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Caught in the Same Net? Small-Scale Fishermen's Perceptions of Fisheries Interactions with Sea Turtles and Other Protected Species

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Small-scale fisheries are responsible for high numbers of animals caught as bycatch, such as turtles, cetaceans, and seals. Bycatch and its associated mortality is a major conservation challenge for these species and is considered undesirable by fishermen. To gain insights on the impact of bycatch on small-scale fishermen and put it in context with other financial and environmental challenges they face, we conducted questionnaire-based interviews on fishermen working on Crete, Greece. We investigated fishermen's perceptions of sea turtle and other protected species interactions, and the impacts of such interactions on their profession and livelihoods. Our results indicate a connection between declining fish stocks, related increased fishing effort, and reported increased frequency of interactions between fishermen and sea turtles. Respondents believed that their livelihoods were endangered by industrial fishing and environmental problems, but thought that combined interactions with turtles and other marine megafauna species were a larger problem. Responses suggested that extending compensation to fishermen may be a good conservation intervention. Small-scale fishermen hold a wealth of knowledge about the marine environment and its resources. This may be of help to researchers and policy makers as it could be used to achieve a better managed, sustainable fishery. Including small-scale fishermen in the process of developing regulations will both enhance those regulations and increase compliance with them.

Keywords: small-scale fisheries, bycatch, fishermen's perceptions, fisheries management, sea turtles, loggerhead turtles, fisheries

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INTRODUCTION

Small-scale fishing is a source of income and sustenance and a way of life for millions of people around the world. It is also projected by some as a more sustainable alternative to industrialized fishing methods that are depleting stocks worldwide (Preikshot and Pauly, 2005). However, small-scale fisheries are responsible for large amounts of bycatch that affect marine megafauna such as sharks, cetaceans, monk seals, and sea birds (Stevens et al., 2000; Lewison et al., 2004a,b, 2014; Read et al., 2006; Anderson et al., 2011; Croxall et al., 2012). Associated declines in many populations pose a serious challenge for conservation of many species

(Hall et al., 2000; Lewison et al., 2004a,b, 2014) but also represent a prominent management issue for small-scale fishermen (Kelleher, 2005). Because of the characteristics of small-scale fishing activity, its impacts on marine megafauna are hard to quantify (Komoroske and Lewison, 2015). The small-scale fishing fleet is unregulated, dynamic in nature, and the number of registered fishing vessels does not necessarily accurately represent the number of active boats (Chuenpagdee et al., 2006), which changes constantly as fishermen may receive subsidies to retire their boats (European Commission, 2008), or go into retirement. On-board observation programs are not feasible to implement locally for logistical reasons (size and distribution of fleet, size of vessel, etc.; Moore et al., 2010; Komoroske and Lewison, 2015). Social science and survey research methods are used as a way to glean information about how fishermen interact with and understand their environment, and have so far revealed important clues on the potential enormity of the impact of small-scale fisheries on marine megafauna populations (Moore et al., 2010; Alfaro-Shigueto, 2012; Goetz et al., 2014; Komoroske and Lewison, 2015).

The Mediterranean Sea is a region offering unique perspectives on fisheries bycatch. It is one of the most intensely fished regions in the world and hosts a substantial fishing fleet comprising an estimated 91,540 fishing vessels, of which the small-scale fishing vessels represent approximately 80% of the total (FAO, 2016). The intense fishing effort is depleting fish populations (FAO, 2016) and impacting many vulnerable species such as sharks (Ferretti et al., 2008), whales, dolphins, and porpoises (Bearzi, 2002; Bearzi et al., 2006; Fratzis, 2007), Mediterranean monk seals, *Monachus monachus* (Karamanlidis et al., 2008), and sea turtles (Cami-as and De Málaga, 2004; Lewison et al., 2004a,b; Casale, 2008; Wallace et al., 2010).

Case studies of sea turtles and their incidental capture in small-scale fishing gear can offer useful insights into the study of fisheries interactions with protected species. In the Mediterranean, small-scale fisheries are responsible for approximately 60,000 sea turtle captures/year, or 45% of the total turtle captures estimated for the region (Casale, 2011). The majority of these captures involve loggerhead turtles, *Caretta caretta*, and to a lesser extent green turtles, *Chelonia mydas,* the two species with established populations in the region (Casale and Margaritoulis, 2010; Casale, 2011). Gear used by small-scale fishermen such as gill nets (including drift nets, monofilament nets, trammel nets) have high mortality rates (up to 60–70%) probably due to long soak durations (Cami-as and De Málaga, 2004; Snape et al., 2013). The large size of the small-scale fleet suggests that overall cumulative bycatch and the associated mortalities represent a sizeable sea turtle conservation challenge in the region (Soykan et al., 2008; Casale, 2011; Snape et al., 2013).

There is relatively little information providing insights on how interactions with protected species affect small-scale fishermen, who are key actors in this region. Fishermen's opinions and attitudes have been explored for species that include *Dalmatian pelicans*, *Pelecanus crispus*, and other wetland birds in Prespa, Kerkini, and Vistonis lakes in Greece (Pyrovetsi and Daoutopoulos, 1989), Mediterranean monk seals in Greece (Glain et al., 2001), gray seals, *Halichoerus grypus*, in Cornwall, UK (Glain et al., 2001), and in the Baltic sea (Varjopuro, 2011), whales, dolphins, and porpoises in the Mediterranean (Fratzis, 2007) and otters, *Lutra lutra*, in Czech Republic aquatic ecosystems (Vaclavicova et al., 2010). In these studies, fishermen are reported as having negative attitudes and opinions toward these species because they are perceived to be responsible for damages caused to fishing gear and/or as competitors to their fishery. Damage caused by protected species such as sea turtles, cetaceans, and monk seals, may be one of the reasons behind hostile fisherman behavior and retaliatory attacks (Koutsodendris, 2007; Margaritoulis et al., 2007; Casale and Margaritoulis, 2010). Bycatch studies further imply that interactions with sea turtles and other species of marine mega fauna are linked to small-scale fishermen's notions of competition and antagonism toward more intensive fishing practices such as trawling which in the Mediterranean is primarily an industrial fishing fleet (Glain et al., 2001; Carreras et al., 2004; Chuenpagdee et al., 2006; Jacquet and Pauly, 2008; Chuenpagdee, 2012). Those studies indicate that interactions between sea turtles and other threatened species and small-scale fisheries present a multi-dimensional issue whose socio-economic aspects should not be ignored.

The Greek small-scale fishing fleet is one of the largest in the Mediterranean (15,832 registered vessels or 88% of the total Greek fishing fleet; Data: Hellenic Center for Marine Research, 2010). Greek small-scale fishing boats are typically between 6 and 12 m long, with 1–2 people working on board and fish an average of 209.2 days a year (13–20 days/month; Stergiou et al., 2002; Tzanatos et al., 2005; Greek Ministry of Agriculture, 2007). They are licensed to use more than one type of gear, and the most common among these are gill nets (39.0%) and demersal long lines (34.4%). Because of the vessels' small capacity and low engine power, fishing grounds are generally close to shore (Stergiou et al., 2002; Tzanatos et al., 2005; Greek Ministry of Agriculture, 2007). In addition, available data show that small-scale fisheries are responsible for a high level of undesirable interactions and related mortality of loggerhead turtles in Greece (Cami-as and De Málaga, 2004; Koutsodendris, 2007; Panagopoulou et al., 2008). For these reasons, Greece provides an excellent setting to investigate how small-scale fishermen perceive their fishing activity and their interactions with sea turtles and other species.

Greece hosts important nesting areas for loggerhead sea turtles, representing some 55–60% of the total nesting effort recorded in the region (Margaritoulis et al., 2003; Casale and Margaritoulis, 2010; Casale, 2015). While loggerhead turtle populations in the Mediterranean are assessed as Least Concern (LC) by the IUCN, it is emphasized that this status is entirely conservation dependent and interactions with fisheries is a major threat that needs to be addressed (Casale, 2015). The purpose of our study was to offer a socio-economic perspective on small-scale fisheries interactions with sea turtles and other protected species by conducting interviews with fishermen. Our work was conducted on the Greek island of Crete, which hosts important nesting habitats for loggerhead turtles in Rethymno, Chania, and the Bay of Messara and is considered a site of regional importance for Mediterranean loggerheads (Margaritoulis and

Panagopoulou, 2010). For this reason, these areas have been included in European Union's NATURA 2000 Network of Protected Areas as Sites of Community Importance (SCIs). Using adapted grounded theory, we analyzed quantitative and qualitative interview data to provide insights on the impact of sea turtles and other protected species on small-scale fishermen and their profession and recommended solutions, emphasizing the respondents' views. We already know that fisheries represent a sizeable threat for sea turtle populations in the Mediterranean (Casale and Margaritoulis, 2010; Casale, 2015), that sea turtle nesting populations on Crete are facing severe declining trends (Margaritoulis et al., 2010). Our work was an effort to identify and describe some of the socio-economic parameters of the issue and provide insights on the impact of small-scale fisheries interactions with sea turtles and other protected species on fishermen, in the context of other financial and environmental challenges they face such as the presence of invasive species, declining fish stocks as a result of overfishing and competition with other more intensive fishing gear such as trawlers and purse seines.

METHODS

Between June and August 2013, we visited 18 fishing ports geographically distributed around Crete (**Figure 1**), where we conducted semi-structured interviews with small-scale fishermen using a questionnaire as the basis for discussion. Fishing ports are optimal locations for interacting with fishermen, as fishermen tend to spend several hours each day at their fishing vessel preparing their catch for the market, mending their gear, or carrying out other maintenance tasks (e.g., Carreras et al., 2004; Moore et al., 2010; Alfaro-Shigueto, 2012). In addition, fishing ports provided a great opportunity to conduct interviews because we did not disrupt the fishermen's work or their daily routine, which helped to reduce possible negative feelings and increased fishermen's willingness to participate (Silver and Campbell, 2005).

In each port visited, we first identified and made contact with the local opinion leader. This would be the "gatekeeper," that is the person who was in a position to directly or indirectly facilitate access to potential respondents (Campbell et al., 2006). This would typically be the President of the local Fishermen's Association or an older, more experienced fisherman. We identified the "gatekeeper" by contacting the local Coast Guard Station, by visiting the Fishermen's Association Office (if available) or by directly asking fishermen during our first visit at the port. Connecting with and securing endorsement from these "gatekeepers" contributed to establishing a better rapport with local fishermen, and increased general willingness to participate (Campbell et al., 2006). We then proceeded with interviewing other fishermen, typically approaching boat skippers/owners first. Interviews were conducted in Greek, and lasted between 40 and 60 min. Before beginning the interview, we provided a brief overview of the project, and asked the fishermen if they would like to participate. If they agreed, we guaranteed anonymity and confidentiality of responses and made it clear that they could interrupt the interview or ask questions at any time. Since this was a "minimal risk" research project, we requested and confirmed oral consent for participation in this project at the start of each interview, when fishermen began giving answers.

Questionnaire Design

We used a questionnaire as the basis for semi-structured interviews. This allowed for greater flexibility and the ability to incorporate comments volunteered by the participants, without jeopardizing comparability of results. The questionnaire included a combination of open-ended (qualitative) and closed-ended (quantitative) questions. It used diverse query techniques to obtain information on similar topics in different sections of the questionnaire. This type of triangulation is used to facilitate testing consistency of responses, and reduce purposeful false reporting (Olsen, 2004; Silver and Campbell, 2005).

Before collecting formalized data, we piloted the questionnaire by conducting "mock" interviews with eight professional and recreational fishermen operating in Rethymno, Crete. We checked for clarity of questions, errors, and the presence of potentially polarizing queries that might detract from participation. Data collected in these interviews were not included in data analyses for this study.

Data Collection

As of the last government census prior to the study, there were a total of 819 fishing vessels registered on Crete, based in fishing ports or fishing refuges around the island (Data: Hellenic Center for Marine Research). By the time field research was conducted in 2013, an unidentified number of vessels had been decommissioned as their owners had retired or participated in national and European Union programs providing incentives to reduce the fishing effort through decreasing the size of the fishing fleet (Stergiou et al., 2002; European Commission, 2008). Furthermore, some vessels licensed to fish professionally were inactive. These factors presented sampling constraints both in terms of determining sample size and selecting a probability sampling method. To offset these challenges, interviews were restricted to one person per fishing vessel using a combination of convenience and snowball sampling (Babbie, 2009). Snowball sampling was applied when some of the respondents recommended us to other potential respondents. This method contributed to establishing successful rapport, generating trust, and increasing willingness to participate in the survey, as fishermen referred each other for participation (Glain et al., 2001). Convenience sampling was applied when we approached fishermen who were present at the time of our initial and subsequent port visits.

Data Analyses

To analyse responses to open-ended questions, we used adapted grounded theory (Charmaz, 2006). Grounded theory usually starts with the collection of data, which are then coded and grouped into themes and concepts from which categories are formed. These categories are used to create a theory, or a "reverse engineered hypothesis" (Charmaz, 2006; Babbie, 2009). We coded responses to open-ended questions, as well as any

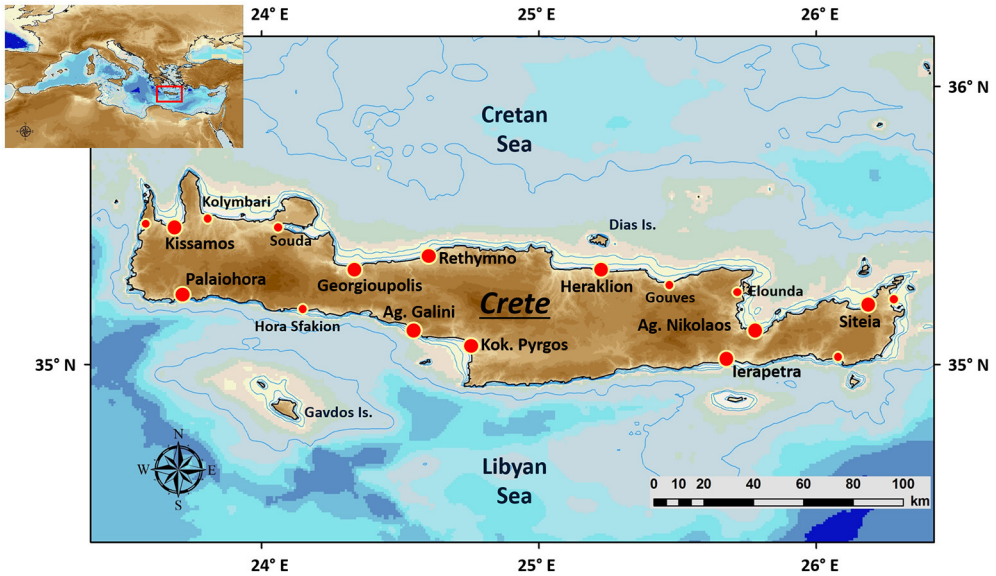

FIGURE 1 | Map of Crete, including main and peripheral ports. Fishing vessels are typically registered at one of the central Coast Guard stations (Heraklion, Chania, Rethymno, Agios Nikolaos). They use one of the main ports as a base for their activities, however they may shift between peripheral ports across seasons so as to maximize yield. We visited each of the 18 ports included in the map at least once over the course of this study (**File S1**). The map was generated on Arc-GIS software (ESRI, 2012).

additional comments provided by the respondents, by grouping responses into themes. A theme was defined when 10 or more respondents provided answers or comments similar in nature. Initial codes were refined and themes were analyzed as data entry progressed and new insights appeared. Themes were grouped into categories derived from the data, but related to interview questions and themes as well. All coding process were conducted using QSR-NVivo 10, a software designed to assist with qualitative data analyses.

The study and questionnaire were designed in full compliance with the principles expressed in the Declaration of Helsinki and the Guidelines for the Protection of Human Subjects of Research drafted by the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research (Belmont Report). The study, including the survey instrument, was approved by Drexel University's Institutional Review Board as a "minimal risk" research project, for which it was deemed sufficient that only oral informed consent is required ("Small-Scale Fisheries and Sea Turtles on Crete, Greece," IRB ID#1305002088).

RESULTS

Between June and August 2013, we visited 18 ports around Crete, spoke with 111 professional fishermen, and conducted a total of 101 in-person interviews (**File S1**). This corresponded to interviewing crew members working in 101 fishing vessels which represented 12.3% of the total registered small-scale fishing fleet for the island. Of the 10 fishermen who declined participating in the study, four gave no reason for their refusal. The other six did so because they "were not in the right frame of mind" ($n = 3$) or felt that this study was not going to help with anything ($n = 3$).

All participants were male and had fished professionally for an average of 30 years. Respondents generally reported fishing as their primary source of household income (**Table 1**). Their fishing vessel was typically <10 m long (average = 8.6 m) and licensed for diverse gear including gillnets and demersal long-lines. Fishing grounds were typically within 6 nm from shore, and fishermen reported limited distribution networks for their catches (**Table 2**). The majority of respondents were 45 years or older (72%) and only 9% were younger than 35. These demographics reflect a lack of recruitment of young people to the profession (**File S2**).

Fishing Activity—Reported Changes in Catch

All fishermen who had been active for more than 5 years ($n = 98$) reported changes in their catch. Nearly all (98%) stated that their catch had decreased by as much as 90% in the last 5–10 years (**Figure 2**). Further, 97% reported a general decline in fish abundance (**Figure 2**). Respondents identified declines in average fish sizes (79%) and number of species caught (60%) (**Figure 2**). Some fishermen reported that number of fish species remained the same (30%) or that it was increasing (10%) but they mostly attributed this to the appearance of new species that migrated from the Indian Ocean and the Red Sea through the Suez Canal (Lessepsian migration; **Figure 2**; **File S2**). Some fishermen elaborated that many of the high-value fish and invertebrates like groupers (*Epinephelus aeneus, Epinephelus fasciatus, Epinephelus marginalis*), dentexes (*Dentex dentex, Dentex macrophthalmus*),

TABLE 1 | Demographic characteristics of fishermen who participated in the study of fisherman interactions with sea turtles ($n = 101$).

Position in relation to Fishing Vessel (FV)	%	Fishing is	%	Age (years)	%	Educational level	%	Years active as a professional fisherman	%	% of household income derived from fishing	%
Skipper/Owner	93	Full-time job	88	<24–34	9	Primary school	38	Up to 10	9	More than half (50% +)	70
Crew member	7	Part-time/ Seasonal job	12	35–44	19	Middle/High school	43	11–15	10	About half (~50%)	16
				45–54	33	Upper education (college)	19	16–20	9	Less than half (<50%)	14
				55–64	26			21–25	10		
				65–75+	13			26–30	21		
								30–40	22		
								41 or more	19		
								Mean ($n = 101$)	30 years		

F/V stands for Fishing Vessel.

TABLE 2 | Fishing activity characteristics of participants responding to interviews conducted on Crete.

Boat length (m)	%	Crew size (incl. respondent)	%	Type of gear used	%	Fishing grounds (Distance from shore)	%	Where is the catch sold?	%
4.0–8.9	60	1	30	Gillnets (set nets, trammel nets, etc.)	94*	<2.0 n.m.	16	On the boat/At port	58*
9.0–12.0	33	2	45	Bottom longlines	77*	2.1–5.0 n.m.	42	Local fish markets	53*
12.1–15.0	7	3	22	Surface longlines	7*	5.1–10 n.m.	34	Door-to-door, local hotels/restaurants	45*
		4	4			More than 10 n.m.	8	Wholesale market	8*
Mean ($n = 101$)	8.6 m					Mean ($n = 97$)	5.3 n.m.		

**Percentages do not add up to 100% because some respondents provided more than one answer. Fishermen may be licensed for and use more than one type of gear. They also use multiple venues to sell their catch.*

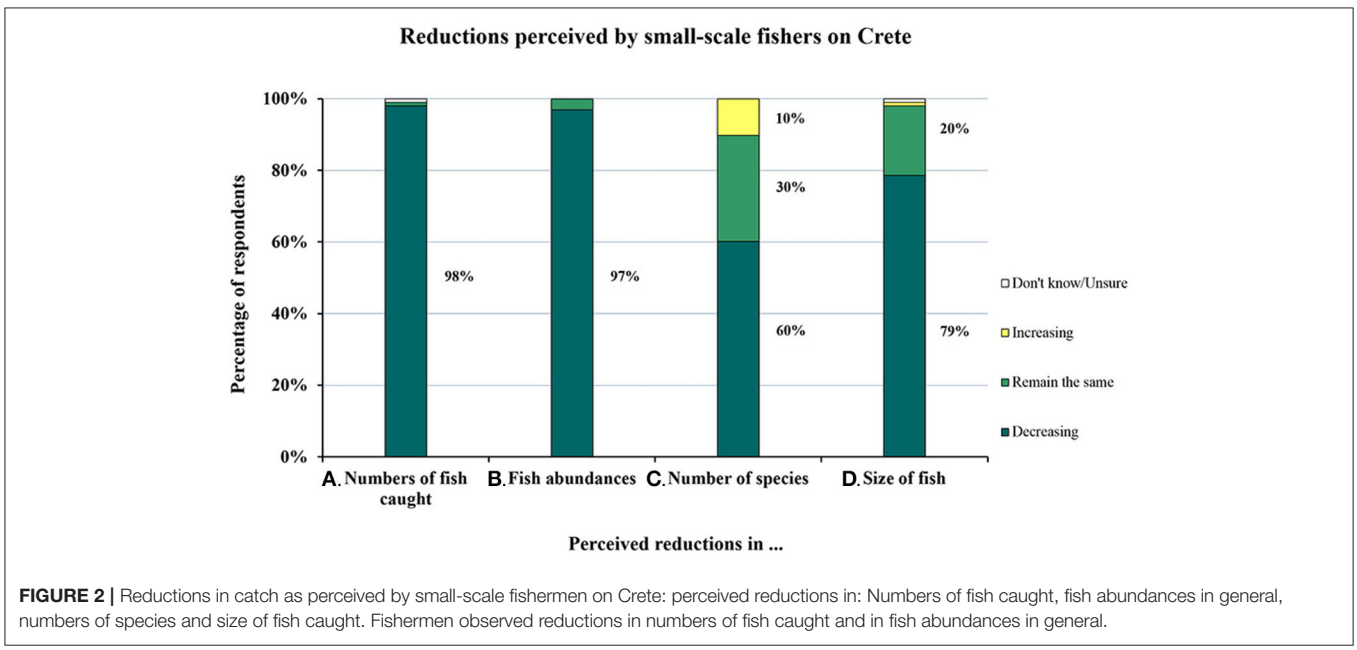

FIGURE 2 | Reductions in catch as perceived by small-scale fishermen on Crete: perceived reductions in: Numbers of fish caught, fish abundances in general, numbers of species and size of fish caught. Fishermen observed reductions in numbers of fish caught and in fish abundances in general.

and lobsters *(Palinurus elephas, Scyllardes latus)* had all but disappeared.

Many respondents (55%) perceived trawling activity as responsible for depleted fish stocks. They commented that bottom trawlers indiscriminately capture fish before they could breed, destroy benthic habitats that serve as refuges for juvenile fish, and illegally haul their gear too close to shore. Several respondents (37%) reported that non-professional fishermen with recreational fishing licenses and/or who go spear-gun fishing have the highest impact on their catch. Respondents viewed these fishermen as using fishing gear in excess of what is allowed, as having better boats with stronger engines and/or purchasing better and more expensive bait. Spear gun fishermen were reported to engage in illegal fishing practices, such as fishing using scuba equipment and fishing at night. Further, they were reported as selectively targeting larger species of higher commercial values such as groupers and dentexes, therefore contributing to their decimation. Non-professional fishermen were also believed to undercut fish prices by illegally selling their catch to shops and restaurants. Some respondents (19%) identified overall increased fishing effort as having the greatest impact on their catch, suggesting that several factors cumulatively contribute to the depleted fish stocks. Further, several fishermen (22%) admitted that they also are also partly responsible for the depletion of fish populations (**Figure 3**; **File S2**).

Another commonly reported change (54%) was the appearance of alien species arriving from the Red Sea via the Suez Canal, successfully establishing populations in the Mediterranean (Lessepsian migration; Stergiou et al., 2011). Two of these species, the dusky spinefoot (*Siganus luridus)* and the silver-cheeked toadfish (*Lagocephalus sceleratus),* were discussed as being highly undesirable. Dusky spinefoot is a small fish (average length = 14 cm), but was reported as captured in large quantities, difficult to remove from nets and unpopular with consumers. Respondents described this fish as territorial, and displacing other fish species. Silver-cheeked toadfish can grow to a length of 110 cm and weigh up to 7 kg. It is extremely poisonous because its tissues contain tetrodoxin (TTX), which is a lethal neurotoxin; its sale and consumption are banned within the EU (Stergiou et al., 2011). Silver-cheeked toadfish were reported by fishermen as causing great damage on a daily basis. In addition, 19% of respondents identified silver-cheeked toadfish as having the highest impact on their catch because they were alleged to have eliminated all cephalopods from the area. For these reasons, respondents considered silver-cheeked toadfish as a pest in need of extermination, and called on the government to organize culling campaigns (**File S2**). Twelve percent of fishermen suggested that appearance of invasive species in the area was a result of climate change and warming sea water temperatures (**File S2**).

All respondents stated that the above changes brought great financial strain to them; they reported income losses alongside increased operating costs (**File S2**). To maintain their income and to compensate for reduced catches, 74% of respondents admitted to having increased their fishing effort, recognizing that this may have aggravated the problem of depleted fish stocks (**File S2**). Increased fishing effort was explained as increases in the amount of gear used (61%), an increase in the amount of time invested in fishing (and the resulting increase in fuel expenses and other operating costs) (41%), having to travel further to fish (15%), and/or reducing the size of gear to catch smaller fish (6%). In short, many fishermen (45%) summarized their plight as one of having to work harder while facing increased operating costs and all the while, catching fewer fish. They reported that they were having a difficult time staying in business.

Interactions with Turtles and other Species

Nearly all respondents (95%) stated that they interacted with sea turtles. These interactions were reported as incidental captures in their fishing gear (77%), but also as incidents where turtles were believed to have caused gear damage without getting captured (95%). Based on the 41% of respondents who reported having captured turtles in their gear during the 12 months prior to the interview, an estimated 111–123 sea turtle captures occurred during the 12 months prior to the interviews.

Of all respondents actively fishing for over 5 years (n = 98), the majority (69%) suggested that sea turtles had been increasing in the last 5–10 years. Others stated that sea turtle populations were decreasing (12%), or remaining the same (14%). Some fishermen indicated that sea turtles and the perceived increase in their numbers was bad for fishing, and 11% of all respondents suggested that their populations should be moderated or eliminated.

Many respondents reported occasionally catching turtles in their gear (77%), but only 41% indicated captures in the 12 months prior to interview, and those occurred mostly in gillnets. Respondents affirmed that all encounters with sea turtles resulted in damage to fishing gear. Some fishermen (28%) reported that turtles ate their catches. In 21% of cases this was not perceived as a big problem, and respondents described this behavior as "natural" and possibly attributable to other factors such as a lack of food sources (**File S2**). Others viewed this as a problem with livelihood implications for fishermen (income loss; **File S2**).

In addition to sea turtles, respondents also interacted with other marine megafauna including monk seals (98%), dolphins (97%), large fish such as elasmobranchs and amberjacks (*Seriola dumerili*) (24%), as well as invasive silver-cheeked toadfish (59%), and sea birds (7%) (**Figure 4**; **File S2)**. They attributed observed gear damages to certain species (sea turtles, dolphins, or monk seals) depending on the nature of the damage and stated that sea turtles left distinctive marks on gillnets. These were described as typically consisting of 1–5 holes (51%) and small rips (21%) created as turtles tried to pull fish away from the net using their beak and flippers. Turtles were also seen as responsible for leaving clumps of fish that have been chewed into a hard to remove thick mass (pulp) on nets (33%). Dolphin damage was characterized as completely depredated and destroyed nets, and monk seals were seen as responsible for big net holes. Thus, each species was associated with distinctive gear damage and depredation "calling cards."

Some respondents stated that interactions with sea turtles had no associated financial costs (7%), that such costs were negligible (11%), or that they amounted to <100 € (4%). These respondents predominantly used demersal long lines or said that sea turtles

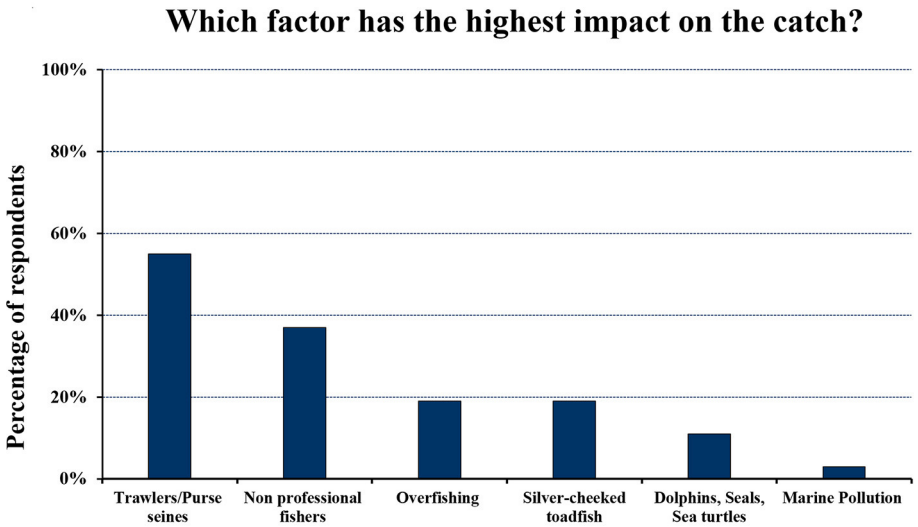

FIGURE 3 | Perceptions of respondents regarding which factors have the greatest impacts on their catch. Percentages did not add up to 100, because several fishermen gave more than one factor as equally affecting their catch.

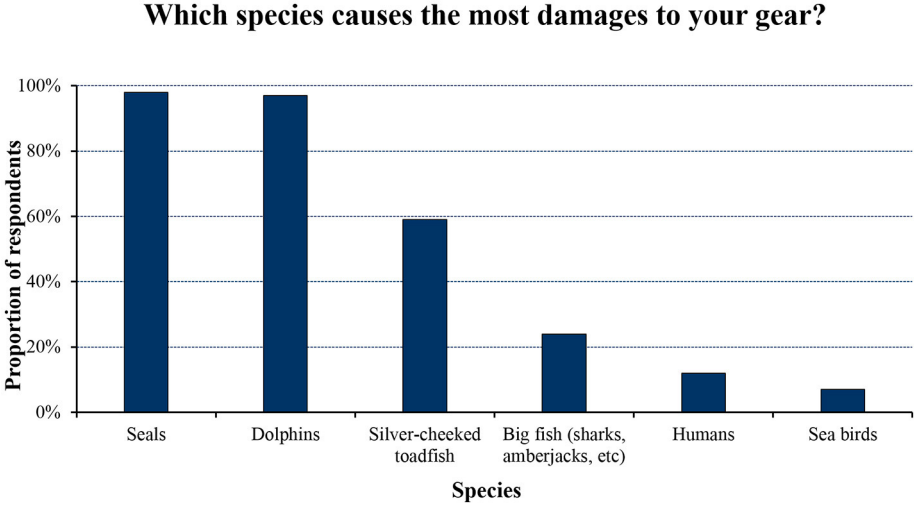

FIGURE 4 | Species reported to be causing damage to fishing gear of fishermen on Crete. Figure represents responses to the question "What [other] species [damage your gear]?" Fishermen described several species they were interacting with, therefore, the percentages did not add up to 100. It was interesting to note that even desirable fish species like amberjacks caused damage to gear and that on a few occasions even humans were reported to cause damage.

were responsible for only a small fraction of the total damages they encountered. Stated damage to gillnets was more costly: 36% of respondents spent between 100 and 1,000 € to replace damaged gear, and another 18% indicated costs of between 1,000 and 2,000 € for the 12 months prior to interview. An additional 20% spent sums in excess of 2,000 € (**Figure 5**). Lowest amounts were for the most part reported by fishermen predominantly using longlines—they stated that the cost to replace the line and hook was negligible. Thirty-three fishermen stated that they had spent between 500 and 2,000 € in the 12 months prior to the interview. Some respondents (34%) spent no time fixing gear damaged by turtles claiming it was unfixable, while others (46%) dedicated up to 60 days to mending gear in the 12 months prior to interview. Some fishermen (21%) perceived sea turtles as blameless because the sea was their natural habitat (**File S2**). A few respondents expressed appreciation for sea turtles, but also stated that they represent a problem for fishermen.

On the whole, respondents did not name the sea turtles as "worst offender" in terms of fisheries impacts; only 8% claimed sea turtles caused the greatest damages. Most respondents (49%) viewed dolphins as the leading species in terms of damages, followed by the invasive silver-cheeked toadfish (22%) and monk seals (19%) (**Figure 6A**). Respondents described sea

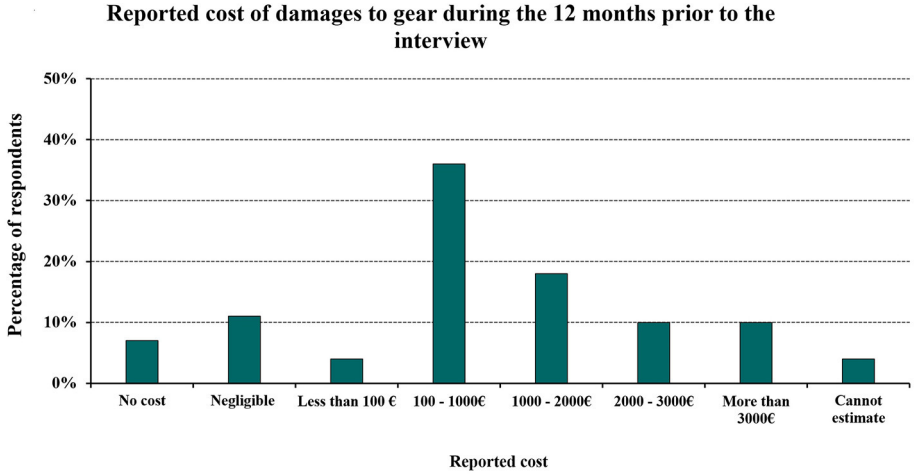

FIGURE 5 | Estimated cost of damages caused by sea turtles on Crete in the 12 months prior to the interview. Amounts are given in Euro (€).

turtles as interfering with their fishing activity a little bit (55%) or not at all (19%), and suggested that they posed limited (52%) or no (22%) threat to the local fishery (**Figures 6B,C**). Combined, however, interactions with sea turtles, dolphins and seals were seen as one of the top three challenges for the local fishery by 59% of respondents (**Figure 7**), presumably due to the associated costs resulting from their interactions with these species. Some fishermen expressed frustration and desperation over damages caused by dolphins, seals and sea turtles, and they lamented the lack of related government action (**File S2**).

Respondents' Management Recommendations

Of respondents who listed interactions with dolphins, seals, and sea turtles as among the top challenges faced by the local fishery, the vast majority (83%) recommended that the government should provide compensation to fishermen to offset resulting gear damage costs (**File S2**). Some fishermen ($n = 6$) proposed measures to restore fish stocks as the best way to alleviate undesirable impacts of interactions with large marine vertebrates (**File S2**).

A third of respondents (31%) supported the idea of removing turtles from the area and relocating them to other areas. The majority (63%) were opposed to such a proposal, partly because they did not consider such a measure to be feasible (30%). Similar responses were provided for dolphins and seals: while 38% of the fishermen would like them removed, 58% were opposed to relocation because of feasibility issues (28%).

The majority of participants reported support for the establishment of Marine Protected Areas (MPAs) in the form of areas closed-off to fishing (76%), and 87% of respondents (87%) favored establishing MPAs in the form of fishing refuges where fishing activity would be regulated, preferably by restricting access of more industrialized methods of fishing such as trawlers. However, such stated perceptions of MPAs were complex. Some fishermen (17%) expressed doubts about whether such areas could be properly implemented, citing problems with supervision and enforcement as being likely.

Of the respondents that provided additional comments about MPAs ($n = 71$), 69% expressed favorable views of MPAs. Some (23%) stated that MPAs would be good for fish while recognizing that MPAs could result in loss of fishing grounds. In addition, while some respondents (38%) suggested MPAs as a good management tool, they noted that MPAs required certain conditions for success. A few fishermen did not further explain what they meant by "conditions." However, 28% of the respondents stated that proposed MPAs or areas closed to fishing should not be permanent, and that protected areas should be flexible and adaptable over time, or be combined with additional measures to restore fish populations. Some respondents (9%) suggested potential support for MPAs, but wanted to be compensated income losses resulting from related fishing restrictions. The reported understanding of the establishment of MPAs or areas closed to fishing as likely to impose further restrictions on small-scale fishermen was the main reason for opposition to them (21%).

DISCUSSION

Our findings offer important insights into views and perceptions of fishermen about their interactions with sea turtles and other protected species. Respondents also commented on the potential for MPAs, and highlighted the many challenges in their profession. Qualitative data provided via replies to open-ended questions allowed for informed interpretations of the quantitative data, providing a more comprehensive description of small-scale fishermen's views and opinions.

Respondent characteristics (age, years as a fisherman, type of boat used, fishing activity, etc.,) were similar to those previously reported for small-scale fisheries in Greece (Tzanatos et al., 2005, 2006; Greek Ministry of Agriculture, 2007; Stergiou et al.,

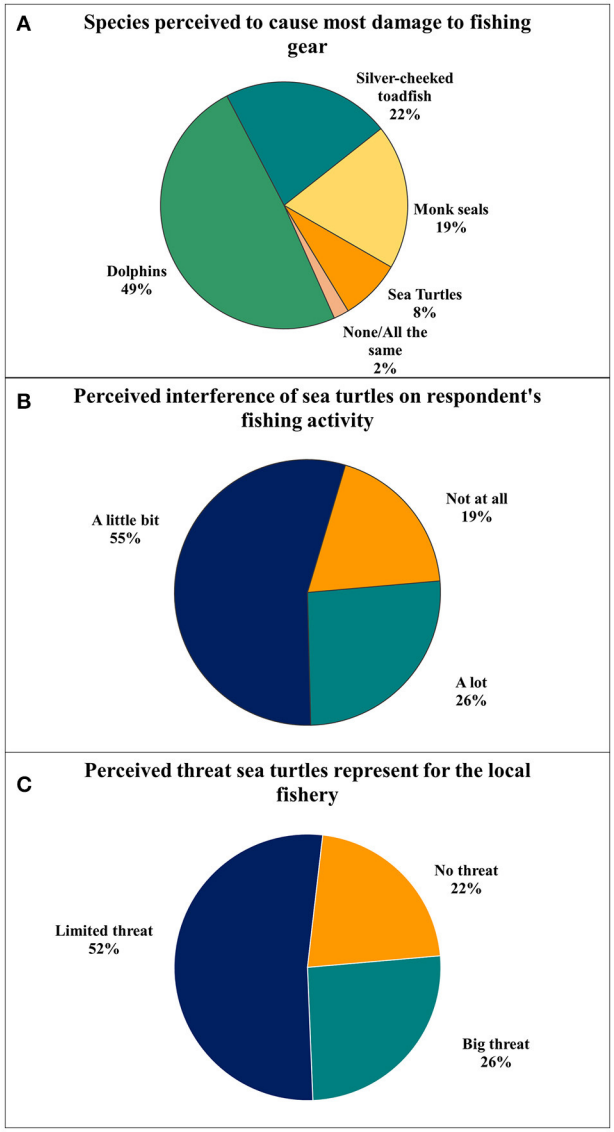

FIGURE 6 | (A) Fishermen of Crete responses regarding which marine vertebrate is perceived to be causing the greatest amount of damage to their gear. Dolphins were perceived to be causing the most damage, with sea turtles ranking lower than all other species. **(B)** Perceived interference of sea turtles on respondents' fishing activity. Almost three quarters of respondents believed that turtles interfered with their fishing activity a little bit or not at all. **(C)** Perceived threat sea turtles represent for the local fishery. Respondents believed that turtles posed a limited or no threat to the local fishery.

2011; Gonzalvo et al., 2014), and other areas in the world (Chuenpagdee et al., 2006; Chuenpagdee, 2012; Silva and Lopes, 2015). These studies show an aging population of small-scale fishermen due to lack of recruits and a high dependence on fishing as a source of family income. In addition, the majority of small-scale fishermen use small boats of low engine power, with rarely more than two crew members, that generally fish close to the shore using primarily gillnets and demersal long lines. This suggests that the demographic characteristics of respondents were like those represented in other small-scale fisheries studies and therefore have more general importance.

The Dynamic Relationship between Sea Turtles and Small-Scale Fishermen

Nearly all respondents stated that they interacted with sea turtles and that those encounters resulted in damages to their gear. Our results indicate that a significant number of sea turtle captures in small-scale fishing gear occur annually in Greece. On Crete alone, between 111 and 123 sea turtle captures occurred in respondent's gear during the 12 months prior to the survey. The fate of these animals was unknown. If captures in gillnets result in a mortality rate of 60% (Snape et al., 2013) then these reported captures resulted in 66–74 deaths. While this is a small number viewed by a single fisherman, it implies a very large level of bycatch for the entire country. Other studies in the Mediterranean indicate that small-scale fisheries have a great impact on sea turtle populations in Spain (Carreras et al., 2004; Quevedo et al., 2010), Cyprus, Turkey (Godley et al., 1998; Snape et al., 2013), and Israel (Levy et al., 2015). Similar results are reported for Peru and Baja California, Mexico (Peckham et al., 2007; Alfaro-Shigueto et al., 2011). Therefore, it is apparent that "small" can be "large" and interactions between sea turtles and small-scale fishermen remain a key conservation challenge.

Small-scale fishermen in Crete face many challenges, such as depletion of fish populations, and the rise of industrialized fishing practices. These are shared by their colleagues across the globe, (Thomson, 1980; Berkes, 1985; Chuenpagdee, 2012). Our respondents almost unanimously reported severe declines in numbers of fish caught, and in fish populations in general over the last 5–10 years. Small-scale fishermen report similar declines in Western Greece, (Gonzalvo et al., 2014) and in the Aegean Sea (Glain et al., 2001). Further, this perception is supported by research indicating overexploitation and declines of fish stocks in Greece (Stergiou and Koulouris, 2000; Moutopoulos and Stergiou, 2012; Moutopoulos et al., 2015) and the Mediterranean as a whole (Sala, 2004; Coll et al., 2010; FAO, 2016). Respondents attributed these stock declines to increasing fisheries competition (industrialized fishing, non-professional fishermen, increased fishing effort in general) and to environmental factors (climate change, invasive species, sea turtles, dolphins, and seals, marine pollution).

These declines caused significant financial strain for fishermen, who were dependent upon fisheries resources for their livelihood. Small-scale fishing activity is associated with poverty (Béné, 2003). Many small-scale fishermen have few options to improve efficiency by modernizing their fishing vessel and their gear, or altering their fishing activities to go further off-shore to fish. Such improvements bring increased costs, which rather than improving fishermen's well-being, can push them further into "a vicious circle of poverty" (Chuenpagdee, 2012). This is the case in Greece, where the mean annual gross income for small-scale fishermen in 2006 was 10,451 € (Tzanatos et al., 2006). Respondents compensated for catch declines by increasing fishing effort and/or amounts of gear used, traveled further to fish, and/or worked longer hours. That in turn

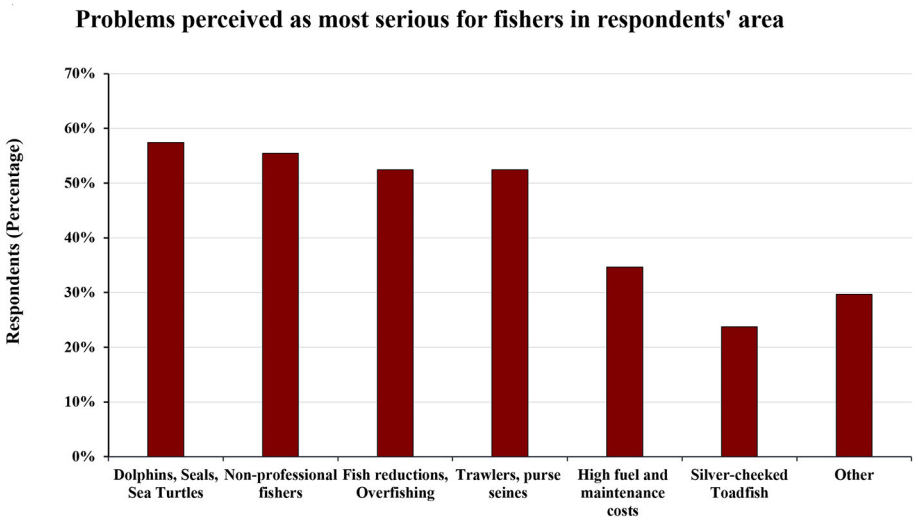

FIGURE 7 | Top problems for the local fishery on Crete as reported by the respondents. When asked to list the three most serious problems for small-scale fisheries in the area, interactions with sea turtles, dolphins and seals combined rated highest amongst fishermens' problems. Problems can be separated into subsets: (a) those associated with environmental conditions like interactions with marine vertebrates and silver-cheeked toadfish and (b) those having to do with fishing activity in general (competitive fisheries, high operating costs).

increased operating costs (fuel, maintenance, etc.), with no real financial gain. This change in behavior was a typical example of "maladaptation," where fishermen reacted to diminishing fish populations by increasing their fishing effort, thus further exacerbating the problem without any real financial gain.

Increased fishing effort probably caused an increased number of interactions with sea turtles. Most respondents (69%) believed sea turtles were increasing in the area, however this perception was not consistent with scientific data from major nesting beaches on the island, which indicated sharp declines in numbers of nesting turtles (Margaritoulis et al., 2009; Margaritoulis and Panagopoulou, 2010). This increased number of interactions resulted in a possibly false impression that sea turtle populations on Crete were increasing.

Fisherman-turtle interactions can represent significant revenue loss for fishermen. Combined with increased operating costs, this could contribute to heightened apathy toward or animosity for sea turtles, given the difficult conditions fishermen are facing.

Our findings suggest that interactions between sea turtles and small-scale fishermen represent a highly dynamic relationship, influenced by external factors such as the state of fish stocks and/or perceived fisherman-turtle interactions. Declining fish stocks are potentially driving what can be termed a "spiral of death": declining fish stocks prompt adversely impacted fishermen to increase their fishing effort, which in turn subjects sea turtles to a higher chance of being caught in fishing gear. Increased turtle bycatch results in a demand for increased regulation of fishermen. Bycatch mitigation measures will prove insufficient if they are not part of a more holistic fisheries management approach that encompasses measures to ensure the sustainability of the small-scale fishing sector.

Sea Turtle Bycatch Is One Side of a Larger Problem

In addition to sea turtles, fishermen also spoke of interactions with dolphins, monk seals, and large fish such as dogfish and amberjacks. Respondents claimed that they suffered extensive damages caused by the invasive silver-cheeked toadfish. Those occurred on a daily basis and in some areas were the primary problem.

Respondents were more concerned with damage from dolphins and seals than from sea turtles. Sea turtle-related damage was conceptualized as part of a larger problem that could be labeled as "animals interfering with gear." This was also reflected in the way respondents referred to dolphins, seals and sea turtles; many fishermen (24%) used a single term when discussing damages to gear, whether it was "the beasts," "the animals," "the spirits," or "*miara*" (which means the "unholy ones" in local Greek dialect).

Fisherman responses should be interpreted with geographical, ecological, and cultural contexts in mind, as well as information about the species of interest. For example, on Crete, dolphins, followed by silver-cheeked toadfish and monk seals, were listed as causing the greatest damage to gear, while only 8% of respondents thought that sea turtles were responsible for the greatest destruction. However, this is not the case in other regions of Greece and the Mediterranean. For example, fishermen in Alonnissos (Northern Sporades Islands, Greece), where a large Mediterranean monk seal population resides, stated that most damage to gear is caused not only by dolphins but also sea turtles (Glain et al., 2001). Fishermen working in the Amvrakikos Gulf (Western Greece) view resident sea turtles as causing more damage than dolphins. In the Ionian Archipelago, Mediterranean monk seals are named "worst offenders" by fishermen (Gonzalvo

et al., 2014). In Turkey, dolphins and Mediterranean monk seals are reported by fishermen as having the greatest impact on gear, while in Cyprus, local fishermen view sea turtles as most impactful (Godley et al., 1998). Such differences can be explained by the ecology of the species. In the case of turtles, the extent of interactions and resulting damages on gear may be dependent on the presence of turtles. They may not be causing great damage on fishermen on Crete because most turtles are present locally during their reproductive season (April–August), when they fast and opportunistically forage only if food is available (Hochscheid et al., 1999; Tucker and Read, 2001; Schofield et al., 2007; Fossette et al., 2008). On the other hand, sea turtles that are present in a foraging area as is Amvrakikos Gulf (Rees et al., 2013), may cause more damage to fishing gear because they are actively feeding there.

Our findings show that for small-scale fishers, the impact of interactions with marine megafauna in general is of concern to them, and it is secondary as to which species in particular (sea turtles, monk seals or dolphins) is responsible for the greatest amount of damages. A particular species may be more harmful to fishermen in some regions as compared to others, depending on its biology and ecology. As a result, a more holistic approach that considers all of these factors and interactions between them is needed both in research and in fisheries management decision-making.

Compensation as a Mitigation Measure

Most respondents (83%) indicated that government compensation would be helpful in repairing damage to fishing gear from sea turtles, dolphins, and seals. Fishermen in Alonissos made a similar recommendation (Glain et al., 2001). Fishermen recommended compensation as a mitigating measure in other situations as well. For example, some respondents suggested that they would support the establishment of Marine Protected Areas if they were compensated for the restrictions they would endure as a result (**File S2**). Some respondents claimed that unless they were compensated, they and/or their colleagues would start or continue killing turtles (**File S2**). Respondents claimed that compensation, even if modest, would go a long way toward supporting their livelihoods and indicate government support for local fisheries. Conservation-related compensation is known to strengthen the economic viability of small-scale fishermen (Varjopuro, 2011), and to provide economic help to people who interact with protected species (Wagner et al., 1997; Nyhus et al., 2005).

Compensation programs for damages caused by threatened species on small-scale fishermen may appear appealing in principle, but they are difficult to design and implement. First of all, the true cause of damages on gear may be hard to verify. For example, fishermen on Crete claimed that they could tell which animal had damaged their gear, but the descriptions provided were not identical. Further, some fishermen may attempt to declare a greater amount of damages in an effort to receive a higher compensation. Local fishermen in the Northern Sporades Islands were originally in favor of establishment of the National Marine Park of Alonnissos because they were promised compensation for damages caused by monk seals and because of the restriction of fishing grounds. However, compensation was never implemented and several years after establishment of the Park, they were disappointed and no longer as supportive of the Park (Frangoudes and Alban, 2004; Oikonomou and Dikou, 2008).

Compensation programs also have to be assessed in light of existing state and international policies and laws. Compensations to fishermen in Greece, which is an EU member state, may be interpreted as subsidies in violation of EU competition regulations (Simila et al., 2006). Nonetheless, compensation schemes have great potential as a mitigation measure to address the adverse effects of interactions between threatened species and small-scale fisheries, especially if they are integrated in a wider fisheries management plan (Nyhus et al., 2005).

Fishermen's Ecological Knowledge

Small-scale fishermen hold a wealth of knowledge about the marine environment and its resources. This includes knowledge about fish abundances, benthic environment, fish behavior, and ecology and environmental conditions. This experiential wisdom has been accumulated over many years of direct contact with the sea, and has also in many cases been passed down from one generation of fisherman to the next. Fishermen who participated in this study demonstrated a wealth of ecological knowledge. First, they were very vocal about the diminishing fish populations, and knowingly attributed such declines to unsustainable fishing practices such as overfishing, removing juvenile fish, catching fish during their spawning season, and destruction of the benthic environment. Some described the effect of the removal of fish as a perturbation having cascading effects on the local ecosystem in ways very similar to how ecologists might explain such scenarios. Many respondents recognized sea turtles, dolphins and seals as unavoidable inhabitants of the local ecosystem, while labeling themselves (fishermen) as intruders (**File S2**). Several respondents disagreed with the suggested removal of sea turtles, dolphins and seals from the area, recognizing this measure as not being feasible. Respondents displayed awareness of global warming and climate change (**File S2**). They also associated such changes with the displacement of fish populations and problematic successes of invasive species like silver-cheeked toadfish that were colonizing much of the Greek coastline due to warming ocean waters. Respondents also acknowledged that creation of MPAs and areas closed might help to restore fish abundances even if fishing grounds would be reduced.

Fishermens' Ecological Knowledge (FEK) may have an important complementary role to scientific research. FEK contains long-term empirical information passed down through several generations of fishermen, while scientific research collects shorter but more systematic observations while looking for generalizations over a broader scale. FEK can offer opportunities and ideas for new research, while scientific research may derive research ideas and test hypotheses from FEK. More importantly, FEK can be an immense help to researchers and policy makers as it can provide rich contextual information that could be used to improve management of fish populations, and/or restore ecosystems (Johannes et al., 2000). For example,

studies have reported previously unknown information gleaned from fishermen's knowledge, such as about significant increases in boat strike-related porpoise kills and bycatch numbers in the Yangtze River (Turvey et al., 2013). Sardà and Maynou (1998) found scientific support for local fishermen's preference for Fridays as the best days to fish for shrimp, attributing it to the effect of the removal of shrimp predators which were fished the other days and the higher demand for shrimp which drives higher prices on that day. In both of these cases, the pairing of science, management, and fishermen's knowledge benefitted multiple parties and led to better-informed and more locally-appropriate decisions. Some biologists and policy makers tend to ignore fishermen's knowledge because it can be difficult to assess, evaluate, and corroborate using scientific methods. It is true that FEK is not always straightforward, as there may be discrepancies when compared to scientific research conclusions. We observed such discrepancies when talking to small-scale fishermen: many reported the perception that sea turtles were on the increase in the area. They often attributed this "increase" to their belief that sea turtles are protected by law and, therefore, no longer being "hunted" anymore. Nesting data did not indicate recovering populations. FEK is frequently transmitted in a simplified form, where some ecological parameters may be unknown or misinterpreted. Optimal interpretation of FEK frequently requires further probing and putting into context both by researchers and policy makers.

To ignore FEK can result in catastrophic consequences. The most prominent example of this was the case of cod fisheries in Newfoundland, Canada. For years if not decades, in-shore fishermen complained to the Canadian Department of Fisheries and Oceans (DFO) that they were experiencing declines in cod, suspecting that offshore fisheries were extracting too many cod fish to allow for successful migration inshore and spawning. These complaints were scoffed at by biologists and ignored by the DFO until the sudden and complete collapse of the fishery. This later led to a moratorium on cod fishing, beginning in 1992 (Kurlansky, 1997). Including fishermen and their experiential and cultural knowledge when making decisions might, therefore, be a key element in designing and successfully implementing effective management decisions. Fishermen's knowledge may provide fine-scale details about the area that could improve the efficacy of management measures. Moreover, including fishermen in the decision-making process may lead to greater buy-in or acceptance among fishermen, who are often among the groups most likely to be directly affected by marine conservation measures.

CONCLUSIONS

The island of Crete in Greece provided a fruitful setting for observing some of the complexities involved in studying how fishermen's actions and perceptions fit within wider contexts of interactions between threatened species of megafauna such as sea turtles and small-scale fisheries. Our research suggested that sea turtles and fishermen were both under threat. Small-scale fisheries faced numerous compounding problems associated with intensive fishing practices, overfishing, climate change and invasive species. Respondents acknowledged that fishing interactions with sea turtles should be understood as being part of a larger set of animal-fisherman interactions. Given the multiple challenges fishermen are facing, compensation may offer benefits as a conservation intervention. It could be used to reduce bycatch of protected species, or increase support for MPAs. Local Fishermen's Ecological Knowledge should be incorporated early on fisheries management decisions, and in a more integrative way. If the current situation remains unchanged, and attitudes toward fishermen and their knowledge of the marine environment do not shift, interactions between fishermen, sea turtles and other protected species will likely continue to contribute to the decline of these species. At the same time, fishermen too will remain "under threat" and continue to suffer economically and culturally, representing a loss for individual fisherman families as well as the local communities they are a part of.

ETHICS STATEMENT

The study was conducted in full compliance with the principles expressed in the Declaration of Helsinki. This was a "minimal risk" research project. We requested and confirmed oral consent for participation in this project at the start of each interview, when fishermen began giving answers. A copy of the oral consent statement is included in the questionnaire submitted as supporting information (**File S3**). The research, including the survey instrument (questionnaire), was approved by Drexel University's Institutional Review Board, who assessed that oral informed consent from respondents was sufficient for this study. Title of Project: Small-scale Fisheries and Sea Turtles on Crete, Greece IRB ID Number: 1305002088

AUTHOR CONTRIBUTIONS

AP conceptualized the project, designed the research, acquired the data, analyzed, and interpreted data collected and was the principal author of this work. ZM participated in designing the research, provided feedback on data acquisition, participated in data analyses, and interpretations and contributed to the writing up of the work. DM participated in designing the research, participated in data analyses, and interpretations and contributed to the writing up of the work. JS conceptualized the project, participated in designing the research, provided feedback on data acquisition, participated in data analyses, and interpretations and contributed to the writing up of the work. All authors gave final approval to the manuscript submitted and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fmars.2017.00180/full#supplementary-material

File S1 | Interviews Basic Demographic Data. List of interviews including basic demographic data on respondent and their fishing activity.

File S2 | Respondents' Quotes. Representative quotes provided by respondents during the course of the interviews.

File S3 | Questionnaire.

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