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Risk perceptions and conservation ethics among recreational anglers targeting threatened sharks in the subtropical Atlantic

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ABSTRACT: Recreational fisheries management has traditionally been more concerned with quantifiable, catch-centric goals than angler-centric perceptions. However, the attitudes of fishers affect their behavior, which can alter the effort they make towards conservation actions, and ultimately, the outcome for exploited or threatened species. We conducted a quantitative human dimensions study into the drivers of conservation attitudes and perceptions of recreational fishers towards sharks. This was accomplished through a targeted online snowball survey on a sample of 158 recreational anglers in the state of Florida, a global hotspot for recreational fishing. Subjective knowledge of shark conservation issues was the most consistent driver for pro-shark conservation attitudes. Anglers ranked the great hammerhead and tiger shark as being the most threatened species, a result that is generally consistent with empirical data. Anglers did not identify species-specific differences in capture stress as an important factor in determining survivability, a result that somewhat contradicts available empirical data. In general, fishers were more supportive of management actions that would be the least restrictive to fishing, except in the case of highly threatened species. Anglers believed commercial fishing had the largest impact on shark populations, and recreational fishing the least, which is largely consistent with empirical information but could also reflect angler bias. Taken together, our findings suggest anglers generally care about shark conservation, but are unaware of some potential angling threats to sharks and possible conservation solutions. Further, anglers who consider themselves knowledgeable about shark conservation will be more sympathetic to shark management and more likely to adopt fishing practices that reduce shark mortality and sub-lethal impacts.

KEY WORDS: Fishing · Shark · Conservation · Vulnerability · Risk · Angler

INTRODUCTION

It is increasingly recognized that understanding the human dimensions of natural resource and conservation issues is a crucial factor in the development of strategies that are embraced by stakeholders and yield tangible conservation benefits (Mascia 2003). Indeed, biological or ecological knowledge alone is insufficient given that human behaviors are almost always associated with both conservation problems and solutions (Fox et al. 2006). Given that so many fisheries issues are regarded as 'wicked problems' in that they are difficult to define, multi-dimensional, and difficult to de-couple from other environmental issues (Jentoft & Chuenpagdee 2009), it is not surprising that there has been rapid growth in the appli-

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cation of human dimensions studies to inform fisheries conservation and management (Salz & Loomis 2005). Nonetheless, there are still many gaps in research. For example, in a global synthesis of the history and status of catch and release recreational fisheries, Arlinghaus et al. (2007) found very few studies that examined the beliefs and practices of recreational anglers, and their associated willingness to comply with management practices or adopt voluntary conservation-oriented behaviors. This is surprising, since fish are an ecologically diverse taxonomic group of animals that experience varying degrees of threats from human activities, and also because risk can be socially constructed and can play a key role in shaping environmental policy (Slovic 1999).

Human dimension information might also be important for augmenting our understanding of the dynamics of the recreational fishing sector whereby the fishers themselves often act as their own resource managers. Indeed, there is growing recognition that the voluntary actions of anglers may supplant the need for formal regulations in some cases (Cooke et al. 2013). Since recreational fishing is gaining attention from the research community in regard to both its role in the global fish crisis (Cooke & Cowx 2004) and the conservation of iconic and threatened fish species such as grouper, tunas, billfish, and sharks (Pine et al. 2008, Phyne et al. 2013, Cooke et al. 2014, Shideler et al. 2015), understanding and incorporating recreational fisher perspectives into management and conservation plans seems prudent.

Sharks are an ancient, diverse, and generally threatened group of predatory marine fishes that exhibit slow life histories that render them especially sensitive to overfishing (Stevens et al. 2000). The reported declines of many species of sharks in recent years have made them a popular focus for conservation scientists (Baum et al. 2003, Dulvy et al. 2008, Gallagher & Hammerschlag 2014). Commercial exploitation is a larger contributor to their overall extinction risk compared to recreational fishing (Worm et al. 2013). Although it is generally accepted that shark fishing mortality is much higher in commercial fisheries than in the recreational sector (Pine et al. 2008) and that fishing mortality in general is more detrimental to shark populations than other anthropogenic impacts, sharks have been highly prized in recreational fisheries globally since the mid-20th century, and is a growing source of significant mortality (Pepperell 1992, Campana et al. 2006). In the USA alone, more large sharks were killed by recreational anglers than commercial fishers in 2013 (Lowther & Liddel 2014, Shiffman 2014). Recent work has contended that even low levels of mortality from recreational fisheries (either by direct harvests or post-release in catch and release) could contribute or even add to the threatened status of certain shark species (Shiffman et al. 2014), whereas other studies suggest anglers engaging in responsible non-consumptive catch and release fishing activities could represent overlooked conservation allies (Granek et al. 2008, Lynch et al. 2010, Shiffman & Hammerschlag 2014).

A recent email-based survey of charter boat fishing captains in Florida found that shark fishing was often the most expensive trip offered, most fishers practiced catch and release shark fishing, and that their primary motivation was the excitement of catching a big fish (Shiffman & Hammerschlag 2014). However, the study found that charter boat anglers were most excited about catching hammerhead sharks (*Sphyrna* spp.), a group of species that is extremely vulnerable to both at-vessel and post-release mortality (Gallagher et al. 2014a,b). McLennan Press et al. (in press) surveyed shark anglers across the USA and revealed that 88% of respondents claimed to have released the last shark that they caught, and that most respondents typically released sharks. Although these studies provided much useful information on angler attitudes towards catch and release, they did not explore species-specific threat perceptions. A deeper understanding of which fisher demographic variables are the best predictors of angler conservation ethics and beliefs on sharks may allow for comparisons of angler-based vulnerabilities, with estimates of vulnerability obtained via fishery-independent assessments of behavioral, physiological or survival-related endpoints. This may in turn assist in the identification of knowledge gaps and potential angler misconceptions, while providing a mechanism to help managers determine which policies may be most supported by anglers, aiding in establishing effective management strategies for threatened shark species.

We conducted a quantitative analysis of the conservation attitudes and perceptions of Florida-based recreational fishers towards sharks. Florida is a global epicenter for recreational fishing in general and for sharks specifically (Shiffman & Hammerschlag 2014). Our study had 3 main objectives: (1) to evaluate the significance of fisher-related demographic variables and subjective knowledge (the individual's perception of how much he/she knows on a particular subject) on their perception of the vulnerability of shark species; (2) to quantify angler-generated rankings of shark vulnerability to fishing

and the value of potential management tools for threatened sharks; and (3) to gauge the perceived impacts of recreational and catch and release fishing on shark survival and rank them against other human threats facing sharks. We compared these fisher-generated vulnerability rankings with existing empirical data on shark physiological and behavioral responses to capture and release. Finally, we discuss the role that recreational anglers can play in the conservation of sharks. Collectively, we hope this study provides a way to maximize angler stewardship, education on shark conservation, and sustainability of catch and release fisheries targeting sharks, thereby providing a unique opportunity to make stakeholders part of the solution to this contemporary conservation problem (Brown 2003).

METHODS

Survey design

An internet-based quantitative survey was conducted among recreational fishers who catch sharks throughout the state of Florida. The survey was hosted on a basic, user-friendly and professional online interface (www.surveygizmo.com). It was initiated on 15 August 2013 and remained available until 31 December 2013. To capture the highest proportion of dedicated and experienced anglers that were knowledgeable about local issues related to sharks and shark fishing, the link to the self-administered survey was featured in 3 regional issues of Coastal Angler Magazine (The Florida Keys, Miami, and the North Coast), a widely-read, free monthly fishing periodical published in print only in Florida. The link to the survey was also posted online in September 2013 on the 'Florida' section of the Coastal Angler Magazine website; therefore respondents could share the link freely with colleagues and/or friends. The objective was to target stakeholder knowledge (referred to as local ecological knowledge, LEK; Davis & Wagner 2003, Boudreau & Worm 2010) and obtain information from a relatively specialized demographic of shark fishers with a history of saltwater fishing in Florida. As such, we utilized non-probability sampling, specifically chain-referral (herein called purposive snowball) sampling, where individuals in a targeted community suggest or pass along the survey to subsequent users (Henry 1990, Penrod et al. 2003). This method of survey distribution and data collection has been widely used in the social sciences as well as in the fisheries literature (e.g. Hasler et al. 2011, Cooke et al. 2012, Peterson & Carothers 2013), and is well suited to obtaining valuable responses on potentially sensitive issues from informed and experienced users (Neis et al. 1999, Boudreau & Worm 2010). Purposive snowball-style internet surveys have a number of advantages over conventional survey designs but also have important limitations — notably the non-random sampling-based survey design, which precludes generalized insights (Fricker & Schonlau 2002, Beidernikl & Kerschbaumer 2007). Our survey was only distributed in English, therefore the ability to read English was a prerequisite for understanding the survey. We recognize the potential for bias associated with the 'digital divide' (Norris 2001) related to factors such as age, race, and socio-economic status, among others. However, our sampling efforts were focused on a particular region and demographic (i.e. boat anglers that targeted sharks) which in itself inherently limited the pool of respondents. In other words, the sampling was non-random relative to the broader population. Indeed, purposive snowball surveys are regarded as being particularly effective at targeting hard-to-reach populations (Atkinson & Flint 2001).

We tracked survey IP addresses to determine the location of each respondent and to ensure that only a single submission could be generated from each IP address. Survey respondents were provided a statement of consent which assured anonymity and informed them that completion of the survey would result in a chance to win one of several gift bags. All statements of consent and survey questions were designed with and approved by the University of Miami's Human Subjects Research Office.

The survey was comprised of 22 questions separated into 3 sections: A, fishing practices; B, education and conservation; and C, angler demographics (see Part A of the survey in Supplement 1 at www.int-res.com/articles/suppl/n029p081_supp.pdf). Section A of the questionnaire contained 7 questions that focused on fishing style, experience with sharks, and their typical at-vessel behavior when a shark was captured. Section B presented 8 questions related to the respondents' knowledge of shark-related research and conservation, the ecological importance of sharks, and the regional population status of specific species, management tools for these species, and the perceived impacts of catch and release and other anthropogenic impacts/activities on sharks. The final 7 questions in Section C asked basic questions related to a participant's gender, age, years of experience, avidity (days spent fishing each year), education level, geographic location, and whether

they believed they were knowledgeable about shark conservation issues. These questions were chosen after consultation with the peer-reviewed literature and informal consultation with recreational fishers, managers, and policy specialists. Respondents were not allowed to advance to the next question in the survey until a response of some type had been provided for the previous question (either selecting an answer and clicking 'submit' or not selecting anything and clicking 'submit'), and respondents were not allowed to go back and change answers. We tested 8 hypotheses (see Table 2), which were formulated after consulting surveys from the recreational fishing literature (Arlinghaus & Mehner 2005, Arlinghaus et al. 2007, Nguyen et al. 2013).

We collected data from all respondents even if they did not complete the entire survey. All categorical demographic (i.e. independent) variables were recoded into ordinal levels (for specific details, see Supplement 2 at www.int-res.com/articles/suppl/n029p081_supp.pdf). Prior to any statistical analysis, we tested for any correlation between our independent variables using Spearman's correlation, and any highly correlated variables were removed from the analysis. We excluded gender in all analyses because of the low number of female respondents, which may have led to Type I error and a false rejection of null hypotheses.

Statistical analyses

We used a generalized linear model (GLM) approach (ordinal regression) to examine the effects of fisher demographics and subjective knowledge variables on (1) the proportion of sharks selected as 'threatened' (only the 'highly threatened' and 'critically threatened' categories, see Supplement 1); (2) the proportion of management tools for 'threatened' sharks (respondents that did not select any threatened species were removed from the analysis); and (3) the proportion of factors selected which respondents believed may affect shark survival after release. We used non-parametric Kruskal-Wallis with Tamhane's multiple comparison post hoc tests (with Bonferroni correction, following Pflugfelder et al. 2005) to investigate whether the respondents' mean risk-rankings (i.e. the level or degree of threat status) differed among shark species and anthropogenic impacts on shark populations. To investigate whether there was a significant difference in the management tools selected between threatened and non-threatened shark species, we used a paired *t*-test on a subset of responses (n = 60, excluding those individuals who did not designate any species or selected 'nothing' in either category). A chi-squared analysis was used to examine the potential significance between fisher demographic variables and fishing style (catch and release only vs. catch and release or catch and keep) with perceived changes in shark populations in Florida and estimated catch and release mortality levels. All statistical analyses were conducted in SPSS; results were considered significant at $p < 0.05$.

RESULTS

A total of 175 individuals viewed the survey, of whom 158 individuals answered at least one question; 147 individuals completed the entire survey. All respondents' IP addresses originated from the state of Florida except for 25 individuals (~16%). The intended nature of our snowball survey means that this small proportion of the sample were likely friends or acquaintances of other respondents, who also spent considerable time in Florida (either seasonally or previously). Alternatively, these individuals may have received a copy of the magazine in which the survey was advertised. As such, we did not exclude them from our analyses. Of the 158 individuals, the majority were male (89%) and fit into an age class of 41 yr old and older (~82%, Table 1). Only 11 respondents indicated that they were 30 years old or younger (Table 1). Of the 147 individuals that provided education information, approximately 21% had a high school education or less; ~27% had completed an associate's degree or technical coursework (including some college classes); ~27% had attained a bachelor's (or similar) university degree; and ~26% had received an advanced degree or coursework beyond a bachelor's (i.e. master's or doctoral). Of 147 respondents, 20% had 10 yr or less experience fishing in Florida; ~12% between 11 and 20 yr; 19% between 21 and 30 yr; and ~49% more than 30 yr. The majority of anglers fished between 40 and 60 d yr^{-1} (Fig. 1a). In total, 76% of anglers considered themselves knowledgeable about shark conservation issues, while 24% did not. Fifty percent of respondents indicated they were affiliated with a conservation-based fishing club or group. The variable 'knowledge of shark conservation' was deemed a better potential indicator for modeling the potential influence of 'conservation knowledge' than the 'affiliation with a conservation group,' and it was thus used for all relevant analyses. Ninety-four percent of

Table 1. Socio-demographic variables and other fishing characteristics of the Florida recreational shark angler sample

Socio-demographic variables	No. of respondents	Percentage (%)
Gender (n = 146)		
Male	130	89.0
Female	16	11.0
Age (years) (n = 146)		
<21	1	0.7
22–30	10	6.8
31–40	16	11.0
41–50	34	23.3
51–64	48	32.9
65+	37	25.3
Education (n = 147)		
Grade 12 or less	4	2.7
High school graduate/GED	27	18.4
Associate/technical school/ college coursework	39	26.5
Bachelor's degree	39	26.5
Advanced degree or advanced coursework	38	25.9
Geographic tendency in Florida (n = 144)		
Northwest	23	16.0
Northeast	18	12.5
Southeast	30	20.8
The Florida Keys	55	38.2
Southwest	18	12.5
Association with conservation clubs (n = 146)		
Yes	72	49.3
No	74	50.7
Knowledgeable of shark conservation (n = 152)		
Yes	116	76.3
No	36	23.7

Angler typology or perception variable	No. of respondents	Percentage (%)
Fishing experience (yr) (n = 147)		
<5	18	12.2
6–10	12	8.2
11–20	17	11.6
21–30	28	19.0
31–40	32	21.8
41+	40	27.2
Fishing activity (d yr^{-1}) (n = 147)		
<20	8	5.4
20–40	31	21.1
41–60	39	26.5
61–100	23	15.6
101–150	17	11.6
150+	29	19.7
Fishing style (n = 151)		
Catch and release	76	50.3
Catch and keep	3	2.0
Both	72	47.7
Catch and release tendency (%) (n = 151)		
76–100	28	18.5
51–75	87	57.6
26–50	26	17.3
1–25	8	5.3
0	1	0.7
No answer	1	0.7

Angler typology or perception variable	No. of respondents	Percentage (%)
Encounter rate of sharks (%) (n = 152)		
76–100	16	10.5
51–75	43	28.3
26–50	54	35.5
1–25	38	25.0
0 (never)	1	0.7
Shark population trend (n = 151)		
Large increase	17	11.3
Slight increase	30	19.9
Neither increase or decrease	54	35.8
Slight decrease	28	18.5
Large decrease	12	7.9
No opinion/prefer not to answer	10	6.6
Mortality rate of sharks after release (%) (n = 151)		
76–100	2	1.3
51–75	13	8.6
26–50	44	29.1
1–25	85	56.3
0 (everything always survives)	7	4.6
Importance of large breeding sharks (n = 152)		
Agree	143	94.1
Disagree	3	2.0
No opinion/prefer not to answer	6	3.9

anglers agreed with the statement: 'large reproductively mature sharks are important to the overall ecosystem.'

Correlations between potential predictor variables were detected: age and experience (Spearman's correlation: r = 0.362, $p < 0.001$); encounter rate of sharks and days spent fishing per year (Spearman's correlation: r = 0.204, $p < 0.05$); and days spent fishing per year and education (Spearman's correlation: r = −0.356, $p < 0.001$). Given these correlations, and due to the fact that our sample was skewed towards older respondents, age and education level were removed from any subsequent analyses. Encounter rate of sharks was also removed from any analyses as days per year was considered a more useful and important measure of fishing avidity (inclusive of sharks). Overall, we rejected 4 of the 8 null hypotheses (~50%) across our analyses (Table 2).

The proportion of shark species selected by respondents as threatened was significantly associated with subjective knowledge of shark conservation issues (β = −0.96 ± 0.42 SE, $t = 5.32$, p = 0.021), but not the number of days spent fishing (β = 1.25 ± 0.72, $t = 3.00$, p = 0.084). The 6 shark species differed significantly in their mean risk rankings assigned by the respondents (Kruskal-Wallis test: $\chi^2 = 61.39$, df = 5, $p < 0.0001$). Great hammerhead sharks *Sphyrna mokarran* had the highest mean risk ranking (~41% of 148 respondents classified them as either 'highly threatened' or 'critically threatened'), which was significantly higher than blacktip (*Carcharhinus limbatus*), bull (*Carcharhinus leucas*), nurse (*Ginglymostoma cirratum*), and lemon (*Negaprion brevirostris*) sharks ($p < 0.0001$; Fig. 2). Tiger sharks *Galeocerdo cuvier* had the second highest risk ranking (~26% of 147

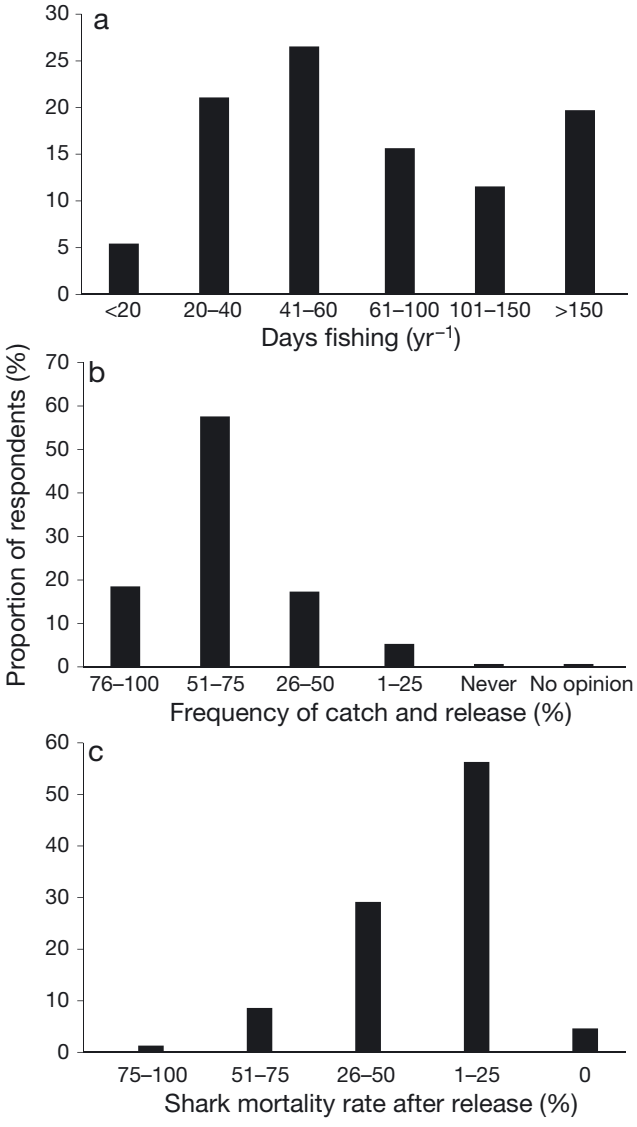

Fig. 1. Selected socio-demographics of our sample. Responses to questions about respondents' (a) fishing activity (days spent fishing per year; n = 147), (b) fishing practices, and (c) opinions (n = 151) on the percentage of sharks which experience post-release mortality

respondents classified them as either 'highly threatened' or 'critically threatened'), which was significantly higher than nurse sharks ($p < 0.0001$; Fig. 2). Nurse sharks exhibited the lowest risk rankings of all species (~47% of 148 respondents classified the species as 'minimally threatened'; Fig. 2), which was also significantly lower than lemon and blacktip sharks ($p < 0.0001$).

The 3 most popular management tools for 'threatened' shark species were mandatory catch and release practices (~45%, n = 66), size regulations (~39%, n = 57), and mandatory use of circle hooks (38%, n = 56). Creation of marine protected areas was the least popular choice (~15%, n = 22). Univariate GLMs (ordinal regression) suggested that there were no significant effects of subjective knowledge of shark conservation issues or days spent fishing on the proportion of management tools selected for threatened sharks. There was no significant difference in the mean number of management tools selected by respondents between the 'threatened' and 'non-threatened' categories of sharks (paired *t*-test, $t = 0.968$, df = 59, $p = 0.337$; Fig. 3).

Most fishers (35%, n = 54) encountered sharks on 26 to 50% of days spent fishing off Florida, and nearly half of our respondents indicated that they specifically targeted sharks while fishing (~49%, n = 74). Fifty percent of anglers exclusively practiced catch and release, whereas 47% practiced catch and release along with catch and keep for any fish (Fig. 1b). The majority of fishers believed that released sharks experienced moderate to low levels of mortality after they were released: 56% of respondents suggested a mortality rate of 1 to 25% (n = 85; Fig. 1c), while 29% suggested a post-release mortality rate between 26 and 50% (n = 44; Fig. 1c). Univariate GLMs (ordinal regression) suggested that there were no significant effects of subjective knowledge of shark conservation issues or days spent fishing on the proportion of factors selected which respondents believed may affect shark survival after they are released. In total, 3 of the 5 factors that were presented for dictating shark survival during catch and release fishing practices were chosen as 'important' in similar proportions: hooking location (86%, n = 131), how long the shark is fought (85%, n = 130), and fishing gear (83%, n = 126). Removal of the animal from the water (78%, n = 120) and whether or not the species was inherently sensitive (55%, n = 84) were less popular responses; only 2 respondents (1.3%) reported that no factors were important. The majority of fishers indicated that there had been no change in the population status of sharks since they began fishing in Florida (36%, n = 54); around 30% (n = 47) perceived an increase in shark populations, while ~27% (n = 40) perceived a decrease (Table 1).

We observed a significant relationship between fishing styles and perceived shark population status ($\chi^2 = 11.04$, df = 2, $p < 0.01$), whereby participants who practiced catch and release as well as catch and keep generally perceived less of a change in shark populations (in either direction) than those who practiced catch and release only. There were no significant relationships between population status and knowledge ($\chi^2 = 2.78$, df = 3, $p = 0.43$), experience ($\chi^2 = 9.62$, df = 6, $p = 0.16$), or days spent fishing per year ($\chi^2 = 22.47$,

Table 2. Hypotheses tested with indication of whether they were accepted or rejected

Hypothesis	Prediction	Accept	Reject
H1	There are no differences among fisher demographic variables or subjective knowledge on the proportion of sharks perceived as 'threatened'		X
H2	There are no differences in the mean risk rankings among species		X
H3	There are no differences among fisher demographic variables or subjective knowledge on the proportion of factors perceived to affect shark survival after they are released	X	
H4	Neither fisher demographic variables nor fishing style significantly affects fishers' perceived changes in shark populations in Florida		X
H5	Neither fisher demographic variables nor fishing style significantly affects fishers' perceived levels of post-release mortality for sharks in catch and release fishing activities	X	
H6	There are no effects of fisher demographic variables or subjective knowledge on the proportion of management tools thought to be suitable for sharks perceived as 'threatened'	X	
H7	There are no differences in the mean number of management tools between sharks classified as 'threatened' and those classified as 'non-threatened'	X	
H8	There are no differences in the mean risk rankings among anthropogenic hazards to shark populations		X

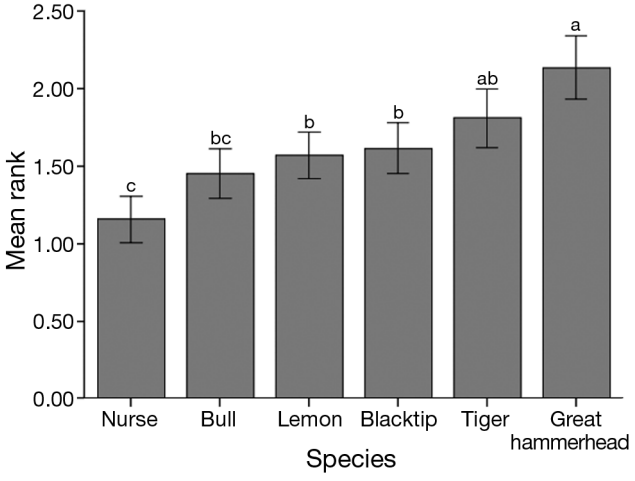

Fig. 2. Mean (±SD) threat rank (higher numbers signify higher threat status) assigned by anglers for 6 species of sharks commonly encountered in Florida. Different lowercase letters indicate significant differences ($p < 0.05$)

df = 15, p = 0.09). We did not detect any significant relationships between perceived mortality rates and fishing style ($\chi^2 = 1.42$, df = 2, p = 0.49), knowledge ($\chi^2 = 0.78$, df = 2, p = 0.68), experience ($\chi^2 = 0.61$, df = 2, p = 0.96), or days spent fishing per year ($\chi^2 = 11.33$, df = 2, p = 0.33).

We detected significant differences in the average impact rankings (ranging from 0 to 4, from low to high impact) among the series of 6 anthropogenic hazards (Kruskal-Wallis test, $\chi^2 = 269.94$, df = 5, $p < 0.0001$). Post hoc tests revealed that there were 3 groups of clustering according to their impact rankings: commercial fishing had the highest mean impact ranking (mean ± SE: 2.72 ± 0.05), which was selected as having a 'large impact' by ~79% of respondents (n = 117) and was significantly different than the other 5 hazards ($p < 0.0001$; Fig. 3). Bycatch, pollution, and habitat loss were all perceived similarly in the 'moderate impact' category (42, 40, and

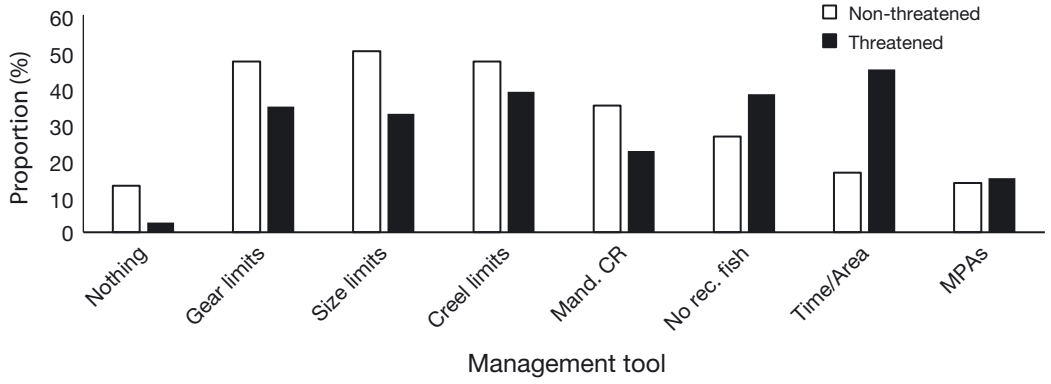

Fig. 3. Proportion of survey respondents selecting preferred management tools for non-threatened (white bars) and threatened (black bars) sharks. Gear limits: refers to mandatory use of circle hooks; Mand. CR: mandatory catch and release fishing; No rec. fish: moratorium on all recreational fishing; Time/Area: time–area closures; MPAs: marine protected areas

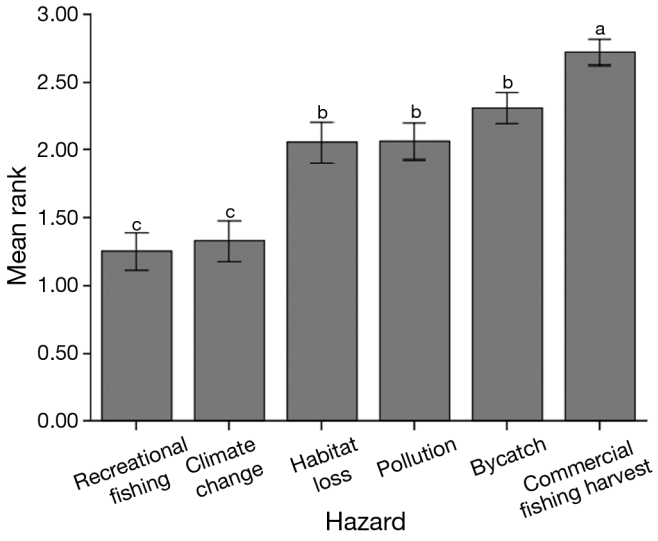

Fig. 4. Mean (±SD) threat rank (higher numbers signify higher threat status) given by anglers for 6 hazards that can affect shark populations. Different lower-case letters indicate significant differences ($p < 0.05$)

36% of anglers, respectively). Overall, these 3 hazards ranked closely (ranging from 2.05 to 2.3) and were all significantly higher than climate change and recreational fishing ($p < 0.0001$ in all cases; Fig. 4). Recreational fishing dominated the 'small impact' category (52%, n = 78), and received the lowest overall impact ranking (1.25 ± 0.07), which was significantly lower than every other hazard except climate change (~37% in the 'small impact' category; Fig. 4).

DISCUSSION

The fate and survival of fishes captured and released in recreational fisheries depends heavily on the behaviors of anglers (Cooke & Suski 2005), which are associated with their underlying attitudes and beliefs (Arlinghaus et al. 2007). This point is best exemplified when anglers choose to remove their catch from the water for photos, a conscious decision that puts the fate of the fish in the hands of the angler prior to release. Anglers also vary significantly in their willingness to adopt solutions to conservation problems facing aquatic species (Salz & Loomis 2005), yet they often attain access to sensitive ecosystems and species (Donaldson et al. 2011, Cooke et al. 2014). Furthermore, natural resource management agencies are traditionally quite sympathetic towards maintaining the livelihoods of fishers and the associated economic expenditures (and tax base) associated with the sector (Arlinghaus et al. 2007). Therefore, quantifying fisher beliefs and attitudes, particularly those perceived when encountering threatened or rare species such as sharks, may help managers target otherwise overlooked sources of threat or risk (Nguyen et al. 2013). We documented a range of underlying angler beliefs on shark catch and release survival, as well as perceptions surrounding the threats facing shark species and their deeper core values surrounding management measures and human impacts.

Subjective (i.e. perceived) knowledge about shark conservation issues was a significant variable in predicting how many sharks were selected as 'threatened' but not the proportion of management tools anglers selected for 'threatened' shark species. Subjective knowledge about environmental issues can correlate with pro-ecological behaviors (Newhouse 1990, Axelrod & Lehman 1993), and our findings agree with a recent survey that found increased knowledge about sharks increased public concern for their conservation (O'Bryhim & Parsons 2015). Sharks have been a focus of conservation-based research for decades, but over the last 10 yr there has been an increase in the volume and accessibility of content surrounding shark conservation issues in the public sphere, particularly on social media (Gallagher & Hammerschlag 2013). While some species have indeed declined drastically in recent decades and others are Threatened according to the IUCN Red List of Threatened Species, not all shark species are a cause for conservation concern (Hepp & Wilson 2014), although the perception among the pro-conservation public seems to be that the populations of all shark species are drastically declining (Gallagher

Table 3. Vulnerability and threats facing the 6 shark species used in our study (higher rank = higher threat) according to various sources: (1) threat of extinction as given by the IUCN Red List www.iucnredlist.org, (2) at-vessel (AV) and/or post-release (PR) mortality estimates from empirical research, and (3) anglers in the present study. At-vessel mortality rate data obtained from Morgan & Burgess (2007); post-release mortality information obtained from Gallagher et al. (2014a); n/a: data not available

Species	IUCN ranking	Mortality rate (%)	Angler ranking
Blacktip	Near Threatened	88 (AV)	4
Bull	Near Threatened	26 (PR)	2
Great hammerhead	Endangered	93/46 (AV/PR)	6
Lemon	Near Threatened	n/a	3
Nurse	Data Deficient	n/a	1
Tiger	Near Threatened	8/0 (AV/PR)	5

& Hammerschlag 2013). In general, it appears that social perceptions of conservation status largely match the current empirical information on population status as well as IUCN Red List rankings (Table 3).

We detected a range of risk rankings for the 6 species presented to anglers. The great hammerhead shark was ranked by anglers as the most threatened species listed, a finding that broadly agrees with the current scientific evidence (Gallagher et al. 2014a,b). Moreover, the nurse shark, by far the most abundant shark in Florida and the greater Caribbean (Heithaus et al. 2007, Ward-Paige et al. 2010), was accurately ranked as the least threatened. Overall, the range of angler-generated vulnerability rankings (from high to low) generally reflects the local abundance of these sharks, as well as their comparative vulnerabilities to physiological stress and post-release survival documented in recent work on the same set of species (Gallagher et al. 2014b). While tiger sharks are indeed robust to capture stress, they are still rare in Florida and are significantly more abundant in the nearby Bahamas, where they are protected from all commercial or recreational harvest.

We did not reveal any influence of fisher demographic variables or subjective knowledge on the proportion of factors that can affect shark survival in catch and release fishing practices. While it may be realistic to assume that increased experience (i.e. days spent fishing annually or years engaged in fishing) would correlate with a greater understanding of the factors affecting shark survival, we speculate that this result is due to the rarity of observing shark mortalities boat-side. Post-release mortality is usually cryptic, delayed and out of sight of humans, a result of the shark's inability to recover from the magnitude of the physiological stress and metabolic disruption (Skomal & Bernal 2010). Indeed, while some species of fishes have very high post-release mortality rates after capture and release (e.g bonefish, Cooke & Philipp 2004; hammerhead sharks, Gallagher et al. 2014a), the average post-release mortality rates for most marine fishes are generally less than 25% (Bartholomew & Bohnsack 2005). In other words, if anglers had not witnessed a dead shark as a result of their behavior before taking our survey, they may not have been able to make this connection regardless of their experience or days spent fishing per year.

None of the factors that could affect shark survival upon release were preferentially selected as 'important' by respondents (Table 1). This finding suggests that most anglers know that all of the factors presented can have important effects on the survival of most fishes when captured, or that they are avoiding acknowledging that angler fishing behavior can impact shark survival. It is worth noting that the least popular factor chosen was 'the species itself may be sensitive' (~50% of respondents; Table 1). However, while only a few of the hundreds of shark species encountered by recreational fishers have been properly evaluated with regards to their stress responses to fishing (most in the last ~5 to 7 yr; Skomal & Bernal 2010), sharks show clear species-specific differences in their ability to survive capture stress. This result is again likely attributable to the inherent difficulty in assessing and detecting post-release survival regardless of experience level. Species-specific information on vulnerability to fishing actually exists for the majority of the species covered in the present study. Gallagher et al. (2014a,b) found that hammerhead sharks, including the great hammerhead, are extremely vulnerable to capture stress and at-vessel and post-release mortality even at low fight times, making the species a very poor candidate even for catch and release fishing practices. In addition, blacktip sharks appear to be sensitive to capture stress, whereas lemon and tiger sharks exhibit higher tolerance at moderate fishing intensity (Gallagher et al. 2014 a,b). It should be noted that although capture stress does not always result in mortality in fishes (Moyes et al. 2006, Musyl et al. 2015), sub-lethal effects can affect population-level processes such as spawning and migration (Cooke & Suski 2005, Arlinghaus et al. 2007). These data loosely match the perceived threatened vulnerability ranks of the species we presented to anglers (Fig. 4). However, education and outreach based on recent biological and ecological research is needed as it may be useful for raising angler awareness as well as helping managers to make better decisions regarding initiatives to promote shark survival in recreational fisheries.

Nearly two-thirds of our respondents perceived either no change or an increase in shark populations since they first started fishing in Florida (Table 1), and fishing style was significantly associated with population status. Anglers in our sample that practiced catch and release only perceived a greater change in shark populations than those who also kept their catch (for all species, not just sharks). Catch and release fishing is a management tool or voluntary conservation ethics intended to benefit fish populations. Therefore, anglers that identify themselves as exclusively catch and release may have adopted this tactic in light of perceived negative shark population changes. In contrast, those who continue to harvest fish (including sharks) might be

more reluctant to admit to or associate themselves with overfishing. However, since most shark populations in the survey area are depressed compared to previous decades (Heithaus et al. 2007, Ward-Paige et al. 2010), it is possible that the anglers surveyed in this study were purposefully trying to overlook the impact of historical overfishing on the resource (McClenachan 2009, 2013). Unlike our study, Shideler et al. (2015) found a significant relationship between fishing avidity and anglers' perceptions on an increase in populations of the teleost goliath grouper *Epinephelus itajara*. This finding may be related to the fact that the goliath grouper had been under a fishing moratorium for nearly 20 yr, suggesting a bias towards relaxing regulations.

There is substantive evidence to suggest that shark populations in Florida are not as healthy as they were in previous decades. For example, by analyzing historical photographic data from the recreational fishing industry in the Florida Keys (the primary location of our survey respondents; Table 1), McClenachan (2009) detected significant decreases in fish size and species composition over the last 50 yr. Through fishery-independent sampling in the Florida Keys, Heithaus et al. (2007) reported significant declines in large sharks, and sharks were classified as absent from many parts of Florida and the Caribbean (Ward-Paige et al. 2010). These studies may suggest a shifting baseline for sharks in Florida, whereby anglers encountering sharks today may perceive what they believe to be a high abundance.

Traditional fishery management tools such as size and creel limits were the most popular in this study, and marine protected areas were the least popular management tool (Fig. 3), a finding which agrees with the controversy surrounding marine protected areas in recreational fisheries (Salz & Loomis 2005, Cooke et al. 2006). This finding also likely relates to the mosaic of marine protected areas, special protected areas, reserves, and marine sanctuaries which exist throughout the Florida Keys and which likely confuse and aggravate Florida anglers. These responses may also indicate that anglers prefer management tools that are the least restrictive to fishing and not necessarily the best for conservation of the resource. However, we found it interesting that these place-based management tools were commonly selected for 'threatened' shark species, suggesting that fishers may be more receptive to generally 'unfavorable' management tools (e.g. those that tend to restrict access or opportunity; Danylchuk & Cooke 2011) for threatened species. However, we did not detect a significant difference in the proportion of management tools selected between sharks that were classified as 'threatened' or 'non-threatened.' Size and harvest restrictions appeared to be among the most popular management tools for sharks regardless of the degree of threat facing the species in question, likely due to the fact that they are common and most often species-specific in design, and least restrictive to overall fishing. However, this is an interesting result given that many fishers tend to exploit marine protected area boundaries (i.e. 'fishing the line'). Moreover, size and harvest restrictions are likely not effective for species with stocks or populations that are severely depressed (e.g. hammerheads). Overall, the management questions revealed that fishers are less accepting of management actions that restrict their ability to fish, regardless of perceived 'threatened' status. This result has significant implications for communicating the value of ecosystem-based conservation management and further justifies the need for better communication between those groups assigning threatened statuses for wildlife (e.g. IUCN) and those who are utilizing the resource.

The recreational anglers we surveyed perceived recreational fishing to have the lowest impact of all of the presented hazards (Fig. 4), a finding that corroborates other human dimensions work in the recreational fishing sector (Lynch et al. 2010). In fact, our respondents seemed to classify climate change as a bigger (but not significantly so) threat to sharks than recreational fishing, even though the former is usually widely denied by the demographic that dominated our sample (older men in the southern USA; Akerloff et al. 2010). In contrast to their actual beliefs, this result could also reflect fishers trying to avoid blame, or choosing answers that would consequently result in the least amount of impact to their activities if additional management regulations were established. This may be particularly the case since there is a predisposed conflict between fishers and scientists, given that conservation science often results in recommendations that restrict fishing activities in both recreational and commercial sectors (Bohnsack 1998, Cooke & Cowx 2006, Danylchuk & Cooke 2011, Cooke et al. 2014). These data possibly elucidate an important underlying source of friction in this community which may limit stakeholder compliance with fishery regulations, and may present a starting point for future conversations on shark conservation. Furthermore, it also suggests that the burden of proof as to the impacts of recreational angling on marine ecosystems lies heavily, if not entirely, in the hands of conservation scientists (Shiffman et al. 2014).

We used a purposive snowball internet survey, which despite some limitations (Davis & Wagner 2003, Neis et al. 1999), enabled us to assess the responses of a group that would otherwise have been difficult to reach (Atkinson & Flint 2001, Cooke et al. 2012). We recognize that snowball surveys may fail to reach certain segments of the population due to lack of internet access, familiarity, trust and skill (known as the digital divide; Norris 2001), thereby warranting caution in generalizing these results to all saltwater anglers. Furthermore, correlations among a few of our fisher demographic variables and the age-skewed nature of our sample may have limited our ability to recommend where and how recreational fisheries management policies may be most effective. We did not examine motivations for angling or satisfaction from the previous fishing year, which may have provided additional insights into the dynamics of our sample. Nonetheless, this approach did yield valuable insight and is a valid means of collating stakeholder knowledge, especially from specialized groups such as those anglers that target and encounter sharks in Florida. Unfortunately, most of the work attempting to understand and correct for bias associated with online surveys and the digital divide is in the realm of health research and policy (e.g. Brodie et al. 2000) and not the human dimensions of natural resource use. The total number of anglers holding saltwater fishing licenses in the state of Florida has been estimated at 2.4 million individuals (US Fish & Wildlife Service 2011); however, the number of active fishers is likely significantly lower. Despite this large pool of anglers, our survey participation rate is in line with other recent published surveys of the same population (Shiffman & Hammerschlag 2014, Shideler et al. 2015). We realize that the low sample size of female respondents (12%, compared to the United States average participation rate of 25%; US Fish & Wildlife Service 2006) precluded any investigation into sex-related influences on angler behavior or perceptions, and future studies should strive to target female anglers more precisely. Future work should also seek to expand the nature of this survey by using a mailed questionnaire with additional creel surveys including versions of the survey posed in different languages.

CONCLUSIONS

Recreational anglers can be great partners in the conservation of fish populations (Granek et al. 2008, Cooke et al. 2014, Shiffman & Hammerschlag 2014). We found our sample of anglers to be relatively well-informed on issues pertaining to shark conservation, although they believed their actions to have minimal impacts on shark populations. While commercial fishing does have a greater overall impact on shark populations globally (Pine et al. 2008), recreational angling represents a significant threat to sharks (Lowther & Liddel 2014, Shiffman 2014), particularly for certain species that are highly vulnerable to capture mortality. Our results show that shark mortalities (at-vessel or post-release) from recreational fishing remain under-appreciated by anglers and are likely difficult to assess regardless of angler experience level. Anglers tended to be more supportive of management regulations that were least restrictive to fishing, except in the case of highly threatened species. Taken together, our results suggest that anglers care about shark conservation, but are either unaware of conservation tools and the potential threat angling poses to sharks, or they avoided acknowledging these — possibly due to perceived fear of incurring fishing restrictions. This underscores the importance of educational initiatives, especially those aimed at young or new anglers, since deeply rooted beliefs (i.e. perceptions on conservation) may begin to form early in one's fishing career (Arlinghaus & Mehner 2005). Thus, engaged and avid anglers may serve as responsible stewards for sharks and may be the best demographic for managers and policymakers when seeking input on new regulations (McClellan Press et al. in press). Lastly, we believe this work highlights the need for effective outreach programs on the impacts of catch and release angling on shark survival, which may in turn have positive downstream benefits such as the adoption of voluntary actions and behaviors that promote sustainability.

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