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Sea turtle bycatch by different types of fisheries in southern Spain

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The bycatch of sea turtles by large-scale fisheries is receiving an increasing attention in recent years due to the high impact it causes on these endangered species. This issue was evaluated in southern Spanish waters that harbor an important feeding ground of loggerhead and leatherback turtles, including the endangered Eastern Atlantic loggerhead population. To quantify the impact that different fisheries represents to sea turtles, 272 fishermen answered to detailed illustrated questionnaires in all the main ports of Andalusia and Murcia (Spain) during 2014. This study has updated the knowledge of turtle bycatch in the southwestern Mediterranean revealing a widespread impact of fisheries on sea turtles. Fishermen recognized an annual catch of 2.3 turtles per boat. Considering the census of operative large-scale fishing boats in the study area (1182), more than 2840 sea turtles could be bycaught per year in that area. Most captures (96.2%) were produced during the summer. These fisherman answers suggest a severe impact of most legal fisheries (surface longline, purse seine, trawling and small-scale fisheries) on loggerhead feeding grounds in the southwestern Mediterranean. Fishermen suggested that drift fishing conducted by foreign or illegal fishermen and almadrabas are also causing a significant bycatch of turtles. Several measures such as reviewing compliance of current fishing and environmental regulations, modifying fishing techniques to reduce turtle bycatch, facilitating the rescue and handle of wound turtles and their transport to the port for recovery, and recognizing the efforts of anglers to perform a more sustainable fishing, are recommended to mitigate this impact.

Key words: bycatch; large-scale fishery; sea turtle; Southwestern Mediterranean; Spain.

The threat to marine life caused by fishing has become an important conservation issue. Marine mammals, sharks or turtles are incidentally captured worldwide in different fishing gears and a significant part of them will die as a consequence of such interaction (Morizur *et al*., 1999; Stevens *et al*., 2000; Lewison *et al*., 2004, 2014; Read *et al*., 2006; Wallace *et al*., 2010). Incidental capture of sea turtles by fishing gear is currently the main threat for many endangered sea turtle populations in the world (Soykan *et al*., 2008; Wallace *et al*., 2010). In the Mediterranean Sea, over 132 000 sea turtles can be bycaught every year, with probably over 44 000 incidental deaths per year (Casale, 2011). Most studies are based on observers getting bycatch data on large-scale pelagic fisheries, and evaluate fishing gears separately and not in an integrated way considering all the fishing gears affecting local turtle popula-

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tions. However, it is evident that small-scale fisheries can also have a deep impact locally by the diversity of techniques and the large number of vessels in operation (BELL *et al.*, 2006; ALFARO-SHIGUETO *et al.*, 2011). For example, in the Western Mediterranean several studies have already analyzed the incidental capture of sea turtles due to drifting longlines (BÁEZ *et al.*, 2006; CAMIÑAS *et al.*, 2006) or trawling (CARRERAS *et al.*, 2004; ÁLVAREZ DE QUEVEDO *et al.*, 2010; DOMÈNECH *et al.*, 2015). However, the Mediterranean is a historically overexploited sea (MORALES-MUÑIZ & ROSELLÓ-IZQUIERDO, 2008) with multitude of coastal nations with different socio-economic and cultural backgrounds. For example, in the Alboran Sea (southwestern Mediterranean) more than 20 different fishing gears are used, especially in neritic zones (CARRERAS *et al.*, 2004). Thus, it is important to conduct *in situ* studies considering together the interactions with the different types of used fishing gears on both temporal and spatial scales (FAO, 2004). Furthermore, the use of neritic habitats by sea turtles could make them more prone to interactions with neritic fishing gears (CARDONA *et al.*, 2009). Thus, it is important to solve the gap of the impact of neritic and pelagic fisheries to sea turtles and compare the contribution of each fishing gear to the overall bycatch in a given zone in order to better understand the problem and to effectively identify the priorities to reduce this threat.

Small-scale fisheries have traditionally received less research effort than large-scale fisheries and are generally understudied in Europe. (GUYADER *et al.*, 2013). Despite their comparatively low volume of catches and economic importance, small-scale fisheries are socially important and heterogeneous. In comparison to large-scale fleets, small-scale fleets are composed of smaller vessels, travel lower distances to fishing grounds, and are more reliant on coastal areas; have smaller crews, use mostly, but not exclusively, passive gears; use multi-purpose fishing approaches, and can change the fish species they target during the year; have lower extraction rates; and the number of vessels is much higher (GARCÍA-RODRÍGUEZ *et al.*, 2006; GUYADER *et al.*, 2013; DIMITRIADIS *et al.*, 2016).

The loggerhead turtle is the most common sea turtle in the southwestern Mediterranean (GÓMEZ DE SEGURA *et al.*, 2006), though leatherbacks are also frequent (CAMIÑAS, 1998) and green and Kemp's ridleys can be sporadically found (CAMIÑAS, 2004; CARRERAS *et al.*, 2014; GARCÍA-BARCELONA *et al.*, 2017). Three different Regional Management Units (RMUs) of loggerhead turtles can be found in the area: the northwestern Atlantic RMU, the northeastern Atlantic RMU and the Mediterranean RMU (MONZÓN-ARGÜELLO *et al.*, 2010; WALLACE *et al.*, 2010; CARRERAS *et al.*, 2011). The main origin of loggerheads is the northwestern Atlantic, where this species is not considered at high extinction risk (WALLACE *et al.*, 2011). However, turtles from the northeastern Atlantic are also frequent (MONZÓN-ARGÜELLO *et al.*, 2009) and are catalogued as the most endangered loggerhead population in the Atlantic and one of the most endangered in the world (WALLACE *et al.*, 2011; CASALE & MARCO, 2015). Thousands of Atlantic loggerheads enter in the Mediterranean fol-

lowing the Gulf Stream, but have severe difficulties to leave the Mediterranean through the Strait of Gibraltar due to the west-east dominant strong currents. Thus, the southwestern Mediterranean constitutes an area of very abundant loggerhead juvenile aggregation from Atlantic populations, which stay in this area until they reach a large body size that permits them to return to the Atlantic (REVELLES *et al*., 2007; BELLIDO-LÓPEZ *et al*., 2018).

The estimation of turtle bycatch is usually addressed by data obtained by onboard observers (MORIZUR *et al*., 1999; SILVANI *et al*., 1999; CASALE *et al*., 2004). This technique is effective for fishing gears performed by large vessels, but is not adequate for small vessels due to their large number, numerous trips, low catch per unit effort (ÁLVAREZ DE QUEVEDO *et al*., 2010; LOZANO *et al*., 2011) or small fishing vessels (NADA & CASALE, 2011; MANCINI *et al*., 2012). Small-scale fishery has been considered as all fishing activities performed by small vessels, including many different types of gears such as gillnets, hooks, traps, pots, rods, etc. The use of standard questionnaires has revealed as an efficient method to obtain a good proxy to compare turtle bycatch among different fishing gears (GODLEY *et al*., 1998; WHITE *et al*., 2005; MOORE *et al*., 2010).

The main goal of the present study was to evaluate the current level of turtle bycatch in the Andalusia and Murcia regions of Spain using questionnaires. A similar study was conducted in the area ten years ago, but fishermen only gave qualitative answers to the amount of turtles captured per year (BÁEZ *et al*., 2006). In the present study, fishermen have provided a quantitative annual estimation of bycaught turtles, which permits a statistical analysis of the relative impact of different fishing gears. Furthermore, we assess any significant change on turtle bycatch in the area during the past decade. Moreover, we also compare our data with those from similar studies conducted in neighbor areas of southwestern Europe using similar methodologies (CARRERAS *et al*., 2004; ÁLVAREZ DE QUEVEDO *et al*., 2010; DOMÈNECH *et al*., 2015). To conduct this study, a collaboration agreement was signed with the 15 fishermen associations of the main fishing harbors of the study area.

MATERIALS AND METHODS

An intensive study was conducted by trained marine biologists in the main 15 fishing harbors of the Mediterranean coast of Andalusia (provinces of Cádiz, Málaga, Granada and Almería) and Murcia (southern Spain) (Fig. 1) during 2014. A total of 272 interviews were completed by fishermen from different boats of both large- and small-scale fisheries in the different ports (56 in Cádiz, 133 in Málaga, seven in Granada, 53 in Almería and 23 in Murcia) (Table 1). Only one fisherman was interviewed per vessel.

The ports were visited mainly when the fishermen arrived at the port. The questionnaires were completed personally by fishermen at their home, boat or port. The questionnaires were based on MOORE *et al*. (2010) and included questions about fishermen's practices, gear use and turtle bycatch. The questionnaire was designed to estimate current bycatch rates and to compare among different fishing gears. Most of the questions had been used in previous

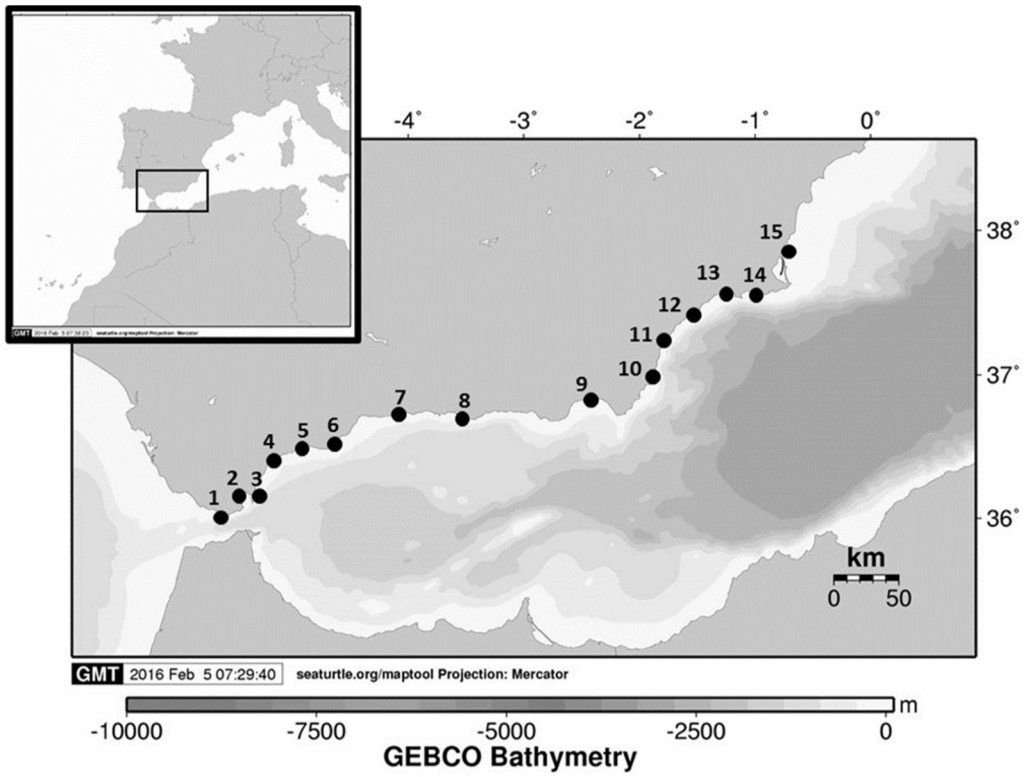

Figure 1: Reported annual bycatch rate of sea turtles on different fishing gears in the southwestern Mediterranean as well as the fishermen opinion about the fishing gear that causes most captures and highest mortality to sea turtles Map of the study zone in southern Spain. The dots and numbers indicate the 15 harbors where the questionaires were done. 1: Tarifa, 2: Algeciras, 3: La Línea de la Concepción, 4: Estepona, 5: Marbella, 6: Fuengirola, 7: Caleta Vélez, 8: Motril, 9: Almería, 10: Carboneras, 11: La Garrucha, 12: Águilas, 13: Mazarrón, 14: Cartagena, 15: San Pedro del Pinatar.

studies conducted in the western Mediterranean (CARRERAS *et al*., 2004; ÁLVAREZ DE QUEVEDO *et al*., 2010; DOMÈNECH *et al*., 2015), which allowed for comparisons among studies. The questionnaire included 43 different questions and the option for incorporating additional observations by the fishermen (Fig. S1). The questions were about their fishing experience and type of fishing gear, their perception of marine turtle local stocks, the interaction with fisheries, bycatches and the condition of caught turtles. Their opinion about the fishing gear that captured and killed more turtles was also gathered. The survey was designed to take less than 15 minutes to answer. Illustrations of sea turtles were used for specific identification because the common names varied among different communities. The vast majority of fishermen gave a single number of annual turtle bycatch. In the few cases that fishermen selected an interval, the central value of that interval was considered for the by-

Table 1: Summary of the number of boats and the number of fishermen interviewed and their fishing gear type from each fishing port. Only one fisherman was interviewed by boat.

Port (Province)	Fishing boats	Interviews	Crawling	Purse seine	Small scale	Longline
Tarifa (Cádiz)	77	17	0	0	17	0
Algeciras (Cádiz)	87	22	0	4	18	0
La Línea (Cádiz)	38	17	0	0	17	0
Estepona (Málaga)	85	39	10	5	24	0
Marbella (Málaga)	61	28	4	4	20	0
Fuengirola (Málaga)	79	20	11	4	5	0
Caleta Vélez (Málaga)	101	46	16	29	2	0
Motril (Granada)	66	7	3	2	1	1
Almería (Almería)	115	15	9	4	1	0
Carboneras (Almería)	66	24	0	5	3	16
Garrucha (Almería)	76	14	4	2	3	5
Aguilas (Murcia)	42	7	2	0	5	0
Mazarrón (Murcia)	56	1	0	1	0	0
Cartagena (Murcia)	67	7	5	0	1	1
San Pedro del Pinatar (Murcia)	98	8	0	2	6	0
Total	1114	272	64	62	123	23

catch rate estimation. The number of vessel crews interviewed included at least 23% of all the registered vessels in the studied harbours. Fishermen were asked to consider turtle bycatch only during the previous fishing year (2013). Incomplete questionnaires were discarded from the analysis. Fishermen were informed before answering about the confidentiality and privacy of the survey.

We also obtained information from the fishermen associations of the 15 study ports regarding the number of active registered fishing boats using each fishing gear (Table 2). We complemented this official information with visual surveys of the boats when all of them were expected to be at the ports. To estimate the sea turtle bycatch rates, the number of individuals caught per boat and year was estimated for each port and fishing gear (MOORE *et al*., 2010). For surface longlines, we identified two main types of bait that were regularly used: only fish, usually mackerel, or a combination of fish and squid. We created two types of surface longlines depend-

Table 2: Reported annual bycatch rate of sea turtles on different fishing gears in the southwestern Mediterranean as well as the fishermen opinion about the fishing gear that causes most captures and highest mortality to sea turtles.

	Fishing boats (%)	Recognized bycatch (turtles per boat and year)	Estimated bycatch (%)	Most captures	Highest mortality
Overall / mean	100.0	2.3	100.0		
Trawling	19.2	0.5	9.6	1.7	5.5
Small scale	67.1	0.7	47.0	6.9	28.5
Purse seine	9.8	1.1	10.8	0.9	5.5
Bottom Longline	0.9	0.2	0.2	0.0	0.0
Surface longline (SL)	3.0	10.8	32.4	67.2	27.9
SL squid + fish bait	0.9	25.0	23.6		
SL fish-only bait	1.6	5.6	8.8		
Set-Net - *Almadraba*	0.0	Not applicable	Not applicable	7.8	21.1
Driftnet	0.0	Not applicable	Not applicable	15.5	11.5

ing on the used bait type. Bycatches were compared among different fishing gears using a Chi-square test. The mean value of bycatch rate per port was multiplied by the maximum number of registered boats on that port in order to obtain an estimation of total bycatches per port, and an overall, annual bycatch rate for the entire study area was then calculated.

RESULTS

The 77.3% of fishermen perceives that turtle abundance is decreasing in the study area. The 16.4% considers that turtle abundance has not changed significantly during the past years and only the 6.26 % of fishermen considers that turtle abundance is increasing.

The information provided by fishermen indicates that a mean of 2.3 sea turtles (95% confidence interval = 1.0-3.6) are captured annually per boat (Table 2). Considering the census of operative fishing boats for each type of fishing gear in the study area (1182), more than 2840 sea turtles could be bycaught per year in the study area. Most of captures (96.2%) happened during summer. The majority of fishermen identified the loggerhead turtle as the species bycaught in their fishing gears.

Sea turtle bycatch rates varied significantly among different fishing gears (X^2 = 616.41, d.f. = 5, $P < 0.0001$). Surface longline had a much higher turtle bycatch rate than the rest of gears per effort unit (10.8 turtles per boat and year). The 3.0 % of vessels used surface longline and were responsible of one third of the overall recognized turtle bycatch. The longline baited with squid captured near five times more sea

turtles than longlines that only used fish (Table 2). Very few fishermen used bottom longline, and this gear was responsible of the capture of very few turtles.

No questionnaires were completed by fishermen using drift netting or *almadrabas* (the specific technique used to trap red tuna). However, the interviewed fishermen answered that drift netting (15.5%) conducted by foreign or illegal fishing boats and *almadrabas* (7.8 %) would be causing a significant bycatch of turtles. For one third of the fishermen, these two fishing gears would also be the most lethal techniques for bycaught sea turtles (Table 2).

Discussion

The assessment of sea turtle catch using questionnaires has been widely used (White *et al*., 2005; Moore *et al*., 2010), although these data may underestimate the threat to endangered populations (Carreras *et al*., 2004). The direct estimation of turtle bycatch is probably more accurate using on-board observers in large vessels (Báez *et al*., 2006), but this technique is not feasible in small vessels or in fisheries with low bycatch rates (Lozano *et al*., 2011; Báez *et al*., 2019). This is the case of the small-scale fishery, which can eventually cause important impact to sea turtles, especially due to the large numbers of small-scale vessels (Godley *et al*., 1998; Moore *et al*., 2010). Thus, and in order to compare statistically the bycatch rate using different fishing gears working in wide geographical areas, the use of a unique technique is needed, and the questionnaire could the most consistent option for this (Davies *et al*., 2009; Moore *et al*., 2010). In the present study, fishermen using all the different large- and small-scale fishing gears in the area were interviewed, covering the main fishing ports and around 12 % of fishermen of the northern side of the Alboran coast. The distribution of fishing gears among different study areas was highly variable and could have influenced the spatial differences in turtle bycatch. We found no other reason to explain such variability comparing different harbors.

The results of the study show that the highest turtle bycatch rate per effort unit corresponds to the surface longline. This fishing gear has been traditionally considered as the most important source of turtle bycatch in the area (Camiñas & Valeiras, 2001; Báez *et al*., 2006; Camiñas *et al*., 2006; Álvarez de Quevedo *et al*., 2010) and other neighbor fishing zones (Lewison *et al*., 2004; Benhardouze *et al*., 2012; Coelho *et al*., 2015). Fishermen still consider the surface longline as the main threat to sea turtles. However, the current number of boats using this fishing gear is very low, and some of them do not even fish in the area, and the overall contribution is not so important and probably decreasing (Báez *et al*., 2019). The increase of depth of longlines implemented in some vessels is also significantly decreasing the capture of turtles (Tomás *et al*., 2008; Báez *et al*., 2019). Moreover, recent reports reveal low levels of post-release mortality in longline bycaught turtles (Álvarez de Quevedo *et al*., 2013). Thus, the overall capture of sea turtles by surface longline is not so high and mortality of bycaught turtles can be relatively low. By contrast, fishing gears with more than 10 times lower bycatch rate per unit effort than surface longline have a

very important contribution to the overall turtle bycatch. Especially important could be the case of the small-scale fishery, which could be responsible of around 45% of the total sea turtle bycatch in the south-western Mediterranean. However, it is very important to clarify that the methodology used in the present study does not permit to assign a bycatch rate to specific small-scale fisheries. Some small-scale fisheries of this area could have a very low or even null impact on turtle bycatch, while other small-scale fisheries could be responsible of most of the turtle bycatch, having bycatch rates higher than the average.

The contribution of the small-scale fishery to turtle bycatch is usually underestimated because of the difficulties in monitoring and regulation (STRINGELL *et al*., 2013). However, an important contribution of small-scale fishery to sea turtle bycatch has been found in other ocean basins (BELL *et al*., 2006; LUM, 2006; PECKHAM *et al*. 2007; MOORE *et al*., 2010; ALFARO-SHIGUETO *et al*., 2011; MANCINI *et al*., 2012; SNAPE *et al*., 2013; STRINGELL *et al*., 2013). For example, in Trinidad and Tobago over 3000 leatherback turtles were captured in gillnets (LUM, 2006), though gillnets in this country could be slightly different to those used in the Mediterranean. In the north Cyprus, eastern Mediterranean region, around 1000 turtles are annually bycaught by trammel nets (SNAPE *et al*., 2013). Similar trends have been found for loggerhead and green turtles in small-scale longlines and gillnets, respectively, in the Baja California (PECKHAM *et al*. 2007; MANCINI *et al*., 2012). Small-scale fisheries in Peru accidentally capture tens of thousands of loggerhead and green turtles annually (ALFARO-SHIGUETO *et al*., 2011). MOORE *et al*. (2010) estimated an annual sea turtle bycatch of few thousands of individuals per country in the seven countries they surveyed (i.e. Sierra Leone, Cameroon, Nigeria, Tanzania, Comoros, Malaysia, and Jamaica).

The loggerhead population of the northeast Atlantic has recently been considered as one of the 11 world most endangered sea turtle populations and the most endangered loggerhead population in the Atlantic basin (WALLACE *et al*., 2011; CASALE & MARCO, 2015). This population is present in the Alboran Sea (MONZÓN-ARGÜELLO *et al*., 2009, 2010) and constitutes between 4 and 10% of loggerheads present in the area (MONZÓN-ARGÜELLO *et al*., 2009, 2010). Considering that loggerheads are around 90% of sea turtles found in the study area (BELLIDO-LÓPEZ *et al*., 2018), we can estimate an annual catch of 125 to 250 loggerheads from this endangered population. This mortality level could be relevant for the conservation of this endangered population, and reducing it should be a priority.

The interviewed fishermen considered that driftnet is still causing an important number of captures and a significant part of the fishing-related turtle mortality. The use of driftnets is prohibited in Spain and many other countries in the European Union. However, all fishermen agreed on the presence of illegal drift netting in Spanish and international waters used by illegal vessels, or by vessels coming from African countries where this technique is still approved. For fishermen, driftnet is the second most important fishing gear causing sea turtle bycatch, and the fourth most

important one causing mortality. Observations in driftnet sighting in western Mediterranean waters confirm a high impact on loggerhead turtles and other protected vertebrates (SILVANI *et al*., 1999). Even if this estimation comes from fishermen opinion, the relevance of illegal drift netting near or within Spanish waters should be evaluated. If this threat is confirmed, surveillance and control should be enhanced in European waters to eradicate this illegal fishery that severely affect non-target, large marine vertebrates.

Some authors have suggested that the purse-seine fishery has a low impact on sea turtles (BOURJEA *et al*., 2014). In the present study, this gear appeared as having a significant impact, with an estimated contribution of the 11% of bycatches, a value close to the percentage of vessels that use this gear (10%). Moreover, the 5.5 % of fishermen answered that this is the gear causing highest mortality on turtles. A previous study considered that this fishing gear has a low impact in the area (BÁEZ *et al.,* 2006). However, considering the opinion of fishermen in our study, we found no reasons to consider the purse-seine as a friendly gear to sea turtles in the study area. Considering the fishermen's answers, the *almadrabas* should be included in the list of monitored fishing gears that can accidentally capture significant amounts of sea turtles in southern Spain. Some studies conducted in the Ceuta's *almadraba* have confirmed the relevance of this threat (GARCÍA DE LOS RÍOS, 2015)

Some recommendations can be provided from this study in order to reduce the sea turtle capture in fisheries of the southern Spanish coast, including the reduction of the use of squid as bait on the surface longline and the disposal of hooks deeper in the water column, where sea turtles are less common. Similar results have been found analyzing data from onboard observers for loggerhead turtles in the same area (BÁEZ *et al.*, 2010, 2019) and other areas (WATSON *et al.,* 2005; GILMAN *et al.,* 2006). The reduction of bycatch eliminating the squids in the bait has been also observed in other turtle species (COELHO *et al.,* 2015; GILMAN & HUANG, 2017). Our results support the recommendations of several public organisms (such as the General Fisheries Commission for the Mediterranean, the International Committee for the Conservation of the Atlantic Tuna, and the International Council for the Exploration of the Sea) of extending the formative activities and awareness campaigns to all fisheries, both large- and small-scale fishery ones, including trawling, purse seine and small-scale fisheries. These campaigns should be conducted before the beginning of the summer, when turtle bycatch is especially intense. It is also important to support fishermen to reduce the mortality on fishing gears, providing them with tools to friendly release the turtles and to transport injured turtles to the port to be further moved to recovery centers .

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