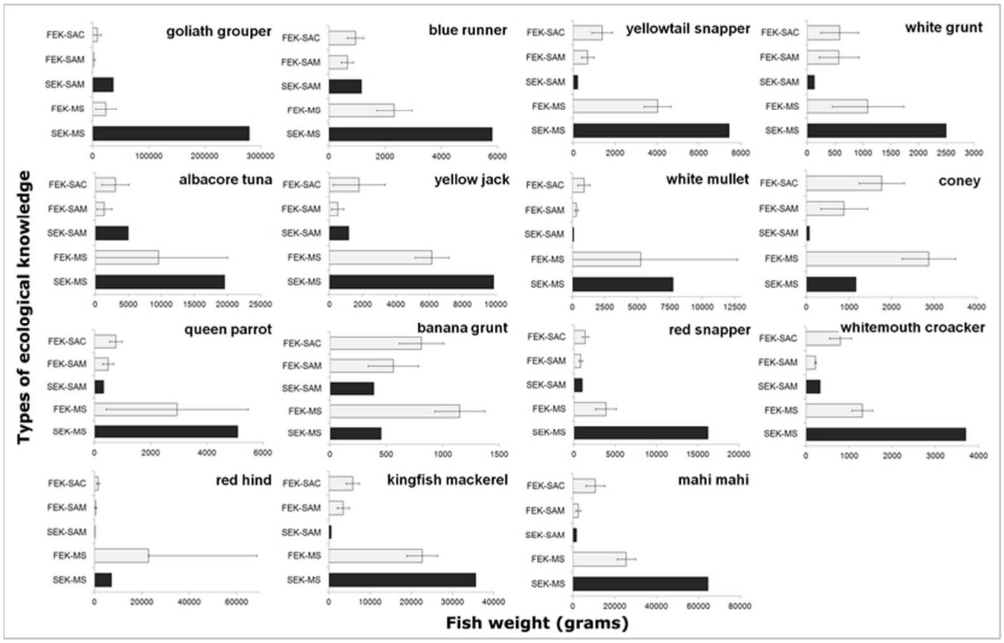
Note 2: the mean size estimates for those that say there have been “no” changes are catching larger fish and estimating larger size of maturity.

Appendix S7. Livelihoods

S7: Table S1. 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



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).

70x44mm (300 x 300 DPI)