An interview-based approach to assess sea turtle bycatch in Italian waters

Alessandro Lucchetti Corresp., [1] , **Claudio Vasapollo** [1] , **Massimo Virgili** [1]

[1] Institute of Marine Sciences (ISMAR), National Research Council (CNR), Ancona, Italy

Corresponding Author: Alessandro Lucchetti
Email address: a.lucchetti@ismar.cnr.it

The loggerhead sea turtle (*Caretta caretta*, Linnaeus, 1758) is the most abundant sea turtle species in the Mediterranean Sea, where commercial fishing appears to be the main driver of mortality. So far, information on sea turtle bycatch in Italy is limited both in space and time due to logistical problems in data collected through onboard observations and on a limited number of vessels involved. In the present study, sea turtle bycatch in Italian waters was examined by collecting fishermen's information on turtle bycatch through an interview-based approach. Their replies enabled the identification of bycatch hotspots in relation to area, season and to the main gear types. The most harmful fishing gears resulted to be trawl nets, showing the highest probabilities of turtle bycatch with a hotspot in the Adriatic Sea, followed by longlines in the Ionian Sea and in the Sicily Channel. Estimates obtained by the present results showed that more than 52,000 capture events and 10,000 deaths occurred in Italian waters in 2014, highlighting a more alarming scenario than earlier studies. The work shows that in case of poor data from other sources, direct questioning of fishermen and stakeholders could represent a useful and cost-effective approach capable of providing sufficient data to estimate annual bycatch rates and identify high-risk gear/location/season combinations.

An interview-based approach to assess sea turtle bycatch in Italian waters

Alessandro Lucchetti[1*], Claudio Vasapollo[1], Massimo Virgili[1]

[1] National Research Council (CNR), Institute of Marine Sciences (ISMAR) of Ancona (Italy); Largo Fiera della Pesca, 1, 60125, Ancona, Italy.

* Corresponding Author address: Email: a.lucchetti@ismar.cnr.it; Tel.: +39 0712078828.

Abstract

The loggerhead sea turtle (*Caretta caretta*, Linnaeus, 1758) is the most abundant sea turtle species in the Mediterranean Sea, where commercial fishing appears to be the main driver of mortality. So far, information on sea turtle bycatch in Italy is limited both in space and time due to logistical problems in data collected through onboard observations and on a limited number of vessels involved. In the present study, sea turtle bycatch in Italian waters was examined by collecting fishermen's information on turtle bycatch through an interview-based approach. Their replies enabled the identification of bycatch hotspots in relation to area, season and to the main gear types. The most harmful fishing gears resulted to be trawl nets, showing the highest probabilities of turtle bycatch with a hotspot in the Adriatic Sea, followed by longlines in the Ionian Sea and in the Sicily Channel. Estimates obtained by the present results showed that more than 52,000 capture events and 10,000 deaths occurred in Italian waters in 2014, highlighting a more alarming scenario than earlier studies.

The work shows that in case of poor data from other sources, direct questioning of fishermen and stakeholders could represent a useful and cost-effective approach capable of providing sufficient data to estimate annual bycatch rates and identify high-risk gear/location/season combinations.

1. Introduction

Mediterranean fisheries are essentially multi-species and multi-gear. Fishing fleets consist mostly of medium to large, highly differentiated, competing vessels that often exploit shared resources (Lucchetti et al., 2014). Intense and prolonged fishing pressure has resulted in overexploitation of fish resources (Colloca et al., 2013) and deterioration of marine ecosystems (Tudela, 2004; Sacchi, 2008). Large vertebrates like sharks (Ferretti et al., 2008), cetaceans (Bearzi, 2002), monk seals (Karamanlidis et al., 2008) and, above all, sea turtles (Casale, 2011) are the most affected species. These species are particularly vulnerable for biological reasons including late maturity and low reproduction rates.

The loggerhead sea turtle (*Caretta caretta*, Linnaeus, 1758) is the most abundant sea turtle species in the Mediterranean Sea (Casale & Margaritoulis, 2010 and references therein; Lucchetti & Sala, 2010). However, it is a priority species in Appendix II/IV of the Habitats Directive, the cornerstone of the EU nature conservation policy, which lists animals requiring close protection (EU, 1992). *C. caretta* is also included in the red list of the International Union for the Conservation of Nature and Natural Resources (Casale & Tucker, 2015). Although recent assessments have downgraded this species from the *status* “endangered” to “vulnerable” at a global scale, the adoption of conservation actions was stressed as crucial point. Its conservation has become a strategic issue in the whole Mediterranean, where commercial fishing appears to be the main driver of mortality for marine turtles (Lucchetti & Sala, 2010; Casale, 2011; Wallace et al., 2011).

Due to their habits (e.g. breeding and feeding migrations), loggerhead turtles interact with several types of fishing gears (e.g. demersal and pelagic towed gears, set nets, longlines; Wallace et al., 2008; Lucchetti & Sala, 2010). In the Mediterranean turtle bycatch is mainly related to the three main fishing methods adopted in the region (Lucchetti & Sala, 2010; Casale, 2011): drifting longlines (Guglielmi, Di Natale & Pelusi, 2000; Piovano et al., 2004; Deflorio et al., 2005; Jribi et al., 2008; Tomás et al., 2008; Piovano, Swimmer & Giacoma, 2009; Clusa et al., 2016), trawling (Casale, Laurent & De Metrio, 2004; Jribi, Bradai & Bouain, 2007; Sala, Lucchetti & Affronte, 2011; Domènech et al., 2015; Lucchetti et al., 2016), and set nets (Lazar, Ziza & Tvrtkovic, 2006; Echwikhi et al., 2010).

Longline bycatch occurs in open waters during the pelagic stage of the loggerhead turtle life, with high rate areas in Spanish (Báez et al., 2007; Clusa et al., 2016), North African (Jribi et al., 2008; Benhardouze, Aksissou & Tiwari, 2012), Greek (Snape et al., 2013), and southern Italian waters (Piovano et al., 2012). Bycatch events involve attraction by bait, hooking, and attempts to escape. Delayed mortality due to lesions caused by the swallowing of hooks and branch lines is a major concern and is suspected to be high (Casale, Freggi & Rocco, 2008).

Bottom trawling mostly interferes with the demersal stage. In the Mediterranean Sea, the main neritic habitats are found in the few, large, continental shelf areas, i.e. the Northern Adriatic Sea, the Gulf of Gabès, Egypt, and East Turkey (Lucchetti & Sala, 2010), where turtles in the demersal stage are more likely to assemble in shallow water, in order to feed on the abundant prey near the bottom. According to several studies (Henwood & Stuntz, 1987; Sasso & Epperly, 2006), direct mortality due to trawling depends on tow duration and hence to the submergence time, being high with prolonged apnoea. However, delayed mortality due to drowning, metabolic disturbance, decompression sickness upon release (García-Párraga et al., 2014) and the possibility of re-capture is suspected to be high.

Set nets are a risk for turtles in the neritic stage. Interactions mainly take place in coastal areas, where they seem to be considerable and comparable to those occurring in other fisheries.

However, considering the wide diffusion of set nets, interactions may actually be greater. Data are scarce. Mortality induced in this case is related to forced apnoea and consequent drowning due to the high soak time of the nets. The available data suggest that the mortality observed at the time of gear retrieval is very high (Lucchetti & Sala, 2010).

Over the past 10 years, satellite tracking has provided important information on many aspects of the biology, ethology, distribution and migration routes of *C. caretta* (Hays et al., 1991; Hays, 1992; Godley et al., 2003; Zbinden et al., 2008; Casale et al., 2012; Luschi & Casale, 2014; Lucchetti et al., 2016) and bycatch estimates in the Mediterranean Sea have been reported for several countries and fishing gears. Seasonal variation in turtle density and abundance can also be studied using aerial surveys; however, these technics are expensive and can be strongly affected by the presence of turtles on the sea surface during the surveys (Lauriano et al., 2011; Bovery & Wyneken, 2015). In Italy bycatch assessment often suffers of logistical problems in data collection, since the information is usually obtained from on board observations involving short periods of time, a limited number of vessels, and small area covered; moreover, sampling procedures are often not standardized (Dmitrieva et al., 2013). The approach is time-consuming and cost-intensive, and reliable information can only be obtained by fielding a massive sampling effort. Moreover, data from some fisheries are particularly difficult to obtain due to difficult observer access or inadequate monitoring. As a result, reviews of sea turtle bycatch in the Mediterranean (Lucchetti & Sala, 2010; Casale, 2011) are largely based on onboard observations and only rarely on logbooks.

An alternative approach to estimate turtle bycatch by direct interviews of fishermen has been adopted in Spain giving promising results regarding the reliability of the derived bycatch rate estimates (de Quevedo et al., 2010; Domènech et al., 2015). Over the past decade, social studies have explored the fishermen's perspective in view of the design of innovative management approaches (Griffin, 2009; Lucchetti et al., 2014; Santiago et al., 2015). More recently, the bottom up-approach (fishermen's perspective and stakeholder engagement) has also been applied in biological and ecological studies (Lewison et al., 2011; Kiszka, 2012; Nguyen et al., 2013) to examine several issues, including fisheries bycatch.

The aim of this study is twofold: 1) to estimate sea turtle bycatch rates in the Italian waters adopting an interview-based approach, with the involvement of fishermen; 2) to assess the implicit risk of bycatch for each kind of fishing gear, identifying possible seasonal and spatial bycatch hotspots.

2. Material and Methods

2.1 Study area

The study was carried out in Italy (central Mediterranean Sea, Fig. 1), which encompasses loggerhead migration routes (Sicily channel and Ionian Sea; Bentivegna, 2002), foraging areas (Adriatic Sea; Casale et al., 2012) and stable nesting rookery in the Ionian Sea (Mingozzi et al., 2007; Garofalo et al., 2009). Data are presented by Geographical Sub-Areas (GSAs) of the General Fisheries Commission for the Mediterranean comprising the Italian coastline, assuming that the bycatch relating to each fishing method and environmental condition in each GSA are sufficiently similar to provide a homogenous bycatch amount. The data from each GSA were then divided by fishing method and season.

2.2 Interview survey design

More than 30 interviewers from 9 institutions from different parts of Italy, including a research body, a regional authority, 2 non-profit organizations, 2 private organizations, 2 marine protected areas and 1 national park, participated in the survey. In total 453 interviews were conducted in

105 Italian fishing harbours, covering all Italian GSAs and about 98% of the Italian coast length (total 7,458 km). About 6% of the entire Italian fleet was interviewed. Sampling distribution across geographical areas was generally in line with the distribution of the fishing fleet, even though the consistency of data collection and reporting varied across GSAs and fishing methods.

Face to face interviews were organized directly in the harbour, on board fishing vessels and during fishermen's associations meetings. A single questionnaire was used for all fisheries and fishing methods.

The interview consisted of 5 sections: (1) '*background information*' involved questions related to the fisherman's experience, fishing gear used and fishing grounds; (2) '*frequency of turtle encounters and fishermen's behaviour*' involved questions on the number of sea turtles caught per season in 2014 and on their management upon capture; (3) '*suggestions to reduce turtle bycatch and knowledge of bycatch reducer devices*' asked how the interviewee thought that turtle bycatch could be reduced and about his opinion on the adoption of Bycatch Reducer Devices (BRDs) and gear modifications (such as circle hooks for longlines, Turtle Excluder Devices for trawl nets or light deterrent for passive nets); (4) '*fishermen's awareness and attitude regarding turtle conservation*', asked about the interviewee's willingness to pursue responsible fishing and turtle conservation; and, finally, (5) '*participation and cooperation*', tested their real interest in participating and cooperating in turtle conservation initiatives and research projects.

The questionnaire was designed to be completed in 15 minutes. Most questions were closed, which allowed collecting quantitative and factual information; some questions exploring fishermen's opinion, in sections (3) and (5), were multiple choice questions that allowed greater freedom to their answers.

2.3 Ethics Statement

All necessary permits were obtained for the field studies described. Interviewees were informed of the purpose of the study and that the data collected were confidential, and that their anonymity would be protected. The interviews were carried out only after fishermen verbally consented to participate.

2.4 Sampling methods

The study included the fishing gear types most commonly used, which were identified by a literature search (Lucchetti & Sala, 2010; Casale, 2011); those for which bycatch had been reported sporadically or not at all (i.e. purse seines) were excluded. Then, the fishermen to be interviewed were identified via opportunistic and 'snowball' sampling, which is widely used in sociological research (Biernacki & Waldorf, 1981; Faugier & Sargeant, 1997) and consists in the recruitment of future subjects from the acquaintances of fishermen interviewed before, overtaking the initial typical fisherman's confidentiality. This kind of sampling permitted to reach a reasonable number of interviews. Fishermen were approached at local harbours or in public places. Since crews generally consist of several fishermen, one single fisherman per vessel was interviewed.

2.5 Data analysis

The data collected in the study related to 2014. Two types of information are required to obtain quantitative estimates and spatial data on bycatch (Moore et al., 2010): the measure of the fishing effort and the bycatch rate.

Data on the fishing effort were obtained from the EU Data Collection Framework (EU, 2008a), set up in 2000, through which Member States collect, manage, and make available a wide range of fisheries data (including biological and socio-economic data) that are needed to obtain scientific advice. Data were collected on the basis of national programmes. Disaggregated data from the DCF dataset, provided by the Italian Ministry for Agricultural, Food and Forestry Policies, were extrapolated to obtain two indexes of fishing effort: the *total number of fishing vessels* operating in each season in the Italian GSAs and the *number of days at sea* recorded in 2014.

Data on sea turtle bycatch were obtained from interviews with fishermen. The bycatch estimates, per GSA and season, were obtained by averaging (geometric mean) the number of turtles reported by fishermen for each GSA, season and gear. The geometric mean was considered to smooth the effect of the extreme values. Then, the *average number of turtles* caught per season, area and gear from a single boat was multiplied by the *total number of vessels* that actually worked with that gear in each season and area, to obtain the total number of turtles caught in Italian waters.

Data from interviews were considered as valid only if, for each combination of gear-season-GSA, at least 5 interviews were performed. Turtle bycatch was rated on a scale from 1 (low bycatch: 0 – 100 turtles) to 6 (very high bycatch> 1,000 turtles).

Fishermen were also asked to report the percentage of death turtles at the end of the gear retrieval (mortality rate). This value was considered to estimate the number of deaths (*estimated turtle bycatch* × *mortality rate*). The mortality rate and the estimated death of turtles obtained in the current study were then compared with those reported by Casale, 2011, who made a complete review of the mortality rates for different areas of the Mediterranean Sea.

Due to the nature of data obtained by the interviews, characterized by an excess of zeros (about 75% of the entire dataset), a zero inflated model regression analysis based on negative binomial distribution (ZINB) with logit link was performed to reduce overdispersion of variance due to the zeros (Zuur et al., 2009). In ZINB analysis the zeros and the counts are analysed as two different datasets: a binomial generalized linear model (GLM) is used to model the probability of measuring a zero (called false zero, generally due to design errors, observer errors, unsuitable habitat and so on); the count process was modelled by a negative binomial GLM and as such, under certain covariate conditions, can produce zeros (in the sense that we can count zero turtles effectively and referred as true, or structural zeros). The expected mean and variance for the ZINB model are calculated as follow:

$$E(Y_i) = \mu_i \times (1 - \pi_i)$$

$$var(Y_i) = (1 - \pi_i) \times \left(\mu_i + \frac{\mu_i^2}{k}\right) + \mu_i^2 \times \left(\pi_i^2 + \pi_i\right)$$

Where $E(Y_i)$ is the expected value of the response variable, μ_i is the mean of the positive count data and π_i is the probability to have false zeros. We also calculated the probability functions of ZINB to have zeros (true zeros) and negative binomial distribution for the count data as follow:

$$f(y_i = 0) = \pi_i + (1 - \pi_i) \times \left(\frac{k}{\mu_i + k}\right)^k$$

$$f(y_i | y_i > 0) = (1 - \pi_i) \times \frac{(y_i + k)!}{(k)! + (y_i + 1)!} \times \left(\frac{k}{\mu_i + k}\right)^k \times \left(1 - \frac{k}{\mu_i + k}\right)^y$$

Where *k* is called the dispersion parameter.

The covariates considered for modelling data were GSA (7 levels), Season (4 levels) and Gear (3 levels). The model selection was performed following a backward selection of covariates starting from a full model with all the covariates and interactions and assessed via Akaike's Information Criterion (AIC); the model with lowest AIC was considered the best. To assess the significance of each single factor and interactions a likelihood ratio test (LRT) based on Chi^2 distribution was

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2826v1 | CC BY 4.0 Open Access | rec: 22 Feb 2017, publ: 22 Feb 2017

used dropping each term in turn (Zuur et al., 2009). The best model selected consisted in the interaction between Gear and GSA (GSA x Gear) in the "count" part and the interaction between GSA and Season plus Gear as single factor (GSA x season + gear) in the "zero" part. The statistical analysis were conducted with R (v. 3.3.2; R Core Team, 2016) using the *pscl* package (v. 1.4.9; Zeileis, Kleiber & Jackman, 2008).

Data on stranded turtles, obtained from the Coast Guard Marine Environment Department (Reparto Ambientale Marino) database of the Italian Ministry of the Environment, were also considered as a rough index of turtle presence and abundance, and were ranked using a 6-point scale from 1 (low strandings: 0 – 25 turtles) to 6 (high strandings > 150 turtles), to confirm the presence of hotspot areas and periods.

An interaction matrix was finally developed to find hotspot areas and periods of interaction between fishing gears and turtles for each gear. For the calculation of this matrix, fishing effort was expressed as *total number of fishing days per season*. The matrix was then calculated by dividing the average catch obtained by GSA, gear and season for the fishing effort expressed as *total number of fishing days*. The bycatch-effort interaction was also ranked from 1 (lowest risk of interaction, 0.000 - 0.018) to 6 (highest risk of interaction, > 0.08).

The data on fishing effort, bycatch, stranded turtles and interaction matrix were plotted on separate maps using QGIS 2.8 software.

3. Results

3.1 Sea turtle bycatch estimates

The fishing effort per gear type (fishing days / season / gear) calculated in the different GSAs varied greatly among seasons and gears (Table 1). For set nets it seemed to be higher in GSA 19 (Ionian Sea), given the large number of vessels operating there, especially in spring and summer.

For trawling, the fishing effort was the highest in GSA 17 (Northern Adriatic Sea), where the low depth, flat seabed is ideal for towed gears, but fell in summer due to the closed fishing season. The fishing effort of longlines was consistently low, except in GSA 19 in summer.

The mean number (geometric mean) of turtles captured per GSA, fishing gear and season, obtained by the fishermen interviewed, is reported in Table 2.

Relying on interview data 52,340 capture events are estimated to occur in 2014 (Table 3). The majority of incidental catches took place in summer (> 15,000 events), followed by autumn and spring (around 13,600 and 13,000 respectively), whereas a lower number were caught in winter (around 11,000) (Table 2). Catches by trawl nets mainly occurred in GSAs 17 and 18 (Adriatic Sea), where they seemed to be numerous throughout the year. Longline bycatch mainly occurred in GSAs 19 and 16 (Southern Italy), especially in summer and, to a lesser extent, in autumn. Set nets seemed to interact with turtles in most GSAs especially in spring and summer, when fishing with this gear is most active due to favourable sea and weather conditions.

The mortality rates obtained from fishermen's interviews enabled to estimate a total of about 10,000 turtle deaths, most of them due to set nets (5743) and trawl nets (3082). By applying the mortality rates reported by Casale (2011) it is possible to estimate that about 21,000 turtles can die every year mainly due to set nets (around 14,000 deaths) and trawl nets (around 4,000 deaths).

The data on stranded turtles, which were especially high in summer and autumn (Fig. 2), confirmed that the Adriatic Sea is the area mostly affected by incidental catch.

The results from ZINB model are summarized in Table 4. All the factors were highly significant. The factor Season did not appear in the count part of the model indicating that it did not influence on the amount of turtle bycatch. On the other hand, Season appears as an important factor, together with the GSA and Gear, in modelling the zero distributions determining the probabilities to find false zeros. In Figure 3 the probabilities to observe false zeros (the “zero” part of the model) are shown. The longline showed the highest probabilities that the zeros counted were false zeros in all seasons with the exceptions of summer for GSAs 9, 11 and 19. Regarding the passive nets, the probabilities of false zeros are lower than the previous although still high with only few GSAs showing less than 50% of probabilities, especially in summer and spring. On the contrary, trawl nets showed the lowest probabilities (less than 50%) to record false zeros in all seasons.

Figure 4 shows the catch predicted values per boat of the count part of the ZINB model. The highest predicted values were observed for the longline fishery especially in GSAs 9, 17 and 19. Smaller values were observed for the other two gears showing similar catching values between them, although in GSAs 17 and 18 trawl net estimates were higher.

Figure 5 reports the probabilities to catch turtles calculated by the count part of the ZINB model. What emerged was that, although, the longline predicted values were the highest, the probabilities to catch turtles by means of this gear are very low in all the GSAs (almost < 5%, except in the GSA 10). In other words, it seems that longlines have less probability to bycatch turtles but when they do that it is in relatively massive amounts. On the contrary, notwithstanding the low predicted values for the other two gears, their probabilities to accidentally catch turtles are extremely higher than longlines (between 6 and >15% for trawl nets and between 3 and 12% for passive nets).

Following these results it is clear that the major risks of turtles bycatch were associated to the trawl nets in all the GSAs (especially in the GSAs 9, 19, 18 and 17) followed by the passive nets (apart GSA 16 where the bycatch probabilities were very low) and lastly the longlines showed very low probabilities to catch turtles except in GSAs 10 and 11 where all the three gears showed almost the same probabilities.

The interaction matrix identified the gears, areas, seasons at the highest risk of bycatch (Fig. 6). Longlines pose a risk especially in GSA 19 and, to a lesser extent, GSAs 9 and 19 in summer. Interactions with set nets cause the greatest concern in GSAs 17 and 10 in summer. Finally, the whole Adriatic Sea is an interaction hotspot for trawl nets, especially in spring and summer.

3.2 The fishermen's perspective

3.2.1 Turtle encounters and fishermen's behaviour

The turtle encounter frequency reported by those interviewed is reported in Table 5. Most fishermen (75%) stated that they had caught at least one turtle in 2014; the lowest number was reported by fishermen using set nets (62%) and the highest number by those using longlines (89%) and trawl nets (88%). About 44% reported a disturbance to fishing activities, set nets (61%) and longlines (50%) being more affected than trawlers (26%).

The main disturbances to fishing activities due to incidental turtle catches reported by fishermen were grouped into 5 categories (Table 5). Waste of time was the most common problem reported by fishermen, regardless of fishing method, and was worst in longline fisheries (46%). Turtles were sometimes perceived as competitors and a cause of gear damage, especially during net hauling and disentangling operations (27% of fishermen using set nets). Catch damage and depredation were reported by fishermen using trawl nets (39%) and set nets (27%). In longline fisheries, bait consumption was a cause of concern to 18% of those interviewed. Another cause of disturbance was the fear of Coast Guard inspections and sanctions. A small number of fishermen denied any disturbance due to turtle bycatch and any concern except for the animal's health.

Direct mortality seems to be low, since 85% of fishermen stated that turtles are usually released in good health conditions (75-100% are alive). Fishermen reported that the direct mortality seems to be high enough for set nets and to a lesser extent, for longlines, while turtles caught with trawl nets are generally released alive (Table 3).

When asked about on board practices (Table 5), 24% of fishermen said that turtles are released immediately, 30% that they are handed over to the Coast Guard or Rescue Centres, and 46% that they are released after allowing them to rest for a short time. Most fishermen reported they were worried about handing the turtles over to the Coast Guard due the bureaucratic hassles and the time wasted, apart from the possibility of catch and vessel inspections. Whereas. the fishermen using set and trawl nets reported that they generally release turtles after a short rest (about 2 hours), the longliners stated that turtles are usually released immediately or delivered to Rescue Centres.

The questionnaire showed that fishermen had no clear perception of the annual trend of sea turtle abundance, since 40% denied noting any difference over the past few years, whereas 26% and 33% stated that the population is decreasing and increasing, respectively.

3.2.2 Suggestions to reduce turtle bycatch and knowledge of BRDs

Nearly all the interviewees felt that applying mitigation devices (BRDs) to traditional fishing gear would be more effective in reducing turtle bycatch rates than moving to another fishing area. When asked about the possibility of BRD adoption in the Mediterranean, half of the fishermen were in favour of it, albeit only under certain conditions (Table 5), and 40% of these, especially the longliners, believed that incentives would be needed. Of those who were not in favour, only 23% failed to qualify their reply. When fishermen were asked about their chief doubts and misgivings, regarding BRD adoption, two main stances emerged (Table 5), as 39% stated that the main problem was a lack of information and BRD knowledge and 38% were worried about modifying their traditional gear, especially for the fear of performance loss. Another important concern was that BRDs or other similar solutions might become mandatory in the future.

3.2.3 Fishermen's awareness and attitude regarding turtle conservation

Fifty eight percent of the interviewees were aware that their actions could adversely affect sea turtle populations, and that something can be done to preserve the species (Table 5). However, many (30%) were sceptical about the fishermen's ability to change things. Only 12% replied that fishermen's behaviour and practices and fishing activities do not affect turtle survival.

3.2.4 Participation and cooperation

Many of those interviewed said they would be interested in participating in conservation research projects only in presence of economical rewards: funding programmes (30%) and economical benefits linked to the adoption of sustainable fishing systems (33%; Table 5). A small fraction were interested in technical information, such as BRD use (8%) and the experimental test results obtained with BRDs (10%). The latter proportions were largely similar among fishermen using trawling and set nets (4 and 6% respectively), whereas those using longlines were more interested in gaining knowledge about BRDs from those who have already tried them (e.g. circle hooks) and in learning the experimental test results obtained with BRDs. In general, there seems to be a lack of interest in participating in projects whose main purpose is the protection of endangered species and only some fishermen seemed genuinely interested in learning about the rescue procedures to save the turtles.

4. Discussion

This study was devised to collect data on sea turtle bycatch, the threat posed by fishing gears, seasonal and spatial bycatch hotspots in the central Mediterranean Sea (Italian waters) using face to face interviews with fishermen. Turtles-fisheries interactions occur wherever fishing activities overlap with turtle habitats (Lucchetti et al., 2016). Different gears seem to involve different capture and mortality rates (Gerosa & Casale, 1999) and to affect different life stages. The interview data leave no doubt on the scale of the turtle bycatch in most Italian GSAs, where hotspots can also be identified in relation to season and gear type, and where the scenario that is thus outline, is more alarming than earlier studies had led to expect (Casale, Laurent & De Metrio, 2004; Lucchetti & Sala, 2010; Casale, 2011). The present data suggest that more than 52,000 capture events and 10,000 deaths could occur in 2014 in Italian waters alone. An even worse scenario can be obtained if the mortality rates reported by Casale (2011) are applied to our figures (more than 20,000 turtles may be killed incidentally in Italy each year).

Among the fishing gears, trawl nets appear to be the most dangerous in terms of turtle bycatch, with the highest probabilities of bycatch events in all the GSAs. Turtle bycatch estimates highlight a situation of great concern particularly for the GSAs 17 and 18. Also passive nets seem to pose a threat for the conservation of sea turtle in the Mediterranean; the probabilities of bycatch in most of GSAs is high, although estimated catch amount per boat seems to be very low. On the other hand, longlines seem to be the most massive catching gear (catch per vessel, particularly in some areas) but the probabilities of positive events are extremely low and generally lower than the other two gears.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2826v1 | CC BY 4.0 Open Access | rec: 22 Feb 2017, publ: 22 Feb 2017

Intense trawl net-loggerhead turtle interactions have already been described in the Northern Adriatic in a study combining fishing effort data and satellite data from tagged turtles (Lucchetti et al., 2016). The area is characterized by shallow waters (< 100 m) and rich benthic communities, and is considered as a key-feeding habitat in the whole Mediterranean, where turtles in the demersal stage spend the winter (Lazar & Tvrtkovic, 1995; Casale, Laurent & De Metrio, 2004; Lazar, Ziza & Tvrtkovic, 2006; Lucchetti & Sala, 2010). However, the Northern and Central Adriatic are also characterized by a wide continental shelf, low depth, and a flat seabed, which is ideal for trawling (Lucchetti, Punzo & Virgili, 2016). The high density of turtles and trawlers in autumn and winter in this area give rise to a bycatch hotspot, also supported by the ZINB analysis that highlighted how trawl net was perhaps the most dangerous gear in terms of predicted catches per boat.

The Ionian Sea is a bycatch hotspot in spring and late summer-autumn due to longline fisheries, particularly drifting longlines targeting swordfish (*Xiphias gladius*) and albacore (*Thunnus alalunga*), as reflected by the fishing effort data and supported by the interaction matrix and ZINB predicted values. Loggerhead turtles spend their pelagic stage in this area, feeding on pelagic prey, and cross it on their way to and from the Eastern Mediterranean basin (Lucchetti & Sala, 2010). Other studies have reported that drifting longlines deployed over the continental shelf and in offshore waters are among the main threats to sea turtles in the Mediterranean (Gerosa & Casale, 1999; Margaritoulis et al., 2003; Deflorio et al., 2005). Notwithstanding, the probabilities of catching turtles in GSA 19 were higher for passive and above all for trawl nets, according to the present results.

The turtle bycatch of set nets is usually difficult to assess, because they are operated by a large number of small boats disseminated along the whole Mediterranean coastline. For these reasons, the literature available for these fisheries is scarce. Set nets seem to pose a moderate threat in summer in the Northern and Southern Adriatic and in Sardinia, showing the highest predicted values of catches, although the highest probabilities to encounter a turtle were for GSA 18. The present study confirmed thus the concern expressed by other researchers (Lazar, Ziza & Tvrtkovic, 2006), who estimated that incidental loggerhead bycatch by gillnets in Slovenian and Croatian waters may be as high as 4,038 a year. They also found that gillnets and trammel nets are responsible for high rates of direct mortality, because turtles become entangled when trying to feed on trapped fish and drown because they cannot swim up for air. The Northern Adriatic Sea is thus a bycatch hotspot also due to set nets in summer. A similar concern was expressed by other authors (Casale et al., 2005) who considered the overall interaction between sea turtles and the static net fishery as important as the interaction with the trawl fishery.

Turtle bycatch data collected by direct interviews have the potential to help develop effective conservation measures in the Mediterranean Sea based on the joint effort of fishermen, authorities, and research bodies, as required by recent policies such as the reformed Common Fisheries Policy (EU, 2011) and the Marine Strategy Framework Directive (EU, 2008b).

However, the present results might underestimate the real figure of sea turtle bycatch in Italy. The main reason is that the bycatch, both of commercial species and of protected species, is usually under-reported by fishermen, presumably because of the perceived negative consequences of accurate reporting. The typical fishermen's reaction to interviews is that nothing good comes from frankness. The fishermen's main concern is that reporting high bycatch figures might lead administrators to impose additional restrictions, such as closed seasons or areas. Moreover, fishermen feel that they have gained nothing from supporting earlier similar studies, and that society's general attitude to fishermen is negative. As a result, interviewees often report minimum bycatch events. This has recently been stressed, among others, by Dmitrieva et al. (2013), who assessed the bycatch of Caspian ringed seals and concluded that yearly bycatch estimates were probably several times or even an order of magnitude smaller than the real figure. For this reason, the bycatch data reported in this paper should be considered as estimates of the real figure that could help to identify areas and periods of high risk of turtle bycatch. The interviews elicited a variety of views on sea turtle conservation as well as the adoption of mitigation devices to reduce the turtle bycatch. Most fishermen are aware that their actions may adversely affect the turtle population and that something can be done to preserve this species. Interviews confirm they are aware that the survival chances of injured turtles can be enhanced by taking them to the harbour, but fear of Coast Guard sanctions and waste of time due to administrative issues are the major concerns.

Many feel that applying BRDs to traditional fishing gears would be more effective in reducing the incidental catch of turtles than changing fishing area or period. However, since they fear that BRDs may become mandatory in the future, most of them said that an incentive-based scheme with financial compensation would be essential for their adoption. Finally, there appears to be no clear perception of the ecological importance of safeguarding sea turtles and other protected species, and the principal means to involve fishermen in protection and conservation seem to be economical rewards.

The interview-based approach here adopted provided bycatch estimates even for those fisheries for which information is usually scarce, unavailable, or even subjective. Moreover, the findings allowed accurate identification of the periods, areas and gears at greatest risk. This approach can easily be replicated to identify the bycatch hotspots of other sensitive species, such as marine mammals or sharks.

Once hotspots are identified, technical measures such as alternative gears, BRDs, alternative fishing tactics (i.e., avoid using certain gears in certain periods) can be applied more efficiently. In this regard, the Adriatic Sea emerges as a Mediterranean region severely affected by sea turtle bycatch. Here, a flexible Turtle Excluder Device (fTED) has recently been tested with promising results, since it achieved two aims: it prevented contact of turtles with the catch and did not affect gear performance (Lucchetti, Punzo & Virgili, 2016).

According to Gavin, Solomon & Blank (2010), present results confirm that in case of poor data, when resources are limited, involving and questioning fishermen and stakeholders may be an effective data collection method. This method can yield data on bycatch sufficient to estimate minimum annual bycatch rates, to identify high-risk gear/location/season combinations, and to prioritize areas for further research and for the introduction of management measures.

Acknowledgements

We are indebted to all interviewers for their huge effort in the fieldwork and especially to Maurizio Giganti. We want to thank the Italian Coast Guard Marine Environment Department (Reparto Ambientale Marino) for the data on stranded turtles. We would also like to thank Word Designs (Italy; www.silviamodena.com) and Mrs. Rosanna Messina for the language revision.

References

Báez JC., Real R., García-Soto C., De La Serna JM., Macías D., Camiñas JA. 2007. Loggerhead turtle by-catch depends on distance to the coast, independent of fishing effort: Implications for conservation and fisheries management. *Marine Ecology Progress Series* 338:249–256. DOI: 10.3354/meps338249.

Bearzi G. 2002. Interactions between cetaceans and fisheries in the Mediterranean Sea. In: Notarbartolo di Sciara G ed. *Cetaceans of the Mediterranean and Black Seas: State of the knowledge and conservation strategies*. Monaco: ACCOBAMS, 92.

Benhardouze W., Aksissou M., Tiwari M. 2012. Incidental captures of sea turtles in the driftnet and longline fisheries in northwestern Morocco. *Fisheries Research* 127–128:125–132. DOI: 10.1016/j.fishres.2012.04.002.

Bentivegna F. 2002. Intra-Mediterranean migrations of loggerhead sea turtles (Caretta caretta) monitored by satellite telemetry. *Marine Biology* 141:795–800. DOI: 10.1007/s00227-002-0856-z.

Biernacki P., Waldorf D. 1981. Snowball Sampling: Problems and Techniques of Chain Referral Sampling. *Sociological Methods & Research* 10:141–163. DOI: 10.1177/004912418101000205.

Bovery CM., Wyneken J. 2015. Seasonal variation in sea turtle density and abundance in the southeast Florida current and surrounding waters. *PLoS ONE* 10:e0145980. DOI: 10.1371/journal.pone.0145980.

Casale P. 2011. Sea turtle by-catch in the Mediterranean. *Fish and Fisheries* 12:299–316. DOI: 10.1111/j.1467-2979.2010.00394.x.

Casale P., Affronte M., Scaravelli D., Lazar B., Vallini C., Luschi P. 2012. Foraging grounds, movement patterns and habitat connectivity of juvenile loggerhead turtles (Caretta caretta) tracked from the Adriatic Sea. *Marine Biology* 159:1527–1535. DOI: 10.1007/s00227-012-1937-2.

Casale P., Freggi D., Basso R., Argano R. 2005. Interaction of the static net Fishery with loggerhead sea turtles in the Mediterranean : insights from mark-recapture data. *The Herpetological Journal* 15:201–203.

Casale P., Freggi D., Rocco M. 2008. Mortality induced by drifting longline hooks and branchlines in loggerhead sea turtles, estimated through observation in captivity. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18:945–954. DOI: 10.1002/aqc.

Casale P., Laurent L., De Metrio G. 2004. Incidental capture of marine turtles by the Italian trawl fishery in the north Adriatic Sea. *Biological Conservation* 119:287–295. DOI: 10.1016/j.biocon.2003.11.013.

Casale P., Margaritoulis D. 2010. *Sea turtles in the Mediterranean: distribution, threats and conservation priorities*. Gland, Switzerland: IUCN/SSC.

Casale P., Tucker AD. 2015. Caretta caretta. *The IUCN Red List of Threatened Species 2015* 8235:20. DOI: http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T3897A83157651.en.

Clusa M., Carreras C., Pascual M., Gaughran SJ., Piovano S., Avolio D., Ollano G., Fernández G., Tomás J., Raga JA., Aguilar A., Cardona L. 2016. Potential bycatch impact on distinct sea turtle populations is dependent on fishing ground rather than gear type in the Mediterranean Sea. *Marine Biology* 163:1–10. DOI: 10.1007/s00227-016-2875-1.

Colloca F., Cardinale M., Maynou F., Giannoulaki M., Scarcella G., Jenko K., Bellido JM., Fiorentino F. 2013. Rebuilding Mediterranean fisheries: A new paradigm for ecological sustainability. *Fish and Fisheries* 14:89–109. DOI: 10.1111/j.1467-2979.2011.00453.x.

Deflorio M., Aprea A., Corriero A., Santamaria N., De Metrio G. 2005. Incidental captures of sea turtles by swordfish and albacore longlines in the Ionian sea. *Fisheries Science* 71:1010–1018. DOI: 10.1111/j.1444-2906.2005.01058.x.

Dmitrieva L., Kondakov AA., Oleynikov E., Kydyrmanov A., Karamendin K., Kasimbekov Y., Baimukanov M., Wilson S., Goodman SJ. 2013. Assessment of Caspian Seal By-Catch in an Illegal Fishery Using an Interview-Based Approach. *PLoS ONE* 8:1–7. DOI: 10.1371/journal.pone.0067074.

Domènech F., Álvarez de Quevedo I., Merchán M., Revuelta O., Vélez-Rubio G., Bitón S., Cardona L., Tomás J. 2015. Incidental catch of marine turtles by Spanish bottom trawlers in the western Mediterranean. *Aquatic Conservation: Marine and Freshwater Ecosystems* 25:539–550. DOI: 10.1002/aqc.2463.

Echwikhi K., Jribi I., Bradai MN., Bouain A. 2010. Gillnet fishery loggerhead turtle interactions in the Gulf of Gabes, Tunisia. *Herpetological Journal* 20:25–30.

EU. 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Council of the European Communities (CEC). *Official Journal of the European Communities* 206:7–50.

EU. 2008a. Commission Regulation (EC) No 665/2008 of 14 July 2008 laying down detailed rules for the application of Council Regulation (EC) No 199/2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisher. *Official Journal of the European Communities* 186:3–5.

EU. 2008b. Directive 2008/56/EC of the European Parliament and of the Council. *Official Journal of the European Union* 164:19–40.

EU. 2011. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: REform of the COmmon Fisheries Policy. *European Commission*. DOI: SEC(2011) 277 final.

Faugier J., Sargeant M. 1997. Sampling hard to reach populations. *Journal of Advanced Nursing*

26:790–797. DOI: 10.1046/j.1365-2648.1997.00371.x.

Ferretti F., Myers RA., Serena F., Lotze HK. 2008. Loss of large predatory sharks from the Mediterranean Sea. *Conservation Biology* 22:952–964. DOI: 10.1111/j.1523-1739.2008.00938.x.

García-Párraga D., Crespo-Picazo JL., De Quirós YB., Cervera V., Martí-Bonmati L., Díaz-Delgado J., Arbelo M., Moore MJ., Jepson PD., Fernández A. 2014. Decompression sickness ('the bends') in sea turtles. *Diseases of Aquatic Organisms* 111:191–205. DOI: 10.3354/dao02790.

Garofalo L., Mingozzi T., Micò A., Novelletto A. 2009. Loggerhead turtle (Caretta caretta) matrilines in the Mediterranean: Further evidence of genetic diversity and connectivity. *Marine Biology* 156:2085–2095. DOI: 10.1007/s00227-009-1239-5.

Gavin MC., Solomon JN., Blank SG. 2010. Measuring and monitoring illegal use of natural resources. *Conservation Biology* 24:89–100. DOI: 10.1111/j.1523-1739.2009.01387.x.

Gerosa G., Casale P. 1999. *Interaction of marine turtles with fisheries in the Mediterranean*. Tunis: UNEP/MAP, RAC/SPA.

Godley BJ., Broderick AC., Glen F., Hays GC. 2003. Post-nesting movements and submergence patterns of loggerhead marine turtles in the Mediterranean assessed by satellite tracking. *Journal of Experimental Marine Biology and Ecology* 287:119–134. DOI: 10.1016/S0022-0981(02)00547-6.

Griffin L. 2009. Scales of knowledge: North Sea fisheries governance, the local fisherman & the European scientist. *Environmental Politics* 18:557–575. DOI: 10.1080/09644010903007419.

Guglielmi P., Di Natale A., Pelusi P. 2000. Effetti della pesca col palangaro derivante sui grandi pelagici e sulle specie accessorie nel Mediterraneo centrale. *Rapporto al Ministero per le Politiche Agricole e Forestali*.

Hays GC. 1992. Assessing the nesting beach fidelity and clutch frequency of sea turtles by satellite tracking. *Wildlife Telemetry: Remote Monitoring and Tracking of Animals*:203–213.

Hays GC., Webb P., Hayes J., Priede I., French J. 1991. Satellite Tracking of a Loggerhead Turtle (carerra caretta) in the Mediterranean. *Journal of the Marine Biological Association of the UK* 71:743–746. DOI: 10.1017/S0025315400053261.

Henwood T., Stuntz W. 1987. Analysis of sea turtle captures and mortality during commercial shrimp trawling. *Fishery Bulletin* 85:813–817.

Jribi I., Bradai MN., Bouain A. 2007. Impact of trawl fishery on marine turtles in the Gulf of Gabes, Tunisia. *Herpetological Journal* 17:110–114.

Jribi I., Echwikhi K., Bradai MN., Bouain A. 2008. Incidental capture of sea turtles by longlines in the Gulf of Gabès (South Tunisia): A comparative study between bottom and surface longlines. *Scientia Marina* 72:337–342. DOI: 10.3989/scimar.2008.72n2337.

Karamanlidis AA., Androukaki E., Adamantopoulou S., Chatzispyrou A., Johnson WM., Kotomatas S., Papadopoulos A., Paravas V., Paximadis G., Pires R., Tounta E., Dendrinos P. 2008. Assessing accidental entanglement as a threat to the Mediterranean monk seal Monachus monachus. *Endangered Species Research* 5:205–213. DOI: 10.3354/esr00092.

Kiszka JJ. 2012. Bycatch assessment of vulnerable megafauna in coastal artisanal fisheries in the southwest Indian Ocean. *Final report for the South West Indian Ocean Fisheries Project (SWIOFP)*:113.

Lauriano G., Panigada S., Casale P., Pierantonio N., Donovan GP. 2011. Aerial survey abundance estimates of the loggerhead sea turtle Caretta caretta in the Pelagos Sanctuary, northwestern Mediterranean Sea. *Marine Ecology Progress Series* 437:291–302. DOI: 10.3354/meps09261.

Lazar B., Tvrtkovic N. 1995. Marine turtles in the eastern part of the Adriatic sea: preliminary research. *Natura Croatica* 4:59–74.

Lazar B., Ziza V., Tvrtkovic N. 2006. Interactions of gillnet fishery with loggerhead sea turtules C. caretta in the Northern Adriatic Sea. In: Frick M, Panagopoulou A, Rees A, Williams K eds. *Book of abstracts of the 26th Annual Symposium on Sea Turtle Biology and Conservation*. Athen, 252.

Lewison RL., Soykan CU., Cox T., Peckham H., Pilcher N., Leboeuf N., McDonald S., Moore J., Safina C., Crowder LB. 2011. Ingredients for addressing the challenges of fisheries bycatch. *Bulletin of Marine Science* 87:235–250. DOI: 10.5343/bms.2010.1062.

Lucchetti A., Piccinetti C., Meconi U., Frittelloni C., Marchesan M., Palladino S., Virgili M. 2014. Transferable Fishing Concessions (TFC): A pilot study on the applicability in the Mediterranean Sea. *Marine Policy* 44:438–447. DOI: 10.1016/j.marpol.2013.10.009.

Lucchetti A., Pulcinella J., Angelini V., Pari S., Russo T., Cataudella S. 2016. An interaction index to predict turtle bycatch in a Mediterranean bottom trawl fishery. *Ecological Indicators* 60:557–564. DOI: 10.1016/j.ecolind.2015.07.007.

Lucchetti A., Punzo E., Virgili M. 2016. Flexible Turtle Excluder Device (TED): an effective tool for Mediterranean coastal multispecies bottom trawl fisheries. *Aquatic Living Resources* 29:1–12.

Lucchetti A., Sala A. 2010. An overview of loggerhead sea turtle (Caretta caretta) bycatch and technical mitigation measures in the Mediterranean Sea. *Reviews in Fish Biology and*

Fisheries 20:141–161. DOI: 10.1007/s11160-009-9126-1.

Luschi P., Casale P. 2014. Movement patterns of marine turtles in the Mediterranean Sea: a review. *Italian Journal of Zoology* 81:478–495. DOI: 10.1080/11250003.2014.963714.

Margaritoulis D., Argano R., Baran I., Bentivegna F., Bradai M., Caminas J., Casale P., De Metrio G., Demetropoulos A., Gerosa G., Goley B., Haddaoud D., Houghton J., Laurent L., Lazar B. 2003. Loggerhead Turtles in the Mediterranean Sea: present knwoledge and conservation perspectives. In: Bolten A, Witherington B eds. *Loggerhead Sea turtles*. Washington DC, USA: Smithsonian Insititution Press, 175–198.

Mingozzi T., Masciari G., Paolillo G., Pisani B., Russo M., Massolo A. 2007. Discovery of a regular nesting area of loggerhead turtle Caretta caretta in southern Italy: A new perspective for national conservation. *Biodiversity and Conservation* 16:3519–3541. DOI: 10.1007/s10531-006-9098-6.

Moore JE., Cox TM., Lewison RL., Read AJ., Bjorkland R., McDonald SL., Crowder LB., Aruna E., Ayissi I., Espeut P., Joynson-Hicks C., Pilcher N., Poonian CNS., Solarin B., Kiszka J. 2010. An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biological Conservation* 143:795–805. DOI: 10.1016/j.biocon.2009.12.023.

Nguyen V., Larocque S., Stoot L., Cairns N., Blouin-Demers G., Cooke S. 2013. Perspectives of fishers on turtle bycatch and conservation strategies in a small-scale inland commercial fyke net fishery. *Endangered Species Research* 22:11–22. DOI: 10.3354/esr00530.

Piovano S., Balletto E., Di Marco S., Dominici A., Giacoma C., Zannetti A. 2004. Loggerhead turtle (Caretta caretta) by catches on long-lines: the importance of olfactory stimuli. *Italian Journal of Zoology* 71:213–216. DOI: 10.1080/11250000409356638.

Piovano S., Basciano G., Swimmer Y., Giacoma C. 2012. Evaluation of a bycatch reduction technology by fishermen: A case study from Sicily. *Marine Policy* 36:272–277. DOI: 10.1016/j.marpol.2011.06.004.

Piovano S., Swimmer Y., Giacoma C. 2009. Are circle hooks effective in reducing incidental captures of loggerhead sea turtles in a Mediterranean longline fishery? *Aquatic Conservation: Marine and Freshwater Ecosystems* 19:779–785. DOI: 10.1002/aqc.

de Quevedo IÁ., Cardona L., De Haro A., Pubill E., Aguilar A. 2010. Sources of bycatch of loggerhead sea turtles in the western Mediterranean other than drifting longlines. *ICES Journal of Marine Science* 67:677–685. DOI: 10.1093/icesjms/fsp278.

R Core Team. 2016. R: A language and environment for statistical computing. *R Foundation for Statistical Computing*. DOI: 3-900051-14-3.

Sacchi J. 2008. Impact des techniques de peche sur l'environment en mediterrannée. *GFCM. Studies and Reviews*:82.

Sala A., Lucchetti A., Affronte M. 2011. Effects of Turtle Excluder Devices on bycatch and discard reduction in the demersal fisheries of Mediterranean Sea. *Aquatic Living Resources* 24:183–192. DOI: 10.1051/alr/2011109.

Santiago JL., Ballesteros MA., Chapela R., Silva C., Nielsen KN., Rangel M., Erzini K., Wise L., Campos A., Borges MF., Sala A., Virgili M., Vidarsson JR., Baudron A., Fernandes PG. 2015. Is Europe ready for a results-based approach to fisheries management? The voice of stakeholders. *Marine Policy* 56:86–97. DOI: 10.1016/j.marpol.2015.02.006.

Sasso CR., Epperly SP. 2006. Seasonal sea turtle mortality risk from forced submergence in bottom trawls. *Fisheries Research* 81:86–88. DOI: 10.1016/j.fishres.2006.05.016.

Snape RTE., Beton D., Broderick AC., Çiçek BA., Fuller WJ., Özden Ö., Godley BJ. 2013.

Strand Monitoring and Anthropological Surveys Provide Insight into Marine Turtle Bycatch in Small-Scale Fisheries of the Eastern Mediterranean. *Chelonian Conservation and Biology* 12:44–55. DOI: 10.2744/CCB-1008.1.

Tomás J., Gozalbes P., Raga JA., Godley BJ. 2008. Bycatch of loggerhead sea turtles: Insights from 14 years of stranding data. *Endangered Species Research* 5:161–169. DOI: 10.3354/esr00116.

Tudela S. 2004. *Ecosystem effects of fishing in the mediterranean. An analysis of the major threats of fishing gear and practices to biodiversity and marine habitats*. DOI: 10.1017/CBO9781107415324.004.

Wallace BP., DiMatteo AD., Bolten AB., Chaloupka MY., Hutchinson BJ., Abreu-Grobois FA., Mortimer JA., Seminoff JA., Amorocho D., Bjorndal KA., Bourjea J., Bowen BW., Dueñas R., Casale P., Choudhury BC., Costa A., Dutton PH., Fallabrino A., Finkbeiner EM., Girard A., Girondot M., Hamann M., Hurley BJ., López-Mendilaharsu M., Marcovaldi MA., Musick JA., Nel R., Pilcher NJ., Troëng S., Witherington B., Mast RB. 2011. Global conservation priorities for Marine turtles. *PLoS ONE* 6. DOI: 10.1371/journal.pone.0024510.

Wallace BP., Heppell SS., Lewison RL., Kelez S., Crowder LB. 2008. Impacts of fisheries bycatch on loggerhead turtles worldwide inferred from reproductive value analyses. *Journal of Applied Ecology* 45:1076–1085. DOI: 10.1111/j.1365-2664.2008.01507.x.

Zbinden JA., Aebischer A., Margaritoulis D., Arlettaz R. 2008. Important areas at sea for adult loggerhead sea turtles in the Mediterranean Sea: Satellite tracking corroborates findings from potentially biased sources. *Marine Biology* 153:899–906. DOI: 10.1007/s00227-007-0862-2.

Zeileis A., Kleiber C., Jackman S. 2008. Regression Models for Count Data in R. *Journal of Statistical Software* 27.

Zuur A., Ieno E., Walker N., Saveliev A., Smith G. 2009. *Mixed effects models and extensions in ecology with R*. New York: Springer.

Figure 1

Study area

Mediterranean GSAs (Geographical Sub-Areas) involved in the data collection and questionnaires.

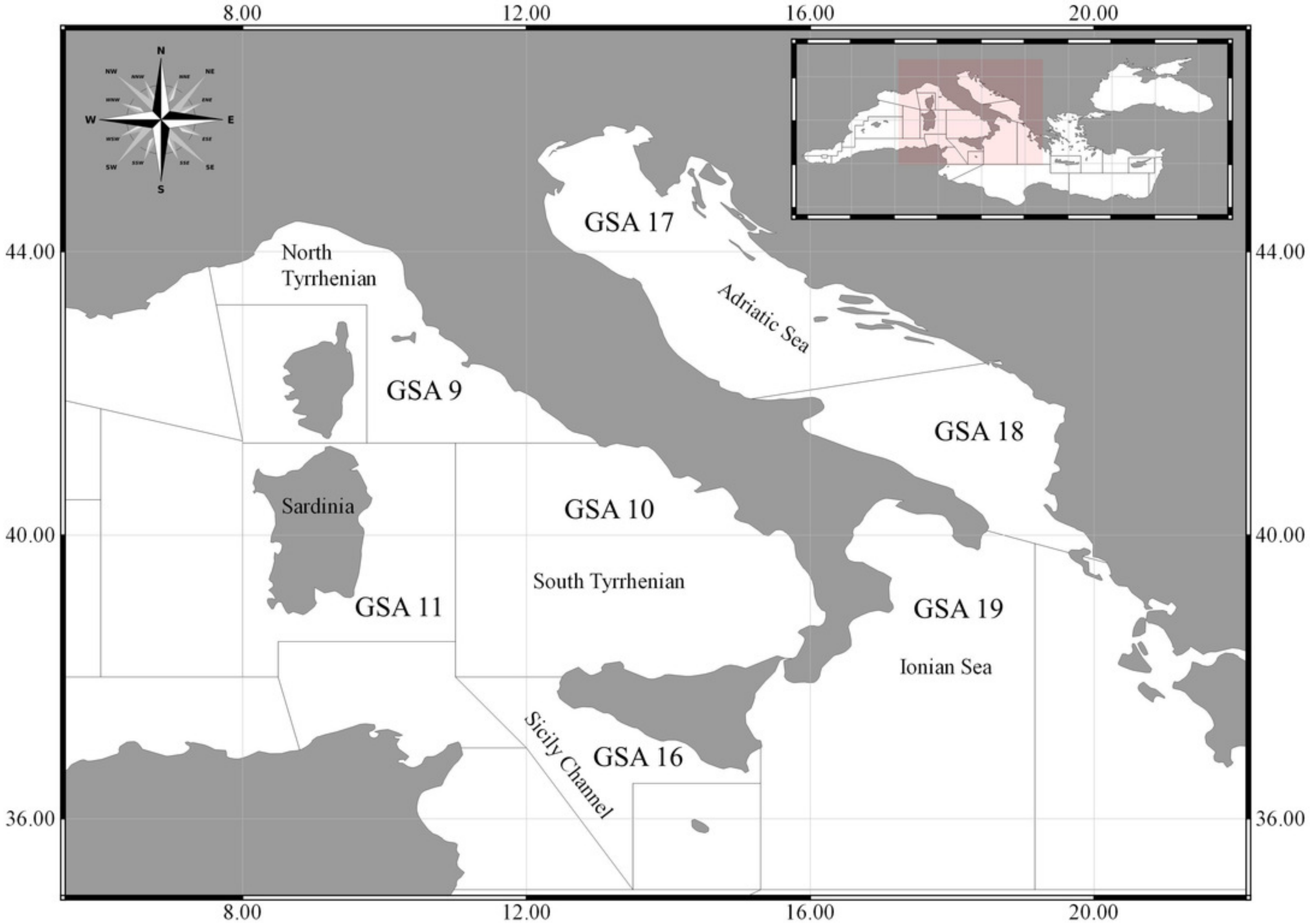

Figure 2

Turtles strandings

Data on stranded turtles ranked using a 6-point scale from 1 (low stranding: 0-25 turtles) to 6 (high strandings: >150 turtles). Source: "Reparto Ambientale Marino", Italian Ministry of the Environment. A = Winter; B = Spring; C = Summer; D = Autumn; F = Total seasons.

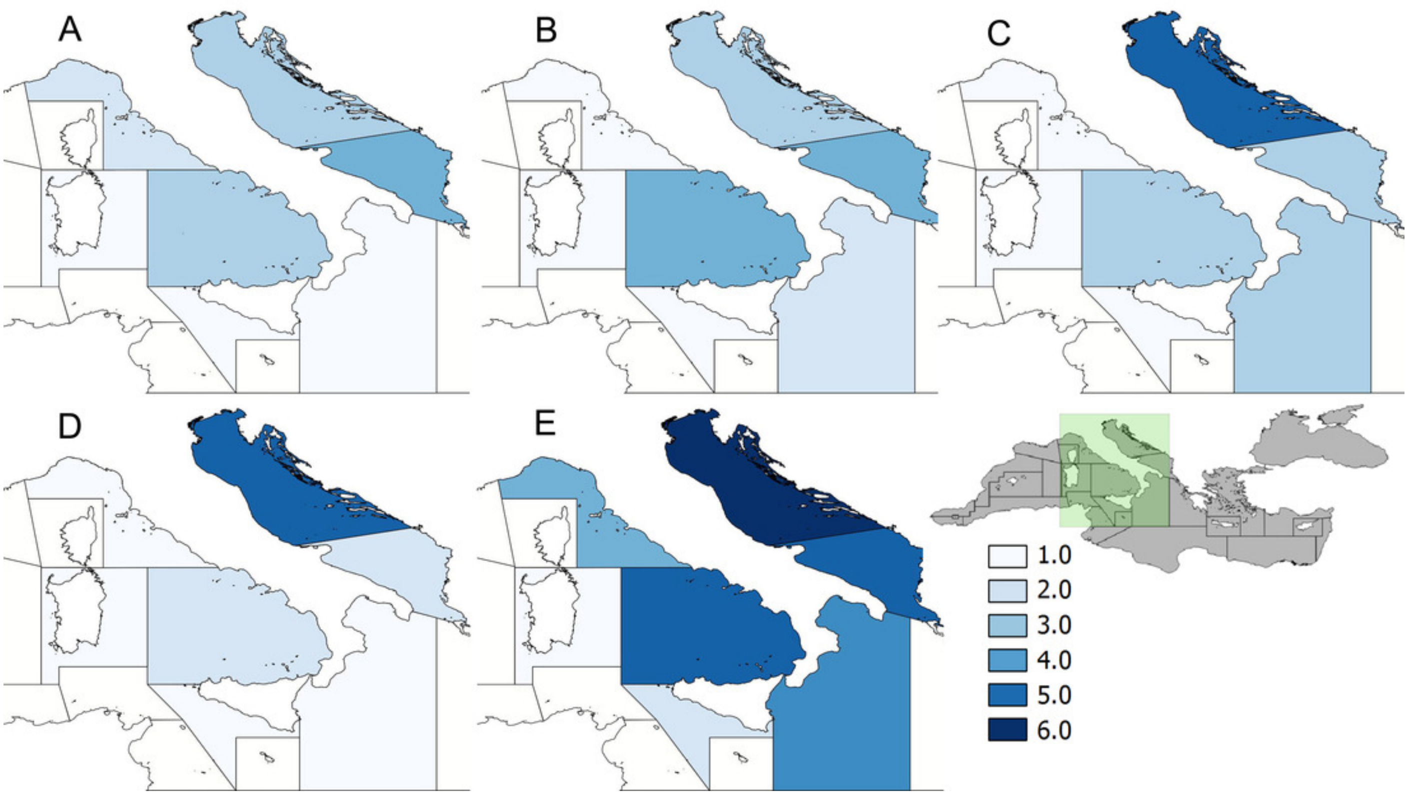

Figure 3

Probabilities to have false zeros

Estimation of the probabilities to have false zeros in the data set measured by the Zero Inflated Negative Binomial (ZINB) model. Bars represent standard errors.

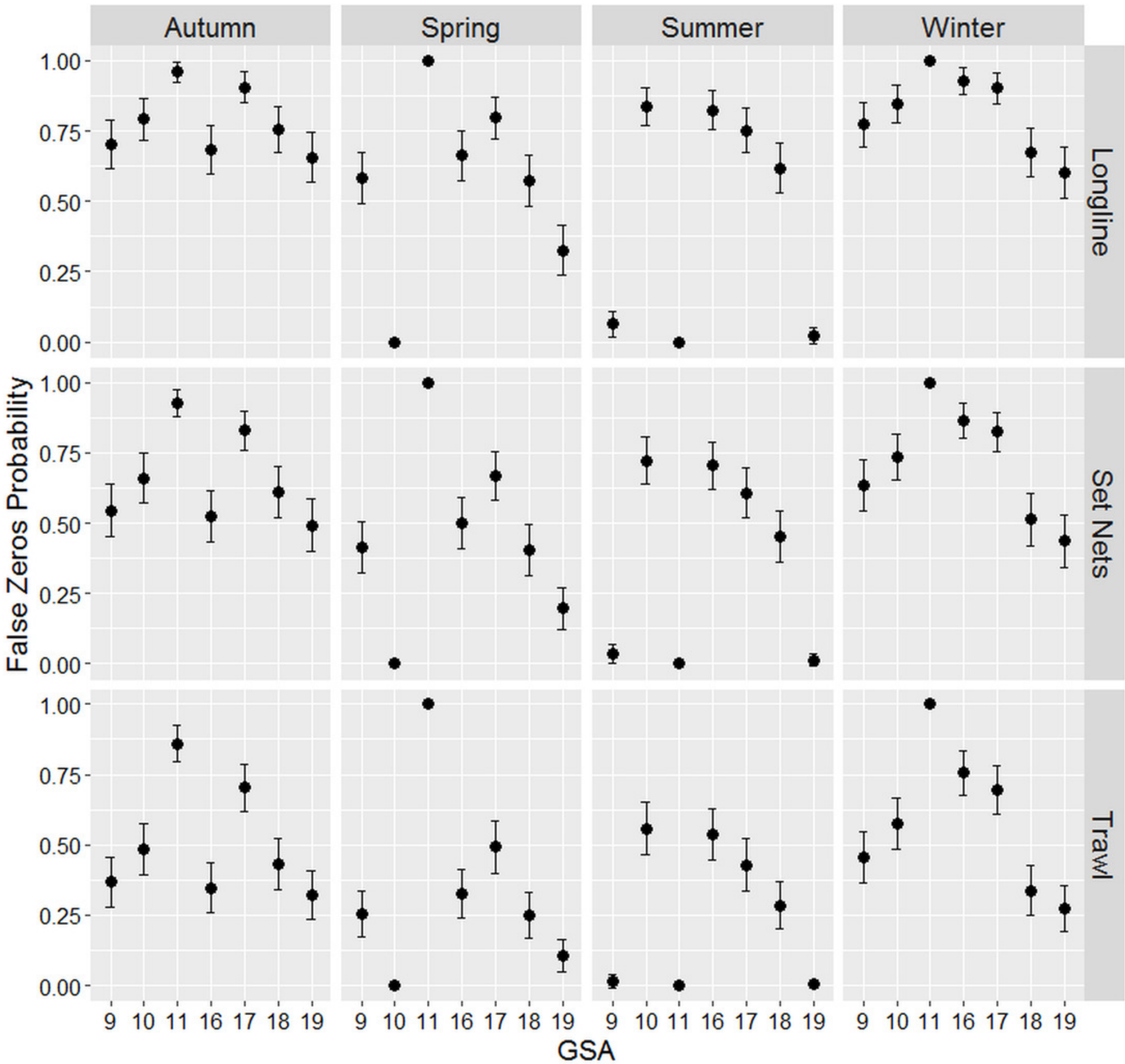

Figure 4

Estimated count

ZINB estimated turtle bycatch per vessel count prediction values for the three gears for each GSA. Bars represent standard errors of the predicted values. A = Longlines; B = Set Nets; C = Trawl Nets.

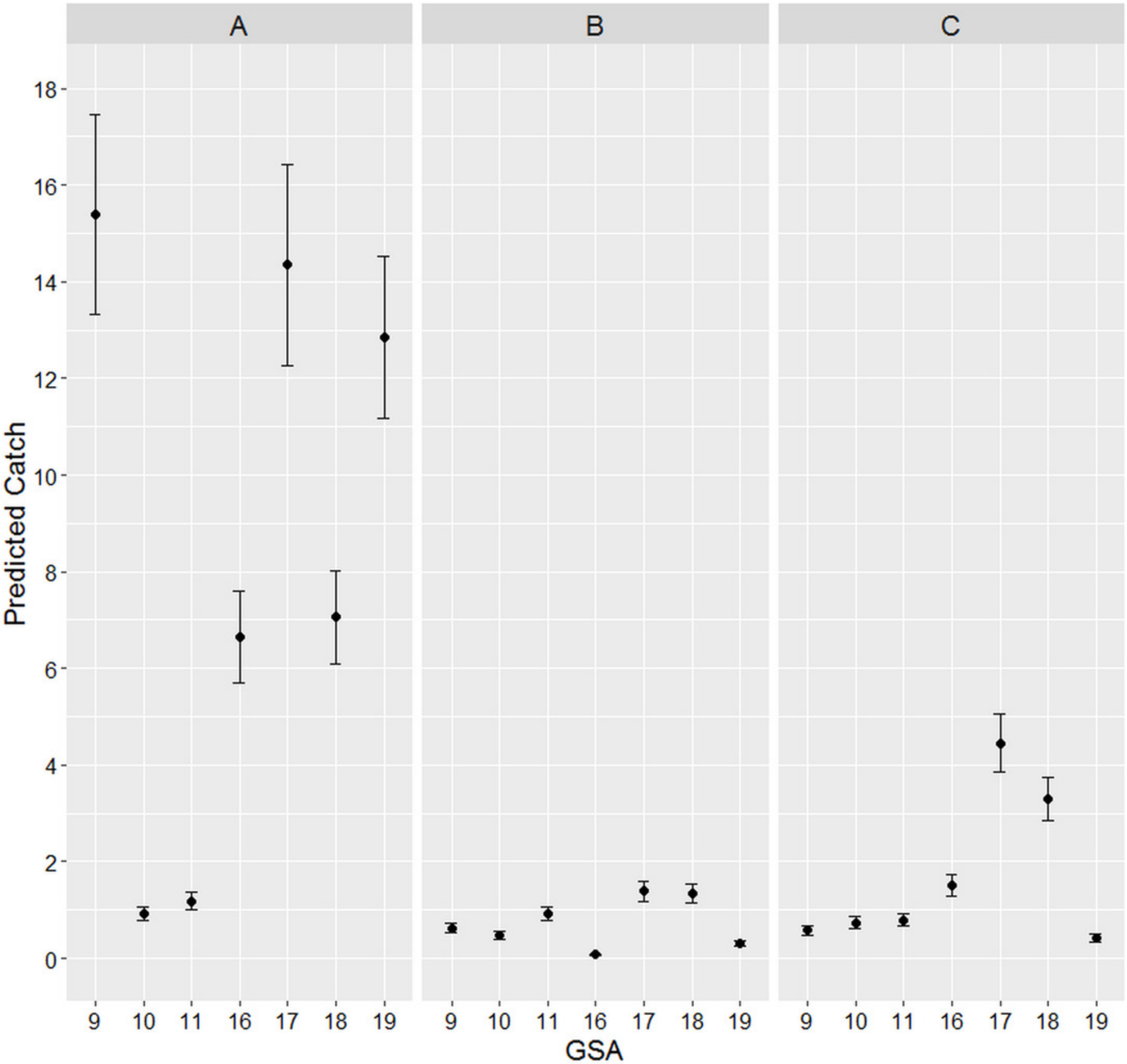

Figure 5

Model estimated probabilities

ZINB model estimated probabilities (phat) to have turtle bycatch events in the GSAs. The graphs are zero truncated to highlight the probabilities associated to a positive event. A = GSA 9; B = GSA 10; C = GSA 11; D = GSA 16; E = GSA 17; F = GSA 18; G = GSA 19.

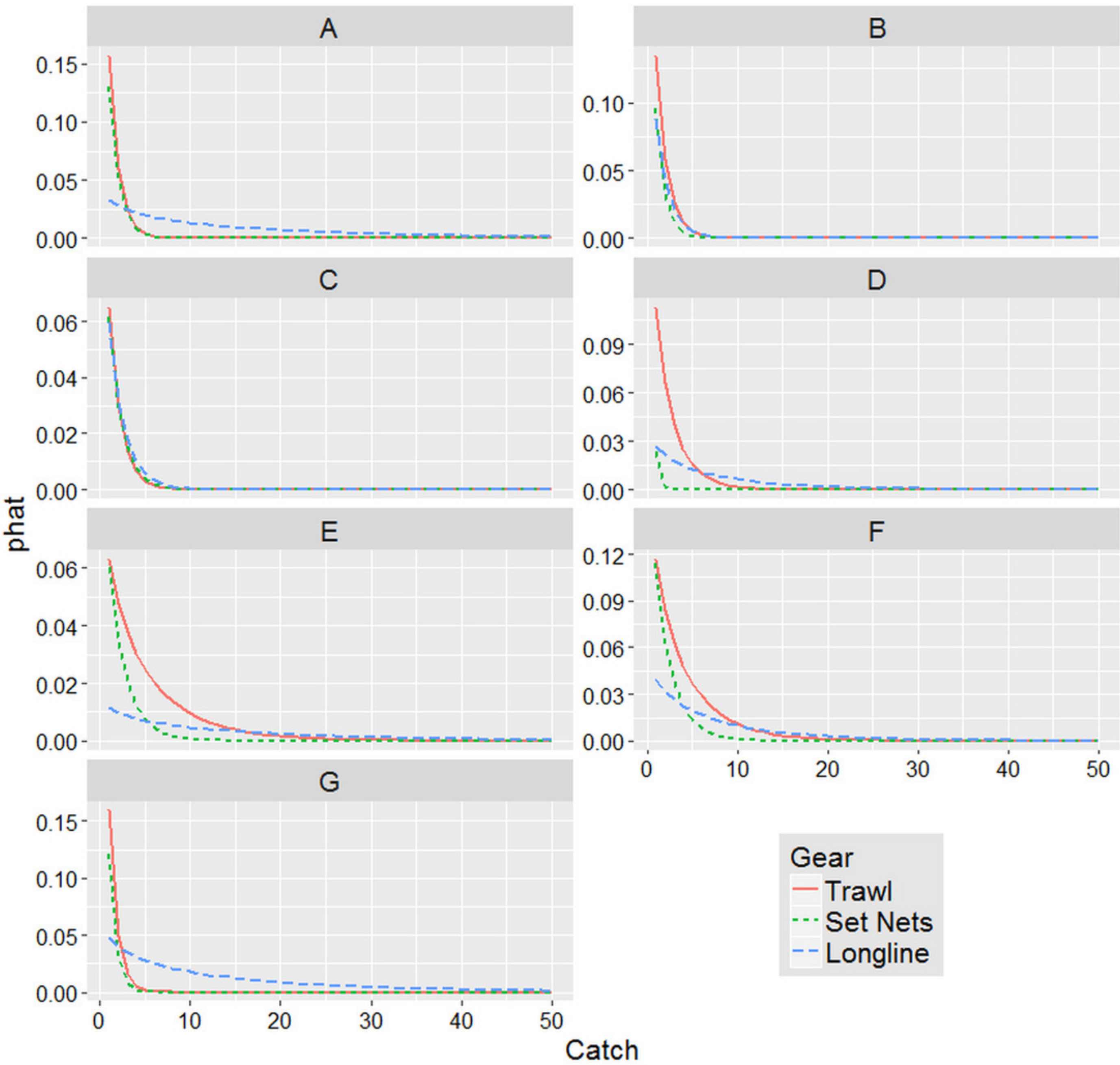

Figure 6

Interaction index

Sea turtle bycatch/gear interaction categorized by gear type and season. Interactions were ranked from 1 (lowest risk of interaction: 0-0.018) to 6 (highest risk of interaction: >0.08). A = Longlines; B = Set Nets; C = Trawl Nets; D = Total gears. a = Spring; b = Summer; c = Autumn; d = Winter.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2826v1 | CC BY 4.0 Open Access | rec: 22 Feb 2017, publ: 22 Feb 2017

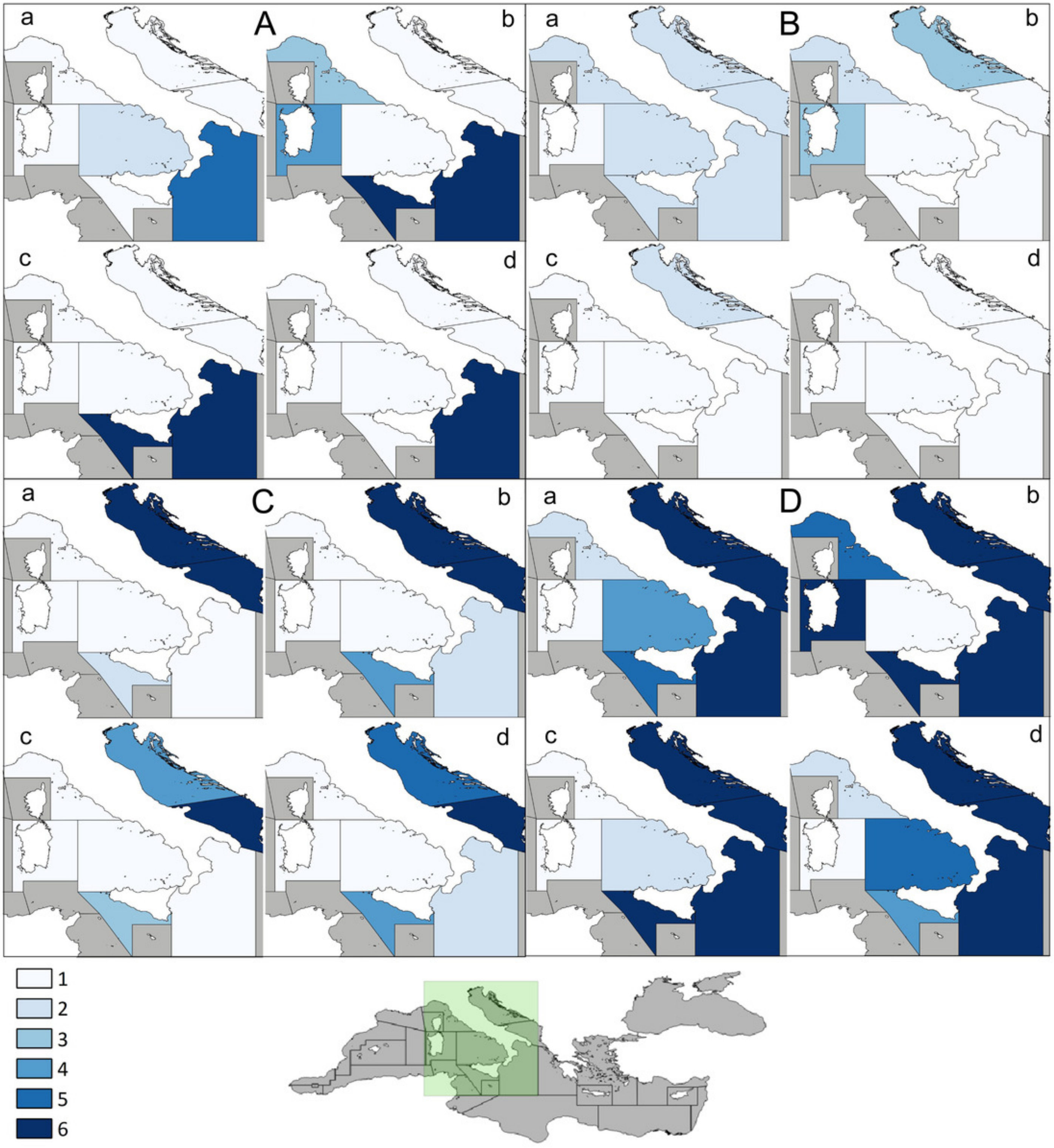
A
B
C
D
a
b
c
d
1
2
3
4
5
6

Table 1(on next page)

Fishing effort

Indexes of fishing effort calculated in 2014: *Number of vessels* (NV) and *Fishing days per season* (FD) in each GSA divided by fishing gear (Longlines, Set nets, Trawls). NT: North Tyrrhenian; ST: South Tyrrhenian; SR: Sardinia; SC: Sicily Channel; NA: North Adriatic; SA: South Adriatic; IS: Ionian Sea; NV: Number of Vessels; FE: Fishing Effort.

Gear	GSA	Spring		Summer		Autumn		Winter		Total	
		NV	FD	NV	FD	NV	FD	NV	FD	NV	FD
Longlines	GSA 09 - NT	65	2131	122	3730	50	623	33	931	270	7416
	GSA 10 - ST	150	7034	181	5896	50	1157	31	388	412	14475
	GSA 11- SR	25	818	49	1503	16	82	18	359	108	2762
	GSA 16 - SC	54	1974	64	2605	31	201	27	321	176	5101
	GSA 17 - NA	15	479	13	355	15	153	16	328	59	1315
	GSA 18 - SA	8	426	8	574	8	113	8	70	32	1182
	GSA 19 - IS	86	5432	165	14480	146	8656	54	2209	451	30777
	Total	403	18295	602	29142	316	10984	187	4606	1508	63026
Set nets	GSA 09 - NT	1024	36148	950	31674	799	22382	870	26408	3643	116612
	GSA 10 - ST	1341	46388	1168	46126	1007	32798	1143	31155	4659	156467
	GSA 11- SR	1096	33978	977	31981	597	11968	687	16162	3357	94088
	GSA 16 - SC	475	17237	502	17104	276	5134	293	7849	1546	47323
	GSA 17 - NA	862	22668	1048	32265	821	20306	697	15968	3428	91208
	GSA 18 - SA	417	17140	348	17984	298	11647	359	8798	1422	55569
	GSA 19 - IS	1095	49586	1153	58907	1020	38976	1144	43137	4412	190605
	Total	6310	223145	6146	236040	4818	143211	5193	149477	22467	751873
Trawl nets	GSA 09 - NT	208	14476	206	13144	181	10495	193	12874	788	50988
	GSA 10 - ST	280	12763	260	11084	270	9504	296	11221	1106	44572
	GSA 11- SR	97	4043	102	3157	101	2412	100	3862	400	13475
	GSA 16 - SC	288	18066	305	15424	233	10338	294	14174	1120	58002
	GSA 17 - NA	596	26915	471	16053	539	23844	605	27194	2211	94006
	GSA 18 - SA	443	14671	429	10299	428	14501	427	13227	1727	52697
	GSA 19 - IS	248	10885	241	9015	264	7646	270	9025	1023	36571
	Total	2160	101819	2014	78176	2016	78739	2185	91577	8375	350311

Table 2 (on next page)

Mean turtle bycatch

Mean turtle bycatch per vessel (geometric mean and standard error: se) obtained from the interviews per GSA, fishing gear and season. NT: North Tyrrhenian; ST: South Tyrrhenian; SR: Sardinia; SC: Sicily Channel; NA: North Adriatic; SA: South Adriatic; IS: Ionian Sea.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2826v1 | CC BY 4.0 Open Access | rec: 22 Feb 2017, publ: 22 Feb 2017

		Spring		Summer		Autumn		Winter	
		Mean	se	Mean	se	Mean	se	Mean	se
Longlines	GSA 09 - NT	0.0	0.0	7.4	9.5	24.5	6.3	1.0	0.2
	GSA 10 - ST	1.2	0.2	0.0	0.0	2.0	0.2	0.0	0.0
	GSA 11 - SR	0.0	0.0	1.5	0.3	0.0	0.0	0.0	0.0
	GSA 16 - SC	2.0	0.3	15.0	2.5	3.9	2.5	0.0	0.0
	GSA 17 - NA	0.0	0.0	14.0	2.1	0.0	0.0	0.0	0.0
	GSA 18 - SA	1.0	0.0	11.0	1.8	0.0	0.0	0.0	0.0
	GSA 19 - IS	6.3	1.7	5.5	5.4	17.3	3.5	9.3	1.8
Set nets	GSA 09 - NT	1.4	0.2	1.3	0.3	1.0	0.1	1.0	0.1
	GSA 10 - ST	1.6	0.2	1.7	0.1	1.1	0.1	1.8	0.1
	GSA 11 - SR	0.0	0.0	1.4	0.2	0.0	0.0	0.0	0.0
	GSA 16 - SC	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	GSA 17 - NA	2.0	0.2	1.8	0.2	2.0	0.1	1.6	0.0
	GSA 18 - SA	1.0	0.3	1.6	0.5	5.0	1.3	1.0	0.3
	GSA 19 - IS	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Trawl nets	GSA 09 - NT	1.4	0.2	1.3	0.2	1.3	0.2	1.0	0.1
	GSA 10 - ST	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
	GSA 11 - SR	0.0	0.0	1.0	0.1	1.0	0.1	0.0	0.0
	GSA 16 - SC	2.0	0.7	3.0	1.0	2.0	0.7	3.0	1.0
	GSA 17 - NA	3.8	0.4	3.4	0.4	4.1	0.4	4.2	0.4
	GSA 18 - SA	3.4	0.5	4.4	0.5	3.8	0.8	2.5	0.9
	GSA 19 - IS	0.0	0.0	1.0	0.2	0.0	0.0	2.0	0.4

Table 3 (on next page)

Estimate of capture events

Estimate of capture events and turtle deaths per GSA, fishing gear and season. The mortality rate obtained from interviews (current paper) and from Casale (2011) (Cas. 2011) were used to calculate the estimates of turtle deaths. NT: North Tyrrhenian; ST: South Tyrrhenian; SR: Sardinia; SC: Sicily Channel; NA: North Adriatic; SA: South Adriatic; IS: Ionian Sea.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2826v1 | CC BY 4.0 Open Access | rec: 22 Feb 2017, publ: 22 Feb 2017

		Spring			Summer			Autumn			Winter			Total		
		Bycatch	Mortality		Bycatch	Mortality		Bycatch	Mortality		Bycatch	Mortality		Bycatch	Mortality	
			Current	Cas. 2011		Current	Cas. 2011		Current	Cas. 2011		Current	Cas. 2011		Current	Cas. 2011
Longlines	GSA 09 - NT	0.0	0.0	0.0	902.9	125.3	270.9	1224.7	169.9	367.4	33.0	4.6	9.9	2160.6	299.8	648.2
	GSA 10 - ST	175.0	24.3	52.5	0.0	0.0	0.0	100.0	13.9	30.0	0.0	0.0	0.0	275.0	38.2	82.5
	GSA 11 - SR	0.0	0.0	0.0	71.2	9.9	21.4	0.0	0.0	0.0	0.0	0.0	0.0	71.2	9.9	21.4
	GSA 16 - SC	108.0	15.0	32.4	960.0	133.2	288.0	120.1	16.7	36.0	0.0	0.0	0.0	1188.1	164.8	356.4
	GSA 17 - NA	0.0	0.0	0.0	182.0	25.3	54.6	0.0	0.0	0.0	0.0	0.0	0.0	130.0	25.3	54.6
	GSA 18 - SA	8.0	1.1	2.4	88.0	12.2	26.4	0.0	0.0	0.0	0.0	0.0	0.0	96.0	13.3	28.8
	GSA 19 - IS	543.9	75.5	163.2	914.0	126.8	274.2	2532.4	351.4	759.7	501.3	69.6	150.4	4491.5	623.2	1347.5
	Total	**834.9**	**115.8**	**250.5**	**3118.1**	**432.6**	**935.4**	**3977.2**	**551.8**	**1193.2**	**534.3**	**74.1**	**160.3**	**8412.4**	**1174.4**	**2539.3**
Set nets	GSA 09 - NT	1460.4	34.3	438.1	1196.9	28.1	359.1	799.0	192.6	479.4	870.0	209.7	522.0	4326.3	1042.6	2595.8
	GSA 10 - ST	2194.0	51.6	658.2	2033.6	47.8	610.1	1156.7	278.8	694.0	2077.0	500.5	1246.2	7461.3	1798.2	4476.8
	GSA 11 - SR	0.0	0.0	0.0	1365.0	32.1	409.5	0.0	0.0	0.0	0.0	0.0	0.0	1365.0	329.0	819.0
	GSA 16 - SC	475.0	11.2	142.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	475.0	114.5	285.0
	GSA 17 - NA	1731.1	40.7	519.3	1840.1	43.2	552.0	1628.8	392.5	977.3	1090.9	262.9	654.5	6290.9	1516.1	3774.5
	GSA 18 - SA	417.0	9.8	125.1	552.4	13.0	165.7	1490.0	359.1	894.0	359.0	86.5	215.4	2818.4	679.2	1691.0
	GSA 19 - IS	1095.0	25.7	328.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1095.0	263.9	657.0
	Total	**7372.5**	**173.3**	**2211.7**	**6988.1**	**164.2**	**2096.4**	**5074.5**	**1223.0**	**3044.7**	**4396.8**	**1059.6**	**2638.1**	**23831.9**	**5743.5**	**14299.2**
Trawl nets	GSA 09 - NT	294.2	2.8	88.2	259.5	2.5	77.9	228.0	35.0	45.6	193.0	29.6	38.6	974.7	149.5	194.9
	GSA 10 - ST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	592.0	90.8	118.4	592.0	90.8	118.4
	GSA 11 - SR	0.0	0.0	0.0	102.0	1.0	30.6	101.0	15.5	20.2	0.0	0.0	0.0	203.0	31.1	40.6
	GSA 16 - SC	576.0	5.5	172.8	915.0	8.7	274.5	466.0	71.5	93.2	882.0	135.3	176.4	2839.0	435.4	567.8
	GSA 17 - NA	2256.1	21.4	676.8	1597.9	15.2	479.4	2194.0	336.5	438.8	2555.8	392.0	511.2	8603.8	1319.6	1720.8
	GSA 18 - SA	1523.6	14.5	457.1	1892.7	18.0	567.8	1618.1	248.2	323.6	1067.6	163.7	213.5	6102.1	935.9	1220.4
	GSA 19 - IS	0.0	0.0	0.0	241.0	2.3	72.3	0.0	0.0	0.0	540.0	82.8	108.0	781.0	119.8	156.2
	Total	**4649.8**	**44.2**	**1394.9**	**5008.2**	**47.6**	**1502.5**	**4607.2**	**706.6**	**921.4**	**5830.4**	**894.2**	**1166.1**	**20095.6**	**3082.2**	**4019.1**
Total	GSA 09 - NT	1754.5	37.1	526.4	2359.4	155.9	707.8	2251.8	397.5	892.4	1096.0	243.9	570.5	7461.7	1491.9	3438.9
	GSA 10 - ST	2369.0	75.8	710.7	2033.6	47.8	610.1	1256.7	292.6	724.0	2669.0	591.3	1364.6	8328.3	1927.1	4677.7
	GSA 11 - SR	0.0	0.0	0.0	1538.2	42.9	461.5	101.0	15.5	20.2	0.0	0.0	0.0	1639.2	370.0	881.0
	GSA 16 - SC	1159.0	31.6	347.7	1875.0	141.9	562.5	586.1	88.1	129.2	882.0	135.3	176.4	4502.1	714.8	1209.2
	GSA 17 - NA	3987.1	62.1	1196.1	3620.0	83.7	1086.0	3822.8	729.1	1416.1	3646.6	654.9	1165.7	15024.7	2861.0	5549.9
	GSA 18 - SA	1948.6	25.4	584.6	2533.1	43.2	759.9	3108.1	607.3	1217.6	1426.6	250.3	428.9	9016.5	1628.5	2940.3
	GSA 19 - IS	1638.9	101.2	491.7	1155.0	129.1	346.5	2532.4	351.4	759.7	1041.3	152.4	258.4	6367.5	1006.9	2160.7
	Total	**12857.2**	**333.3**	**3857.2**	**15114.4**	**644.4**	**4534.3**	**13658.9**	**2481.4**	**5159.3**	**10761.5**	**2028.0**	**3964.5**	**52340.0**	**10000.1**	**20857.6**

Table 4 (on next page)

Factors used in the ZINB model

Factors used in the ZINB model and their significance. Count part refers to the GLM negative binomial part of the model for count predictions, while zero part refers to the GLM binomial to predict the probabilities of false zeros.

	Factors	Chi^2	df	p
Count part	Gear	198.75	32	<0.0001
	GSA	155.91	36	<0.0001
	GSA*Gear	62.39	12	<0.0001
Zero part	GSA	131.92	24	<0.0001
	Season	184.97	21	<0.0001
	Gear	18.9	2	<0.0001
	GSA*Season	55.52	18	<0.0001

Table 5(on next page)

Interview results in percentages

Interview results in percentages per gear: 1) fishermen that reported at least one capture event and 2) eventual disturbance to fishing activities caused; 3) main causes of disturbance due to turtle catch; 4) fishermen behavior in case of a capture event; 5) fishermen's opinion and 6) doubts on the adoption of BRDs; 7) fishermen's awareness of sea turtles conservation issues; 8) fishermen's level of interest in participation in conservation projects.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2826v1 | CC BY 4.0 Open Access | rec: 22 Feb 2017, publ: 22 Feb 2017

ID	Question	Answer	Longlines	Set Nets	Trawl Nets	Total
1	Catch	YES	82.7	57.6	86.8	71.0
		NOT	17.3	42.4	13.2	29.0
2	Disturb	YES	69.6	60.8	24.3	43.1
		NOT	30.4	39.2	75.7	56.9
3	Cause of disturbance	Reduction of fishing time	46.4	25.5	28.6	28.5
		Damage to fishing gear	14.3	27.0	14.3	21.9
		Damage to fish caught	3.6	13.5	38.8	17.5
		Interruption of fishing activities	17.9	18.4	4.1	17.1
		Others (Bait consuming, etc.)	17.9	15.6	14.3	14.9
4	Behaviour in case of catch	Instantaneous release	47.8	18.9	22.3	24.0
		Delivery to Rescue center	39.1	31.1	26.2	29.5
		Release after rest	13.0	50.0	51.5	46.5
5	Opinion on BRD	Yes with money	60.4	33.6	44.1	40.4
		Yes, only training	8.3	19.7	13.6	16.2
		Not, just information	14.6	24.4	16.4	20.3
		Not interested	16.7	22.3	26.0	23.1
6	Doubts and misgiving	Scarse Information	36.4	39.9	38.6	39.1
		Fear to change	43.6	37.8	37.1	38.1
		Why change	3.6	9.2	9.6	8.8
		No interst in conservation	16.4	12.7	10.2	12.1
		Other (bureaucracy, regulations, etc.)	0.0	0.4	4.6	1.9
7	Awareness on sea turtle conservation	YES	62.5	63.1	52.3	58.2
		Neutral	33.3	24.5	34.7	29.9
		NOT	4.2	12.4	13.1	11.9
8	Willingness to collaborate in conservation projects	Knowledge of economical benefits	29.9	27.1	35.9	30.3
		Financial Programmes for fisheries	22.1	34.7	35.9	33.4
		Make experience with BRDs	26.0	6.1	3.6	7.9
		Knowledge on previous experimental experiences	15.6	8.8	9.4	9.9
		Endangered species protection	2.6	7.9	9.4	7.7
		How to rescue a turtle	3.9	15.5	5.7	10.9