Project GloBAL
Global Bycatch Assessment of Long-Lived Species

Workshop Proceedings

TACKLING FISHERIES BYCATCH: Managing and reducing sea turtle bycatch in gillnets

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Introduction

Turtle bycatch in gillnet fishing gear has been proposed as a key threat to turtle populations worldwide (Hays *et al.* 2003, Koch et al 2007, Casale 2008, Moore *et al.* 2009, Witherington *et al.* 2009). Although just one of many gear types in which turtles can be caught as bycatch, gillnets are a ubiquitous fishing gear and likely to be found on every coastline, in every country (FAO, http://www.fao.org/fishery/topic/3456/en). The objective of this workshop was to focus attention on turtle bycatch in gillnets at the 28th annual meeting of International Sea Turtle Symposium (ISTS). ISTS was an excellent venue for this discussion because of the range of expertise and experience of its participants; many participants have worked closely for decades with fishers and fisher communities. The Loreto meeting venue held particular significance in that many participants were from Grupo Tortuguero, an organization of scientists, conservationists and fishers that partner to conserve turtle populations in Mexico. Because of this, Baja California was a particularly meaningful setting for the workshop.

Recent studies suggest that gillnets may have high bycatch rates, which in some areas can result in high mortality rates (Lewison and Crowder 2007). Another issue in addressing gillnet bycatch is the link with artisanal, small-scale fisheries which poses challenges in terms of data collection and management strategies. Gillnet gear is also highly variable within and among countries. Elements such as set depth, mesh size, soak time are very diverse and can change depending on the target species. Location of deployment also varies with target species, ranging from pelagic fishes (drift nets) to nearshore waters to capture coastal fishes.

Given the global challenges and the importance of effectively addressing gillnet bycatch, this workshop provided an opportunity to generate discussion about gillnets among sea turtle specialists, marine conservationists, and fishers. The objectives of this workshop were to focus attention on gillnet bycatch; share information on the importance and likely impacts of gillnet bycatch; discuss mitigation options and strategies to address gillnet bycatch; identify the obstacles to reducing turtle bycatch in gillnets and finally to document our discussion and the information shared. We invited several speakers from countries within the region to share their knowledge and insight. Our speakers and workshop participants were fishers, scientists and fisheries managers. We focused our attention on some three key questions

1) **What is the magnitude of the gillnet bycatch problem?** How much gear is deployed? How do we measure/quantify this? How many turtles are caught and killed? What type of data are required (direct/interview)? Are there bycatch patterns in space and time?
2) **How can scientists, activists and fishers partner and collaborate effectively to tackle gillnet bycatch?** What examples exist of successful approaches?
3) **What are the options and obstacles for mitigation/bycatch reductions?** What lessons or models do we have from existing work?

Invited speakers and participants brought expertise and experience from a wide range of countries. Even so, there were several emerging themes from the workshop. All speakers and participants felt that bycatch of sea turtles in gillnets was part of a larger issue of fisheries sustainability in gillnet fisheries in coastal areas. Across regions, it was commonly reported that fishing effort had increased over the past decade as catches of all species had declined. Given the variability of gillnet gear characteristics and setting practices within and among countries, there was general support for more specific terminology to be used to promote a clearer standardization of bycatch reporting practices. Having more common gear and bycatch currency and terminology was seen as an important step toward information sharing among very distinct geographic regions regarding bycatch reduction successes and obstacles. There was some cautious optimism that a combination of community-level approaches with fishers and gear adaptation and modification may help reduce turtle bycatch.

The workshop was a successful exchange of ideas and data. This proceedings include contributions by the invited speakers and other workshop participants. We have organized these contributions into three broad categories – gillnet impacts on sea turtles in Mexico, gillnet impacts on sea turtles outside of Mexico, and mitigation of sea turtle bycatch in gillnets. Our sincere thanks to all invited speakers, contributors, and workshop participants. We hope this workshop and this proceedings serve to stimulate more dialogue and discussion about sea turtle bycatch and gillnet fisheries.

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Gillnet Bycatch in the Southern Part of "Bahía De Ulloa," Baja California Sur

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I refer here specifically to a small fishing zone in front of the shores of Baja California Sur. This zone goes from Cape San Lazaro until the area in front of Boca Las Animas (Figure 1). In this fishing zone there is a problem of incidental catch of loggerhead sea turtle (*Caretta caretta*) in gillnets used on the fishery of several grouper species, such as Gulf grouper (*Mycteroperca jordani*) and Gulf Coney (*Cephalopholis acanthistius*), and snappers, among others.

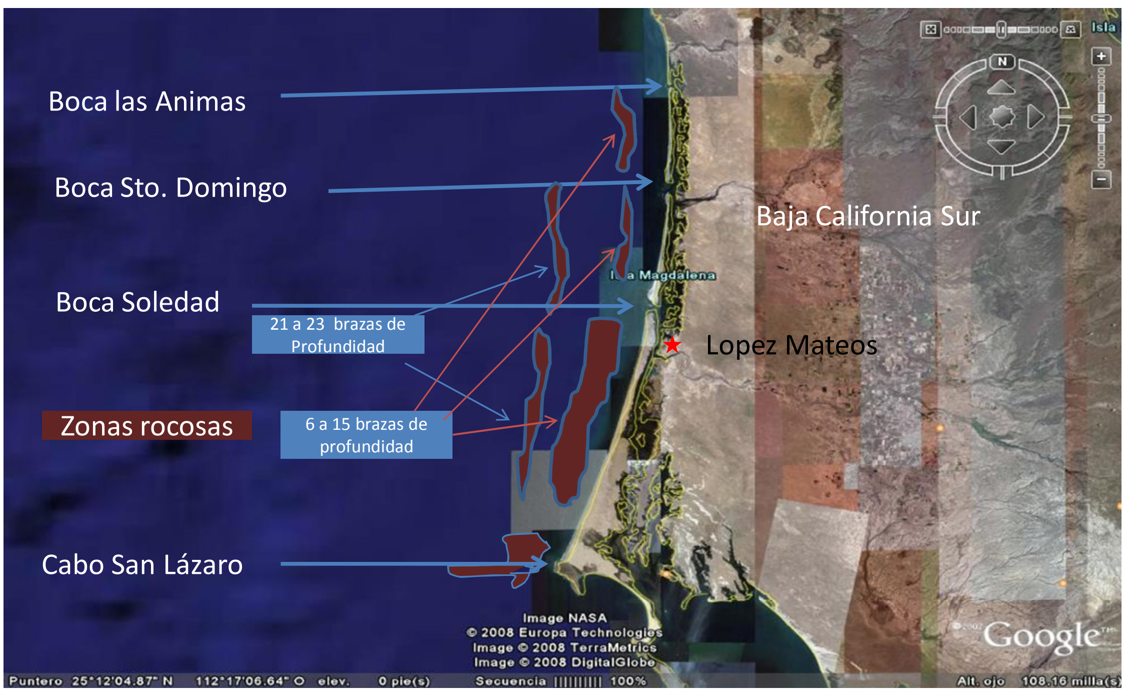

Figure 1. Main fishing zone where the gillnet fishery takes place, from Cabo San Lazaro to Boca las Animas.

In the months from May to September —fishing season in this area— the fishermen start getting their fishing gear ready for the "best" catch (captura de "primera") which refers to the fishery of those species with the highest value like the Gulf grouper, the Gulf Coney and other groupers. Fishermen can receive from $40 to $50 Mexican Pesos per kilogram of these species, an equivalent of USD $4 to $5. Usually, they catch groupers weighting between 5 and 50 Kg each one. These fish products are landed whole and clean (without the viscera or internal organs).

North to Cabo San Lazaro there is an underwater rocky chain that runs parallel to shore, to a distance of one to two miles and with a depth variation between 30 to 90 feet. A wide variety of marine resources are extracted from this area, being the most important species the Gulf grouper, the Gulf Coney, groupers, snappers and flounders. They are usually caught with gillnets, and occasionally with hook and line by hand, and with bottom longlines.

Going back 20 years ago, in these same fishing zones that are exploited today, the several fish species mentioned above used to be much more abundant. Also, for fishermen was very profitable to fish with only hook and line. Only some fishermen had a few number of gillnets that they will used only to catch specific species that could not be fished with hook; these nets were made of silk string and no longer than 200 m (660 feet). Most of the times, fishermen using these nets would have a very good catch with big size fishes, depending on the mesh size set on the nets.

In the fishing zones with depth of 21 to 23 fathom, it was common to observed many loggerheads and olive ridley turtles (*Lepidochelys olivacea*) on the surface. Despite the high number of turtles on this big area I do not remember to have caught any turtle on my nets.

Fishermen only needed to go as far as this fishing zone, no any further into the ocean. The fishery inside this area was sufficient to compensate their economic needs.

Unfortunately, nowadays the incidental catch of non-target species is increasing and there are less and less sea turtles in the sea. This is due to an increase in the use of more sophisticated fishing practices and gear to catch more fish, since the amount of fish caught has decreased.

Fishing effort/ number of gillnets

In the southern part of Bahia de Ulloa the fishery is artisanal ("ribereña") with fishing vessels less than 21 to 15 feet in length, and 65 to 200 horse power outboard engines of 2 and 4 strokes. It is important to remark that each of these vessels works at least with four nets, and some of them use up to 8 or 10 nets. Five to ten vessels start fishing, and if they catch some fish then the number of vessels involved in the fishery will increase up to 20, 30 times or even more, and each of them will have at least four gillnets.

These fishing nets have between 100 m and 150 m in length by 4 to 7 meters in height, with a mesh size between 8 and 12 inches. They used nets made of plastic nylon and other nets are made of silk. The nets of nylon monofilament have a mesh width between 0.95 mm and 1.10 mm, with a mesh size of 10 inches.

In the plastic nylon nets, fishermen hang 2-3 m lines ("tirantes" or "suspenders") every 2-3 m along the net. This is done with the purpose to make the net to be less stretch and to create a "bag" effect, thus the fish get tangle easier and with less chances to break the net. This technique is very effective allowing catching more fish, but at the same time is also more destructive since it is not a very selective and incidentally catches non-target species.

Fishermen do not use the tie-down lines ("tirantes") in the silk nets twine because this material is more resistant and will not break even if bigger fishes get entangled on it. These nets are much more expensive than the plastic nylon monofilament nets. The twine thickness in the silk nets goes from #18 to #24, and the mesh size is between 10" and 12".

For a fisher to make a profit needs to catch 100 kg of the best quality fish ("primera"). Considering that the price of this best catch is MXN $45 a kilogram a fisher could make then MXN $4,500, but from this total MXN $1,000 is spend in fuel. This could vary depending on the season; there are seasons better than others but the fisher always keep the faith that the next day could be better than the one before.

Usually, the nets are set in the morning and then are checked the next day. All the fishermen involved in this fishery every day leave their houses in the mornings, check their nets, collect the species caught in the net, and set the nets in the water again, to then return to their homes. In those occasions when the catch is not good (very low number of fish), they leave the nets for up to two days before they go to check them in order to save fuel.

Amount of bycatch in gillnets

We have worked with some fishermen to check their nets when they go to pull them out of the water or to collect the fish. In this way we have recorded and verified the number of turtles caught in the gillnets.

In the area with 6 to 15 fathoms of depth there is low incidental catch of loggerhead turtles because these turtles are not seen very close to shore. Only a few loggerheads as well as black sea turtles (*Chelonia mydas*) are incidentally caught.

A little further from shore, about five miles away, there is another underwater rocky chain where the fishermen do the same fishing activities and use the same fishing gears. The big difference is that occasionally in this fishing area there is a higher number of interactions with loggerhead turtles due to that this area is highly used by this species. The deeper the area (18 fathoms and more) the higher is the number of sea turtles incidentally caught in the nets. Also, the number of sea turtle by-caught increases when the number of vessels and consequently the number of gillnets used in this area increase. Sometimes one to five turtle get caught in the nets, and other times none; however, all fishermen face this sea turtle bycatch problem on their nets.

An important detail that was mentioned by the fishermen is that they get less sea turtle bycatch in the silk nets ("redes de seda"). Fishermen say that this is because they do not use the "suspenders" or tie-down lines ("tirantes") and therefore these nets remain stretch, without having a "bag" effect contrary to what happens in the plastic monofilament nets.

Options to Mitigate Bycatch

Some tests have been done to modify the fishing gears that fishermen are using, with the purpose of reducing interactions with and mortality of sea turtles. The nets were set lower than what they usually are set at; however turtles were still entangling in the nets. A more successful alternative was to set the nets in shallower areas where sea turtles were less abundant. The last experiment with the nets was to set some nets without buoys, in this way the net was closer to the bottom and not that close to the surface to avoid sea turtle bycatch. Although this last experiment proofed to reduce in some way the bycatch, there were still turtles getting entangled in the nets.

Working with fishermen and fishing communities towards sea turtles conservation

The fishing season of 2007 was not a good one; the catch levels were very low for those nets set in the rocky chain at 20-23 fathoms. During this season high numbers of the Giant Humboldt squid (*Dasidicus gigas*) filled up the fishermen nets, reason why they decided not to set the gillnets in this area.

Most of the fishermen decided then to put away their nets and used the hook and line from the shore. The catch with this fishing gear at depth of 10-12 fathoms was very good. Other fishermen used bottom longlines in this same area and also obtained positive results. Another changed was the used of the circle hooks instead of "J" hooks in the bottom longlines. Circular hooks tangled less in the rocky area where they fish for the Gulf grouper, a member of the Serranidae family that inhabits rocky bottoms. There are about 30 to 40 hooks in each bottom longline, and some fishermen have from two to five bottom longlines per vessel. This fishing gear is checked during the day, and the frequency at which it is checked depends on the number of bottom longlines they have set in the water. The amount of bait that they will catch to set the bottom longlines also depends on the number of this fishing gear that will set on the water. This could be a good alternative to use in the future to eliminate the gillnet sea turtle bycatch. Perhaps, we could promote the use of bottom longlines instead of gillnets in the fishing zone of the southern part of Bahia de Ulloa.

Another option could be to increase the value of those seafood products caught with fishing gears that do not damage sea turtles, for example the fish caught by hook and line could have a higher price than one caught by gillnets. This will provide the right incentive for the fishermen who will realize that is worth it to do a "clean" fishery. But for this a better market needs to be developed.

Loggerhead Bycatch and Reduction off the Pacific Coast of Baja California Sur, Mexico

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The western coast of Baja California Sur (BCS) hosts one of Mexico's richest fishing grounds. Commercially sought fishery resources such as halibut (*Paralichthys californicus*), grouper (Mycteroperca sp.) and rooster hind (*Epinephelus acanthistius*) are primarily targeted by local small-scale fisheries using bottom set gillnets. Gillnets for these species have a mesh size ranging from eight to twelve inches in diameter (from here on referred to as "large mesh") and are typically deployed demersally in near-shore (1-30 meters) habitat.

Coastal BCS is also a high use area for juvenile and subadult Pacific loggerhead sea turtles (Peckham *et al.* 2007), that presumably forage in the region until reaching maturity, at which point they migrate back to Japan to reproduce (Ramirez-Cruz *et al.* 1991; Nichols 2003). Censuses of Japanese rookeries show declines in nesting females as high as 90% within the past three generations to fewer than 1000 yr -1, qualifying the population for critically endangered status (Kamezaki *et al.* 2003).

The use of large mesh bottom set gillnets occurs in summer months (April – September), in near-shore coastal waters, and these fisheries have been shown to cause high levels of loggerhead mortality in the region (Gardner and Nichols 2001; Koch *et al.* 2006; and Peckham *et al.* 2007). The unfortunate overlap between foraging loggerheads and fishers results in what may be the highest known rates of turtle bycatch and strandings worldwide (Peckham *et al.* 2008). Small-scale fishing is the principal source of food and income for coastal inhabitants of the region, with large mesh bottom set gillnets playing an important economic role within the fishery, presenting unique challenges to conservation of loggerhead turtles.

Each summer since 2005 from June - September, we have conducted bycatch reduction experiments in partnership with local large mesh bottom set gillnet fishermen. Modifications to the traditional gillnet setup were proposed by local fisher leaders in workshops conducted in 2004 and 2005 with the ultimate goal of testing the potential of modified nets to maintain or increase the profitability of commercially viable target species, while reducing or eliminating loggerhead bycatch. Gear modifications have included the reduction in height of nets, reduction in length of net suspenders, as well as the complete removal of buoys. In addition to gear modifications, spatial differences in target species and bycatch have been tested. Observed trips were made opportunistically in three depth ranges that spanned the fleet's fishing grounds; Shallow Water (5 to 18 m), Mid Water (18 to 32 m) and Deep Water (32 to 45 m).

During three seasons of experimental gillnet trials we found that modifications of net and suspender height had minimal effect on reducing bycatch. However, preliminary tests in 2007 of buoyless gillnets showed considerable promise in reducing but not eliminating bycatch, use warranting further study. The most effective method of bycatch elimination is to avoid sets in waters deeper than 32m. In the summers of 2005-7, we observed 28 loggerheads caught during 94 gillnet day-trips or 0.3 ± 0.1 loggerheads $boat^{-1}$ day^{-1} (mean ± SD). Sixty-eight percent were landed dead. All were caught in bottom-set gillnets during the 35 trips, observed at the fleet's deepest fishing area (32-45m) where 0.8 ± 0.2 loggerheads were caught $boat^{-1}$ day^{-1} (Table 1). Across all depths, 0.37 loggerheads were caught per km of gillnet; in waters deeper than 32m, 1.04 loggerheads were caught per km of gillnet. Loggerheads retrieved from gillnets were large juveniles (73.3 ± 8.6 cm CCL).

Table 1. Observed mean loggerhead (Cc) bycatch rates with variance and percent mortality and depth fished at Puerto López Mateos, BCS.

fishery	trips	Cc caught	km net observed	Cc/ km net	Cc/ trip	SE	range Cc/trip	percent mortality
gillnet (all depths)	94	28	76.0	0.37	0.30	0.09	0-4	68
gillnet (shallow < 32m)	59	0	49.1	0.00	0.00		0	
gillnet (deep > 32m)	35	28	26.8	1.04	0.80	0.22	0-4	68

Loggerhead bycatch mortality for the region is likely to be considerably higher than the range we estimated because our assessment was limited a small percentage of the fleets which fish in the area. Fleets operated from additional communities that border the loggerhead high use area described in Peckham *et al.* (2007) and based on the location of their fishing and use of large-mesh bottom set gillnets, it is likely that these fleets also catch considerable numbers of loggerheads. Furthermore, migrant fishers from mainland Mexico based at temporary camps along the same coastline fished large-mesh bottom set gillnets in the loggerhead high use area, resulting in additional bycatch mortality (A. Gaos, pers. obs.). Due to the high variability of bycatch rates depending on gear and depths fished, without direct observation we could not determine the bycatch of these boats. But, given the bycatch rates mentioned above, we estimate that their fishing could not have caused fewer than 75 additional loggerhead mortalities yr^{-1}. The actual bycatch mortality of these additional fleets could have been considerably higher.

Given that estimated loggerhead mortality due to large mesh gillnet bycatch observed in the Puerto Lopez Mateos fleet alone numbers hundreds of loggerheads yr^{-1}, reduction of this mortality is essential for the persistence and recovery of the North Pacific loggerhead turtle population. The most effective way to achieve that reduction is by eliminating the use of deep water large mesh bottom set sets.

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Sea turtle bycatch by inshore fisheries in Baja California Sur

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The most important fisheries involved in sea turtle bycatch in Baja California Sur (BCS) are bottom-set and surface gillnets, and long lines that are deployed from fiberglass skiffs with outboard engines (Nichols, 2003; Koch *et al.*, 2006; Peckham *et al.*, 2006). Another type of fishing gear is the "Simplera", which is an anchored line with a large buoy and a single hook near the surface that is often used for sharks. More than 3,600 of these small fishing boats are registered in the state, plus a significant number of non-registered boats (SAGARPA, 2003). These so called "pangas" are about 7 m long, fast and can work up to 30 miles offshore. They are usually operated by two to three fishermen and can deploy large amounts of fishing gear quickly and efficiently.

The fisheries can be separated in two categories, inshore fisheries in coastal lagoons and bays, and offshore fisheries in open waters out to about 20-30 miles from the coast. Industrial long line fisheries and shrimp trawling probably also kill a significant number of turtles; however, their impact has not been studied at all in the area, so no quantitative data are available. In contrast to other regions, research in BCS has focused on evaluating the impact of small-scale fisheries on sea turtles. Here, we will focus on inshore fisheries, as Gaos *et al.* (this volume) talk more in detail about bycatch in open water fisheries.

Inshore fisheries usually use gillnets, and target a wide variety of finfish. Depending on the location and season, croakers, mullets, puffer fish and sea bass, are the dominant species where surface gillnets are used. Bottom set gillnets target especially stingrays and halibut, but also snappers and groupers. The stingray fishery is probably the most important, and also the most problematic fishery due to high bycatch rates, and the fishing gear employed (Koch *et al.*, 2006; Mancini & Koch, 2008).

The inshore fisheries mostly operate in depths of 3-20 meters, in mangrove channels, coastal lagoons and bays, and leave the nets soaking for 24 hours. Nets are often set perpendicular to the tidal flow in deeper channels, or sometimes parallel to the mangrove fringe at high tide or over sea grass beds. Surface gillnets are also set along rocky coasts, mostly to catch snappers and groupers (Lucero-Romero, pers. comm.). The most important fishing seasons are in summer for stingrays and halibut, however, inshore gillnet fisheries operate all year long, targeting a large variety of finfish and being rather unspecific.

The type of net depends on the target species stretched mesh sizes from 3 - 10 inches are common, larger mesh sizes are mostly used for stingrays (which are unfortunately also very effective to catch sea turtles; Rangel, pers. comm.). Smaller mesh sizes are used for mullet, croakers and other species that are found in shallow areas. Bottom set gillnets usually have less buoys and much more weight on the lead line to rest on the sea floor. Often they also include "tirantes", strings of fishing line that connect the buoy and lead lines of the net. These "tirantes" are shorter than the net is high, with the effect that the netting is not extended and taught between buoy and lead line, but is rather loose and deploys in folds, which increases its efficiency. This type of net causes the highest bycatch and death rates in sea turtles because it is highly effective in entangling them. Also, because of the weight on the lead line, turtles can't get to the surface to breathe and consequently drown (Koch, pers. obs.; Peckham *et al.*, 2006, Peckham *et al.*, submitted).

Inshore fisheries almost exclusively catch black turtles, and the occasional Hawksbill (Koch *et al.*, 2006). Loggerhead and Olive Ridley turtles usually occur further offshore, and are thus very seldom affected by this type of fishery. In the state of BCS, we have found a total of 578 black turtles at 18 index beaches and 22 communities in 2006 and 2007 (see figure 1). The minimum yearly mortality is 329 black turtles per year. This mortality includes ALL sources, main mortality cause is fisheries, both directed and incidental (total number of all species combined is 527 per year). This includes turtles found in towns and their dump-yards, as many by-caught turtles are not returned to the water, but are taken home and eaten by the fishermen (Koch *et al.*, 2006; Mancini & Koch symposium 2008; Mancini & Koch, submitted). Almost all specimens were juveniles, the percentage of adult sized turtles is only 8.2% (see figure 2). Average curved carapace length was 61.11 ± 12.74 SD cm, clearly demonstrating that the region is primarily a developmental ground for juveniles and subadult black turtles (Nichols, 2003; Koch *et al.*, 2006; 2007).

The two locations with the highest occurrence of cadavers are Bahía Magdalena and Laguna San Ignacio. In Bahía Magdalena turtle consumption is still very common, and most of the carcasses were found on dump-yards and had been eaten (Koch *et al.*, 2006). In Laguna San Ignacio, black turtles suffer very high rates of bycatch mortality, we found an average of 12.3 black turtles/km of beach/year here in 2007 (Mancini & Koch, 2008). This mortality is primarily caused by an illegal fishery on guitarfish with bottom-set gillnets in June and July, the season lasts only a few weeks, but kills on average 7 turtles per day per fishing boat, with a total of about 15-20 fishing boats, each boat fishing only for six or seven days (Mancini, unpublished data, Mayoral, pers. comm.). During the fishing season, between 630-980 turtles may be thus killed.

Another way to arrive at an approximate number of dead turtles is to use the actual strandings. The beach that is monitored represents with 9 km about 20% of the beach area that is exposed to the fishing area and receives dead carcasses, yielding an estimate of approximately 615 turtles stranded per season (12.3 turtles km-1 x 50 km). These estimates are extremely high and alarming, especially when considering the small size of the guitarfish fleet in San Ignacio lagoon and the duration of the fishing season. However, this means also, that with relatively little effort and vigilance, a significant source of turtle mortality can be remediated.

The situation in Bahía Magdalena is very different, as well as in other parts of the state. Here, fisheries tend to catch turtles throughout the year, in a variety of locations and different fisheries, resulting in a much more complicated management situation.

Finally, it is important to mention that artisanal fisheries in Baja California Sur have shown very high bycatch mortalities that rival those of much larger, industrial fisheries in other parts of the world (Robins *et al.*, 1995; Laurent *et al.*, 2001; Robins *et al.*, 2002; Lewison *et al.*, 2004; Lewison *et al.*, 2007). This indicates that much more attention needs to be put on the evaluation of the impact of artisanal fisheries on sea turtles, as many tropical countries have large fleets of small fishing boats operating in nearshore waters, without much information on their regular catch, and even less data on bycatch (Koch *et al.*, 2006, Peckham *et al.*, 2006)..

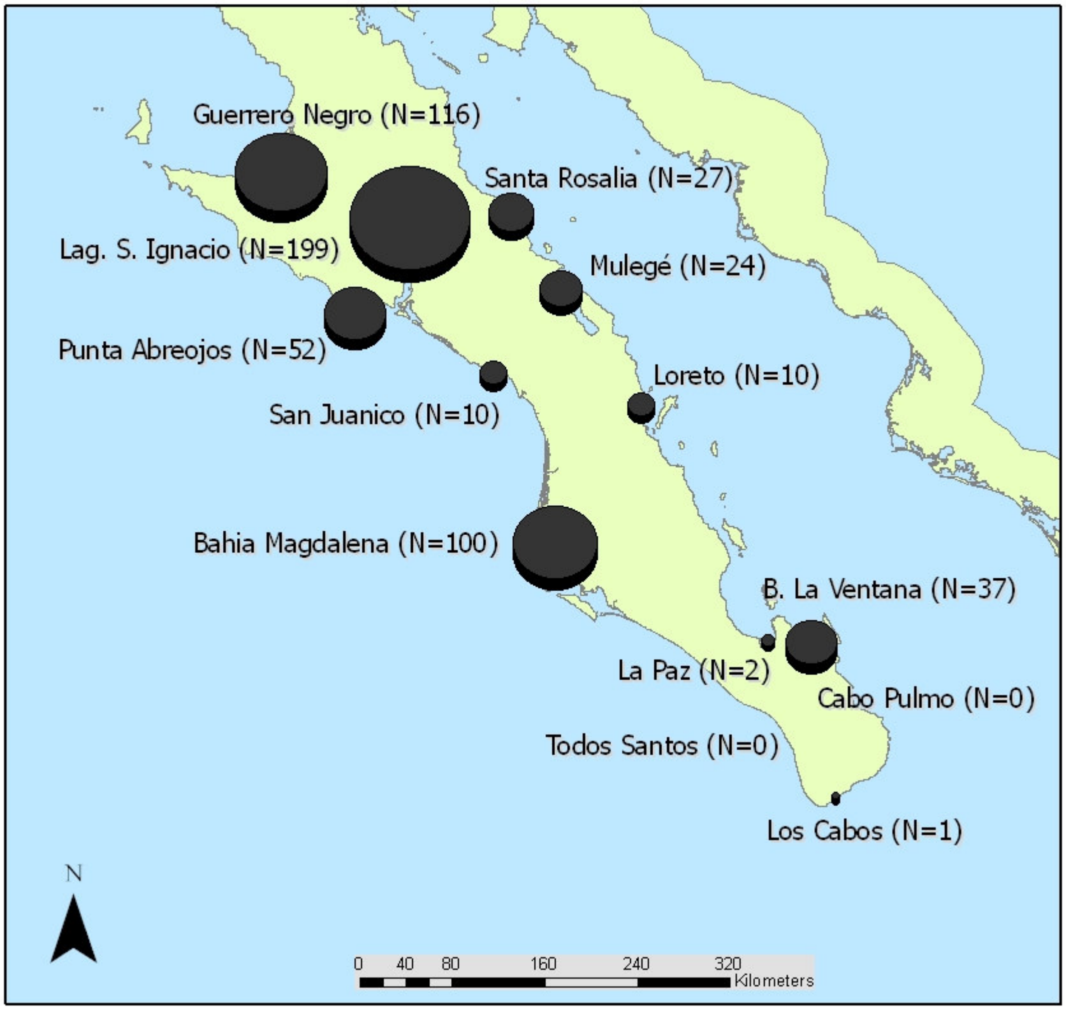

Figure 1. Black turtle mortality reported in Baja California Sur from 2006-7. Main mortality sources were poaching and incidental bycatch.

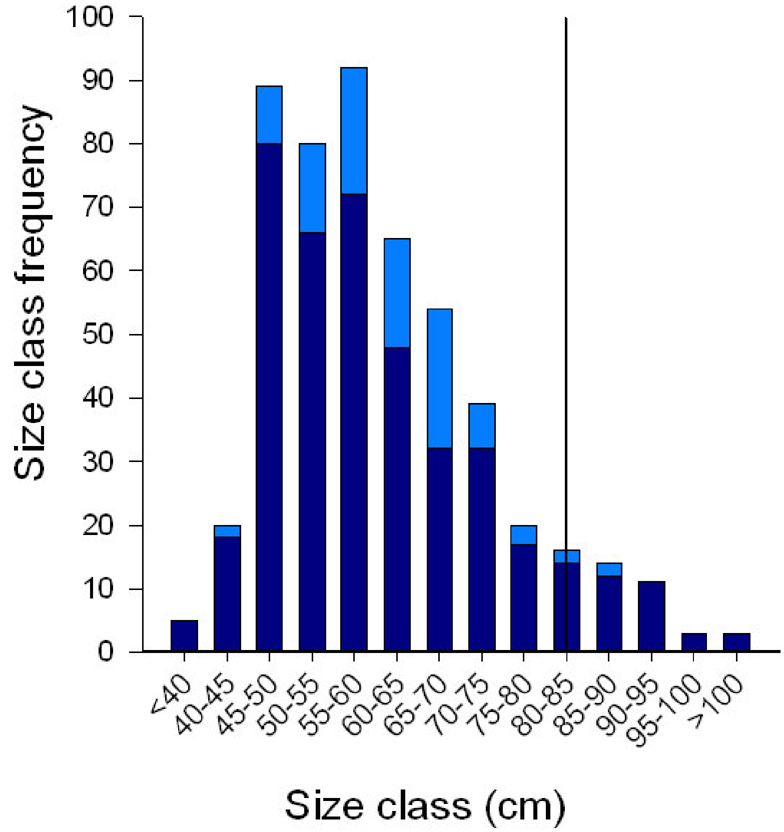

Figure 2. Size class distribution of dead black turtles found in Baja California Sur from 2006-7. Dark blue color indicates turtles found on Pacific beaches, light blue are turtles from the Gulf of California, The black line shows the approximate size at maturity for black turtles.

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Artisanal Fisheries and Sea Turtle Bycatch in Campeche and Yucatan, Mexico

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Campeche, Yucatan and Quintana Roo states form the Yucatan Peninsula, which is located on the southeastern region of Mexico. The coast of Campeche and Yucatán, along with the northern coast of Quintana Roo, host the largest nesting populations of hawksbill turtle (*Eretmochelys imbricata*) in the Wider Caribbean region, and the seventh largest in the world (Garduño *et al*., 1999; Meylan and Donnelly, 1999, Mortimer and Donnelly, 2007). Other sea turtle species such us the green turtle (*Chelonia mydas*), the loggerhead turtle (*Caretta caretta*), leatherback turtle (*Dermochelys coriacea*) and Kemp's Ridley turtle (*Lepidochelys kempii*) are also present in this area.

Besides sea turtles, the Yucatan peninsula has numerous natural resources that are intensively exploited by humans. Fishing, an important boost for this region's economy, is among the most common human activities that use these resources (Mexicano-Címtora *et al.*, 2007).

The fishing vessels could be grouped in two categories depending on their size and the fishing gear they use. Those larger vessels (more than 30 feet long) that go fishing in an autonomous way for periods of time up to three weeks represent the "greater fleet". This fleet includes shrimp trawlers, longliners and vessels that use big nets. Additionally, these vessels could be used to access further areas off shore to catch octopus. On the other hand, those vessels up to 27 feet in length and mainly with outboard engines (lesser vessels) form part of the artisanal fishing fleet, also known as "ribereña". The fishing period of these vessels is limited to one day or even to just half a day, and in areas no further than 15-20 km from shore. They use small scale fishing gear such as hook and line, pole and line, small longlines and small nets. The products of more than 4,000 artisanal fishing fleet vessels are sold to processing plants, which sell and export all this seafood volume at local markets. For this reason, we refer to all these elements as the artisanal fishing industry.

Until 1999, the number of vessels of Campeche's "greater fleet" was 319, and 578 were registered in Yucatan. In addition, there are 311 vessels registered in the Campeche's shrimp fleet, and four in Yucatan (INEGI and SEMARNAP, 2000). On this region each vessel of the shrimp fleet has an average of eight fishing trips a year, with each trip lasting 17 effective fishing days on average. The gear is put in the water four times a day for a period of 4.61 hours each one. The catch per unit of fishing effort (CPUE) reported for the species incidentally caught when using the Turtle Excluder Devices (TEDs) is 12.65 kg/h, and without the TEDs is 16.53

kg/h. It has been reported 1,500 sea turtles excluded by the TEDs (INEGI and SEMARNAP, 2000).

Nowadays, the artisanal fishery is the one with a greatest impact on the marine resources in the Yucatan peninsula region because of the size of its fleet. The total number of vessels registered for Campeche is 5,362, and 4,981 for Yucatan. Despite of the importance of the artisanal fishery, there is not spatial information about the areas where these vessels put their greatest fishing effort (INEGI y SEMARNAP, 2000).

Considering the large information gaps about the "ribereña" fishing activity and its impact on the sea turtle populations several studies were conducted during 2006 and 2007. The purpose of these studies was to know the sea turtle bycatch frequency and to identify the most harmful fishing gear for the sea turtles on the Campeche and Yucatan states.

Interview to fishermen in nine ports of Campeche (Isla Arena, Campeche, Seybaplaya, Champotón, Punta Xen, Sabancuy, Isla Aguada, Isla del Carmen and Península de Atasta) and in four ports of Yucatan (Telchac Puerto, Celestún, Sisal and Progreso) was the methodology used during a first phase of research and planning. The total of interviewed fishermen was 300 in Campeche and 179 in Yucatan.

It is important to mention, as part of the social and economic context of the region, that in Campeche 82% of the fishermen has a monthly income lower than $2,000 Mexican Pesos (USD $1 = MXN $13). This differs from the economic level of the fishermen in Yucatan where 85% of them has an income that ranges from $2,000 to $5,000 MXN a month.

In the entire region is recognized that hawksbill turtle (*E. imbricata*) is the most abundant and widely distributed sea turtle species, follow by the green turtle (*Chelonia mydas*). In a consistent manner with its abundance and availability, the hawksbill turtle is the most common by-caught sea turtle species. However, the second most by-caught sea turtle species differs between both states. In Campeche is the green sea turtle while in Yucatan is the loggerhead (*Caretta caretta*). The most plausible explanation is that Yucatan is located next to Quintana Roo, the greatest nesting and distribution area of loggerheads. On the other hand, in Campeche the loggerhead turtles are only found occasionally; some of them dead stranded on the beach or alive when they stop on this area to feed during their migratory route.

The fishing gears, used in the artisanal fishery, with the highest reported numbers of sea turtle bycatch are different between both states. In the case of Campeche, gillnets with a mesh size greater than four inches are the fishing gear with the highest frequency of bycatch of juvenile and adult sea turtles. These gillnets target medium to big commercial species such as snook, sharks and rays.

From these gillnets, the one used to fish rays is the most efficient[1] catching sea turtles, with an estimated catch of 9.3 sea turtles per fishing season. It is followed, in an importance order, by the shrimp nets and the shark gillnet. Nonetheless, the fishing gear responsible for more than a 20 % of the sea turtle bycatch data is the gillnet used to fish snook (*Centropomus undecimalis*). Because this fishery is one of the three most commercially important at the government level, it is also one of the best distributed and most intensely used along the shores. This is followed, in a descendent order, by the gillnet used to catch spotted and sand weakfish (*Cynoscion nebulosus* and *C. arenarius*) with a 15.7 %, and then by the gillnet used to catch rays with a 12.7 %, (Guzmán and García, 2006)

For Yucatan, the fishing gear with the highest percentage of incidental catch of sea turtles is the weakfish gillnet (C. *nebulosu* and *C. arenarius*), with a 35 %. This is followed by the gillnet used for king mackerel (*Scomberomorus cavalla*) with 32 %, then by the one used on the mullet fishery (*Mugil cephalus*) (30%), the ray gillnet (28%) and last by longlines with a 27% (Labarthe and Cuevas, 2006).

About the particular characteristics of the nets, these usually have an average length of 1000 m, with a mesh size between four and five inches and their average soaking time is between seven and nine hours.

The longlines have an average length between 100 m and 700 m. They are manually deployed from 25 feet long fiber glass vessels in rocky areas at depth from 12 m to 40 m. The longline target mainly species from the Serranidae (groupers) and Lutjanidae (snappers) families. More than 90% of the fishermen that use this technique answered that they catch at least one turtle during their working season, and about 15% of the interviewees answered they catch more than 10 turtles during an entire working season in a year (Cuevas, 2006).

The studies about the sea turtle bycatch in both Campeche and Yucatan states from this first exploratory phase were followed by a second phase of the research. The methodology used on this second phase was the positioning of observers in the artisanal fishing vessels during the fishermen's working day. The purpose was to register the type of fishing gear used, the geographic coordinates of the sets, their soaking time and the number of sea turtles by-caught on each set.

It is essential to generate information about the spatial distribution of the fishing effort for each one of the fishing gears identified on these projects. This type of information will allow assessing the interaction of the fishing gears with the places of highest sea turtle density on this region. This is one of the next steps to be developed in the current line of research about bycatch in the region.

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[1] We refer with this term of efficiency that within few hours in the water a fishing gear will catch more sea turtles than any other fishing gear left in the water for the same period of time. For this reason a fishing gear is more efficient. But, from a conservationist point of view the most efficient fishing gear will be the one causing the most negative impact because of the large number of sea turtles that it will catch.

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An Overview of Sea Turtle Bycatch in Small-Scale Gillnet Fisheries in Nigeria

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Abstract

Fishery related mortality of sea turtles and marine mammals is a global concern. Gillnets constituting about 35.8% (n=3022) are the most abundant and the most widely used small scale fishing gear in brackish and coastal waters of Nigeria. Gillnets are rectangular with floats fixed at the top line for buoyancy and lead weights as sinkers attached to the bottom line for ballasting. They are designed, constructed, and operated on board motorized and non-motorized wooden canoes that target various fish species.

Fish are caught in the mesh either by snagging (at the head), gilling (at the gills), wedging (at the body/girth), or entangling/enmeshing with many parts of the body/projections. Sea turtles entangle mainly in the mesh of the gillnets. An investigation conducted in the coastal waters of Nigeria showed that gillnets caught a lot more turtles than any other small-scale fishing gear type and the 'shark' drift gillnet was the most hazardous. Catch per unit effort ranged between 5 and 25 sea turtles per canoe per annum. This report highlights the design characteristics of gillnets, their operational methods, and their encounters with sea turtles. Recommendations are proffered to mitigate the problem.

Background

Nigeria lies between latitudes 4°16′-13°52′ N and longitudes 2° 96′-14° 37′ E. It has a coastline of 853 km which borders the Atlantic Ocean in the Gulf of Guinea. It has a maritime surface area of 46,000 km^2 between zero and 200m water depth. The continental shelf is relatively narrow and the width ranges between 14.8 km in the west off Lagos, and 27.8 km in the east off Calabar. In 1978, Nigeria established a 200 nautical mile Exclusive Economic Zone (EEZ) which covers an area of 210,900 km^2 over which it has sovereign rights for the purpose of exploiting, conserving, and managing its fisheries resources.

Nigeria also contains a large variety of water bodies including lakes, estuaries, creeks, and lagoons totaling 12 million hectares. The major rivers include River Niger and River Benue with several tributaries. The riverine flow stretching from the fringes of the Niger Delta area and the Cross River estuary has given rise to extensive soft muddy sea beds with abundant penaied shrimp. The adjacent estuarine mangrove belt serves as the breeding and nursery grounds for many commercial fish species.

The fisheries within the territorial waters and the EEZ can be broadly classified into the following categories:

a) Brackish water or estuarine small-scale, artisanal canoe fishery in lagoons, creeks, and estuaries.

b) Coastal (artisanal) canoe fishery within 5 nautical miles of the non-trawling zone mainly with gillnets. Other artisanal groups target pelagic species as well as sharks and sail fishes in deep sea.
c) Industrial coastal (inshore and offshore) fishery is made up of 185 trawlers for targeting demersal fish and shrimp. Deep-water fisheries with high economic potential including the tuna and drift fish Arioma species have remained largely unexploited by local fleets.

Gillnet Types

Gillnets are rectangular nets that are either set or anchored at a location, or allowed to drift with the current. They are operated in both estuarine and coastal waters for the capture of various fish species depending on twine thickness and mesh size. The gillnet types in Nigeria include the following:

a) Set multi-filament (polyamide) gillnet made of netting material with ply 9-36/45 twine diameter/thickness and 40-125 mm mesh are used mainly for catching demersal fish including croakers, *Pseudotolithus spp*., shiny nose, *Galeoides decadactylus,* and cat fish, *Arius spp*. Each set is about 45-50 m long and 2.0-4.0 m deep. About 5 to 10 sets are usually joined together and taken to sea.
b) Set monofilament (PA) gillnet (0.2-0.4 mm twine diameter) with 40-50 mm mesh mainly for African shad, *Ilisha africana,* threadfins, *Polydactylus quadrifilis* and *Pentanemus quinquarius,* and small croakers, P*seudotolithus spp.* It is usually deployed using a paddled wooden canoe, between 6.00 and 10.00 hours in relatively shallow coastal waters 10-20 m depth.
c) Encircling multifilament gillnets (40-50 mm mesh, 500-800 m in length & 20- 25 m depth) are used mainly for catching sawa, *Sardinella maderensis.* After sighting and enclosing a school of pelagic fish, the fishermen beat the enclosed water with paddles to frighten and scare the fish, which become entangled in the mesh in their frantic dash to escape. The wet net taken with fish is hauled/bundled into the canoe and rushed to shore where each fish has to be hand picked and painstakingly disentangled manually.
d) Shark drift gill net is usually constructed with polyamide, multifilament netting materials with 210D ply 45-60 twine diameter and 150 -250 mm (6-8 inches) mesh. It is usually operated overnight (e.g. 8.00 pm–6.00 am) by 2 fishermen in a wooden canoe that is motorized by one 25-40 Hp outboard engine in 25–100 m depth of the coastal waters. The net is tied to the canoe and drifts with the current. It constitutes 8.5% of all the gillnet types and targets big sharks, *Sphyrna couardi* and *Sphyrna diplana*, barracuda, *Sphyraena spp*. as well as sword and sail fishes and blue marlin. It accounts for a relatively high percentage (45-65%) of sea turtle by-catch in small scale artisanal fishing gear.

Details of gillnets and their operational methods as well as other artisanal fishing gear types are described by Udolisa *et al.* (1994) and Solarin and Kusemiju (2003). It was observed that there was direct relationship between mesh size and fish size (Solarin 1989). Color of netting, water turbidity, current direction as well as seasonal variations and lunar cycle have been reported to influence the catch.

Sea Turtle Bycatch

Five species of sea turtles that have been reported as bycatch in gillnets include the Atlantic loggerhead, *Caretta caretta*, Atlantic green sea turtle, *Chelonia mydas*, hawksbill, *Eretmochelys imbricata*, olive ridley, *Lepidochelys olivacea,* and leatherback turtles, *Demochelys coriacea*. Sea turtle bycatch in gillnets was most prevalent between August and December.

Fishing Effort

Catching efficiency is usually expressed as a ratio of catch to fishing effort. The indicators of fishing effort are chosen so that the differences in catching efficiency resulting from inherent biases among gear types are evened out. Catch per unit effort (CPUE) facilitates comparison of catches from different places and environments as well as catches caught by different or various gear types. Gillnet catch can be expressed as per standard length of net (e.g. 100 m) of a given mesh size or area (1000 m^2).

The gillnets ranged between 500–1500 m headline length per canoe. The netting utilization coefficient (EU), an indication of the actual working area of the netting material relative to the hung net, is determined or influenced by the horizontal as well as vertical hanging ratios and ranged between 0.7 and 0.8. However about 65% of them have a horizontal hanging ratio of 0.5 (i.e., EU of 0.8). Therefore, it is easier to express the catch per unit effort (CPUE) as catch $canoe^{-1}$ day^{-1} (man hours ranged between 4 to 12 hours) because of the relatively short headline length of the nets and low power input. The nets are set and hauled manually. For gillnet fishing with kilometers of nets and which are operated mechanically (with net rollers/haulers), it may be desirable to express the catch per unit effort relative to length of net.

Other researchers documented three methods of fishing efforts; the total number of fishing crafts, total number of fishermen, and fishing gear or methods. However, there is seasonal variation in catch for both the target species and sea turtle by catch. In some cases the target species are also influenced by lunar cycle. The latter has not been confirmed for sea turtle bycatch.

Options for Mitigation

From a holistic point of view, options for mitigation are many and include the following:

- Limitation or ban on the construction/fabrication and operation of the gillnet types that have been observed to be very efficient in sea turtle bycatch.
- Limitation on the size of the net (e.g. total headline length) is very important where nets are set mechanically.
- Introduction and adoption of multi-mesh gillnet series will invariably reduce the length of hazardous mesh sizes and their impairment of sea turtles.
- Complete ban on production or importation of harmful netting materials is also suggested.
- Cost price of netting appeared to be a limiting factor in this part of the world. The shark drift nets which catch a lot more sea turtles are operated by a relatively few gillnet fishermen (5%) because of cost. A bundle of PA netting with twine thickness of ply 36 and 250 mm mesh size costs 10 times as much as ply 9 X 50 mm.
- Use of biodegradable float materials should limit ghost fishing by gillnets that are lost during fishing operations.
- Checking of gillnets at relatively short intervals of time (e.g. 3-4 hours) will ensure capture and retrieval of good and wholesome fish specimens and at the same time reduce or

minimize incidences of serious damage or drowning of sea turtles that are inadvertently caught in the net.

- Fishers and fishing communities involvement in conservation of sea turtle and maintenance of biodiversity should be initiated and based essentially on advocacy, education, sensitization, and creating a lot of awareness.
- All activities should involve the fishers and be based on a ‘participatory approach’ in order to gain their confidence and support.
- Creation of a sea turtle eco-tourism program in locations where they nest should be explored to the benefit of the communities including job creation and empowerment of the youth and women.
- Release of sea turtles that are entangled or enmeshed in gillnets should be encouraged and adequately compensated including donation of recharge cards to facilitate communication between the fishers and Researchers and Scientists.

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Loggerhead Bycatch in Sardinian Waters (Italy)

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Abstract

We estimated the fishing impact during the latest 70 years on loggerhead sea turtle *Caretta caretta,* by two different and integrated approaches: interviews carried out in 2006-2007 concerning the impact before 1980 and the present day situation. The actual scenario is compared with data collected by the cetaceans and sea turtles rescue center "Laguna di Nora". This surveys show that the fishing activity is one of the threat that affected loggerheads in the Sardinia island waters and that gillnets play an important negative impact.

Introduction

Fishing impact has been identified as a major threats affecting sea turtles survival in the whole world (Bolten & Witherington, 2003; Lewison *et al.*, 2004). In the Mediterranean Sea, fishing activities with longlines, trawls and gillnets are involved in the incidental catch of sea turtles (Gerosa and Casale, 1999). The Italian fleet is partly responsible of this kind of event (Laurent *et al.*, 1998; Deflorio *et al.*, 2005; Piovano *et al.*, 2006; Casale *et al.*, 2007; Commission of the European Communities), but a complete picture is not yet available. This study deals with fishing impact during the latest 70 years on loggerhead sea turtle *Caretta caretta,* the most frequent sea turtle in the Mediterranean island of Sardinia (Italy).

Materials and Methods

We estimated the fishing impact by two different and integrated approaches: interviews carried out in 2006-2007 concerning the impact before 1980 and the present day situation. The actual scenario is compared with data collected by the cetaceans and sea turtles rescue centre "Laguna di Nora."

1) A historical survey based on face-to-face interview of 44 aged people in order to investigate the impact of fisheries on loggerheads from the '20s to the '80s, before the implementation of legal conservation measures in Italy. Furthermore we wanted to establish if sea turtles were considered food or commercial items and consequently they were deliberately caught by fishermen.
2) A present-day survey concerning the period following the implementation of legal conservation measures. Since 21 of the participants were fishermen still active they were also asked about the actual situation with questions concerning the gears they use, the impact of the different gears on sea turtle and their behavior when finding a sea turtle.
3) Collecting and analyzing data of the 209 loggerheads recovered by the rescue centre we evaluated the current fishing impact. Data were collected within three network programs: Centro Studi Cetacei (1994-2005), Tartanet and Marinet (2006-2007). The fleet operating near by the Rescue Centre is characterized by a multiple-license system, so more than 400 fishing gears resulted authorized for roughly 180 vessels.

4) A complete description of the gears and their own characteristics is available in Ferretti (2002) for the Italian fleet and in Gerosa & Casale (1999) for the Mediterranean fleet.

Results

Interviews focused on the pre-conservation legal measurements period (Table 1) clearly show that loggerheads were captured by fishermen at sea both intentionally (26.9%) and incidentally (73.1%). All the people we interviewed remembered that until the '80s fishermen deliberately caught sea turtles floating on the water by hand. According to fishermen captures were more frequent during summer time because sea turtles were more abundant and their fishing efforts were greater. Moreover, better weather conditions enabled fishermen to spot the turtles more easily. Sea turtles were also incidentally caught by fishing gears and people remembered that bycatch occurred all the year long. In case of bycatch the fishermen perceive that the major impact was caused by longlines and trawls and no impact was caused by gillnets.

The 80% of the interviewed fishermen confirmed they have accidentally caught sea turtles in their gears after the implementation of conservation measures and the percentage of involvement of the different gear in the incidental capture of a sea turtle did not change. Fishermen perception of the local impact of fishing gears on loggerheads sea turtle seems to be directly related to the gears they use more frequently. So nets as trawls and gillnets are perceived as having a major impact.

During the last 10 years, 17% of the 180 local vessels cooperate with the Rescue Center and brought the injured turtles. Overall, more than half (54.5%) of the turtles recovered at the rescue center (N=209) clearly show injuries caused by an identifiable fishing gear. Most of them (69.0%) were injured by a longline gear. Among them, 23.0% had one or more hooks embedded in the flesh or an ingested line (31.1%), or both (45.9%). Evidence of a previous interaction with a longline gear have also been find in some turtle caught by a gillnet (N=31). In fact, x-ray or autopsy analysis allow us to find one or more hooks and/or one or more lines ingested.

Table 1. Fisheries impact on loggerheads as estimated by interviews concerning the period precedent the adoption of legal measures (1980) and present day situation compared to causes of recover at the rescue center when fishing gears can be determined (114 cases out of 209 loggerheads).

	No. of interviews	Intentional capture % of total interviews	Incidental capture in fishing gears % of total interviews	Impact of the different fishing gears as % of total identifiable gears			Undisclosed nets
				Longlines	Trawls	Gillnets	
Pre prohibition	44	26.9	73.1	17.9	28.6	53.5	20.9
Post prohibition	21	0	100.0	16.7	27.8	55.6	16.7
% of loggerheads recovered at the rescue center with evident interaction with a detectable fishing gear (N=114 specimen)				69.0	0.7	30.3	

Discussion

In Sardinian waters intentional captures of loggerheads disappeared as a consequence of the status of protected species given to sea turtles and the implementation of legal conservation measures. In 1980, the Decree of the Ministry for Merchant Marine and Fisheries prohibited not only intentional capture and commerce of sea turtles but also to carry them on the vessel, thus causing a clear change in fishermen customs.

Fishermen perception of the local impact of fishing gears on loggerheads sea turtle are directly correlated to the gears they utilize more often. So nets, in particular trammels[2], and trawls are perceived as having a major impact.

A different scenario emerges from data collected on injures which caused the admission at the Sea Turtles Rescue Centre: the higher percentage of turtles are admitted because of the fishing longlines effects even if those gears are not the most frequently utilized by the local fleet. This data can be overestimated because hooks normally require the assistance of the Sea Turtles Rescue Centre meanwhile turtles captured by trawls are normally alive and consequently they are released in the sea directly by the fishermen. The same is likely to happen if turtles are dead. Also when fishermen are working with trammels or other type of nets they are likely to find specimens either alive or dead but more rarely specimens which needs veterinarian cares. Another reason for underestimation of injuries caused by other gears than longlines can be the less obvious tracks left by the other gears on recovered or stranded animals. Putting together results from interviews and a 45.5% of loggerheads without a clear sign reportable to an interaction with an identifiable fishing gears, it seems that injuries caused by fishing nets are comparable to longlines.

This survey shows that the fishing activity is one of the threat that affected loggerheads in the Sardinia island waters. Further research are required to identify why there are differences between the fishermen perception of the impact of every single type of gear and the causes of hospitalization at the Rescue Centre. In the meanwhile we are carrying out the identification of the type of longlines mostly involved in the interaction with loggerheads by on board observers and experiments to test modification of the fishing gears in order to reduce their impact on the loggerhead inhabiting Mediterranean water thanks to the support received by the European life project TARTANET.

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Bycatch of Sea Turtles in Spain

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The following fishing gears have been reported to catch incidentally sea turtles in the waters off Spain.

Surface Drifting Longlining (Mediterranean Sea)

Target species

Mainly swordfish (*Xiphias gladius*) and albacore (*Thunnus alalunga*) but also other species of tuna such as bluefin tuna (*Thunnus thynus*) (Camiñas, 2005), big eye tuna (*Thunnus obesus*) and yellow fin tuna (*Thunnus albacares*) as well as some species of sharks (Báez *et al.*, 2007).

When and where the line is set

Fishing for swordfish takes place all year round although the highest effort occurs between May and August (Camiñas & Serna, 1995; Rey *et al.*, 1987 in Camiñas, 2005). Setting takes place during daytime starting in the afternoon whereas hauling occurs right after sunrise for the swordfish fishery. In the tuna fishery setting occurs at night and hauling starts in the morning (Alnitak- SEC, 2007). The duration of the setting depends on the length of the gear and the number of hooks whereas the duration of the hauling depends on the previous factors besides the catch numbers as well as other incidental issues such as a cut or entanglement in the line, etc.

The main surface longlining areas are the East Alboran Sea, the Southwest Mediterranean (Algerian Basin and waters off the Balearic Islands) and the Northwest Mediterranean (Baéz *et al.*, 2007).

The main surface longlining ports are located in the Southeast of Spain being Carboneras in Almeria the most important of them with 50% of the fleet (Baéz *et al.*, 2007).

Details of the fishing gear

Characteristics of the longlining boats vary among boats in terms of length, capacity, number of fishers and fishing gear. The later varies according to the target species (swordfish, albacore or bluefin tuna). In general the fishing gear consists of a main line of nylon (Báez *et al.*, 2007) with lengths from 19 to 60 km (Camiñas, 2005) with a varying number of hooks pending attached to a nylon branch line. Approximately in the middle of the branch line there is a weight to help sinking the hooks as well as a device that allows rotation in the line. A float line of rope connects a float to the main line every group of hooks. Floats are also grouped and every certain number of floats a bigger float with a radar reflector is set. Hooks typically used are Mustad 1 or 2 for the swordfish fishery and 4 or 5 for the albacore fishery (Camiñas, 2005; Alnitak- SEC, 2007). Bait is usually bought frozen and it consists of mackerel (Scomber spp) and squid (Illex spp) for the swordfish fishery and sardine (*Sardinella aurita*) for the albacore fishery. The use of artificial lights is common in the swordfish fishery. Fishing depths range from twenty to fifty meters approximately (Alnitak- SEC, 2007). In the bluefin tuna fishery fishing depths are around 100 meters (Camiñas, 2005).

Two different types of longline gears are used by the Spanish fleet, the traditional longline and the "Florida style" being the latter the most common one nowadays. The number of hooks between segments is smaller being the distance between hooks higher compared to the traditional style (Mejuto *et al.*, 2006). The duration of the hauling is shorter in the "Florida style" and it is considered to have played an important role in the last years in the reduction of sea turtle bycatch (Alnitak- SEC, 2007).

Bycatch

Bycatch rates of loggerhead turtles vary seasonally being higher during the summer months (June to August) (Carreras *et al.*, 2004) coinciding with an increase in the fishing effort as well as an increase in abundance of loggerhead turtles in the fishing grounds (Camiñas, 2005).

Loggerhead turtle (*Caretta caretta*) is one of the most common non target species caught. According to recent experiments and regarding the fishing technique catch rates in the southwestern Mediterranean are higher with the traditional style than with the Florida style. In terms of target species catch rates are higher in the albacore fishery than in the swordfish fishery whereas regarding type of bait used bycatch rates are higher with squid than with mackerel (Alnitak- SEC, 2007).

A study carried out by the Oceanographic Centre of Malaga in years 1999 and 2000 reported catch rates ranging from 0 loggerhead turtles in year 1999 in the bluefin tuna fishery to 1.74 per thousand hooks in 2000. Regarding the swordfish fishery catch rates ranged from 0.29 in 1999 to 1.15 in 2000. In the albacore fishery the rate was 1.05 loggerhead turtles in 1999 and 3.27 turtles per thousand hooks in year 2000. Most turtles were alive (Camiñas *et al.*, 2001).

Regarding bluefin tuna fishery catch rates range from 0 loggerhead turtles every thousand hooks in year 1999 to 1.74 in 2000 (Camiñas *et al.*, 2001). Mortality rate is higher than in surface longlining due to drowning. Relative mortality rate for the bluefin tuna fishery was estimated to be 0.058 loggerhead turtles per thousand hooks in year 2000 (Camiñas & Valeiras, 2001).

Catches of leatherback turtle (*Demochelys coriacea*) are very rare in the Mediterranean Sea (Camiñas, 2005). In years 1999 and 2000 catches of two turtles were reported, one each year. Leatherback turtles were entangled in drifting longlines targeting swordfish (Camiñas *et al.*, 2001).

Bycatch in off- shore fisheries in the Atlantic, Indian and Pacific Oceans has been also reported involving loggerhead turtles (*Caretta caretta*), leatherback (*Demochelys coriacea*), kemp's Ridley (*Lepidochelys kempi*) and Olive Ridley (*Lepidochelis olivacea*) (Mejuto *et al.*, 2006).

Other relevant information

The Spanish drifting longline fleet based in the Mediterranean ports consists of 105 vessels (Báez *et al.*, 2007). Fisheries observers from several Spanish research organisms have been occasionally on board surface longliners reporting the fishing activity as well as bycatch issues. Several experiments have been conducted in order to minimize these bycatch rates focusing especially on loggerhead turtles. These experiments have tested the use of circle hooks versus J hooks, the use of mackerel bait and fishing depth. Results so far have shown significant reduction of bycatch by using mackerel bait instead of squid. Circle hooks have not reduced significantly bycatch rates but they have been proved to be more efficient in minimizing the intensity of the lesions caused to the loggerhead turtles therefore reducing post bycatch mortality. Further investigations need to be conducted in order to determine other potential factors to reduce bycatch such as time of setting or soak time (Alnitak- SEC, 2007).

The low incomes generated with surface longlining (Alnitak- SEC, 2007) and the present use of driftnets (banned in the European Union in 2002) by Italy and France as well as other non EU member countries is a constant source of controversy among the Spanish longline fishermen in the Mediterranean, especially in the port of Carboneras (Southeast of Spain).

Trammel Net (Balearic Islands)

Target species: lobster, red mullet, cuttlefish (Carreras *et al.*, 2004)

When and where fishing occurs: Lobster trammel nets are one of the most widely used fishing gear in late spring and summer around the Balearic Islands (Carreras *et al.*, 2004).

Details of the fishing gear: Fishing occurs in water depths that range from shallower than 50 meters to 100 meters (Carreras *et al.*, 2004).

Bycatch: Highest bycatch rates of loggerhead turtles occur in the fishery targeting lobster (Carreras *et al.*, 2004).

Other relevant information:

Immediate mortality associated to bycatch ranges from 78% to 100%. CPUE is much lower for lobster trammel nets than for drifting longlines but the total catch in lobster trammel nets is greater because of a larger fleet. There is an above-average vulnerability to bycatch in the grounds off Minorca that can be explained by greater densities of turtles suggesting that shallower setting of the net in that area favors the take of turtles (Carreras *et al.*, 2004).

Bottom Trawling

Target species: groundfish: red mullet (*Mullus* spp.), monkfish (*Lophius* spp.), sole, hake (*Merluccius* spp), shrimps, etc.

When and where trawling occurs:

Trawlers usually return to port every day. The duration of the trawls is usually around 3 to 5 hours and normally 3 to 4 trawls are carried out every day. In some areas some trawlers can get a permit go to further fishing grounds depending on the target species. In this case they can spend a few days fishing without returning back to port.

Trawling is forbidden within a distance of three nautical miles from the coast and in waters shallower than 50 meters by the Spanish law (although there are several exceptions in some regions) (BOE num. 56/2000) but illegal fishing in these waters still occurs.

Bycatch:

The effect of bottom trawling on loggerhead turtles in the Spanish fisheries is not very well known. Reported bycatch is very rare in spite of being the most important fishing gear in the Western Mediterranean in terms of number of boats and fish landed (Bas, 2002 in Camiñas, 2005). The Spanish Oceanographic Institute data base from 1990 to year 2000 contains only six turtles caught in bottom trawlers during all seasons. Two of them were caught in Atlantic waters (Gulf of Cadiz) and the rest in the Mediterranean Sea. All turtles were alive (Camiñas, 2005). More recent studies in the north east of Spain show that loggerhead turtle bycatch is rare where the continental shelf is narrow but common where it widens, as off Tarragona and Castellón provinces (Catalonia). In these latter areas, each bottom trawler catches one turtle per year, mainly in winter. Most turtles are caught alive, but comatose. Annual bycatch by trawlers from Catalonia is therefore estimated to be around 250 turtles (Alvarez de Quevedo *et al*., submitted).

Purse Seining

There is not much information about coastal fisheries because bycatch events are rare. In the Atlantic, Indian and Pacific oceans there is a fleet of offshore vessels targeting several species of tuna like skipjack tuna (*Katsuwonus pelamis*), big eye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*). Interaction with turtles has been reported, especially when using floating objects. Most turtles are caught alive and mortality occurs when turtles get entangled in the net that hangs from the object (Mejuto *et al*., 2006).

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Analysis of the Artisanal Longline Fishing Gear at Zapara Island: a Threat for Subadults Loggerhead Sea Turtles?

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Abstract

Longline fisheries can interact with several sea turtle species and negatively affect their populations on a global scale. Longlines have been reported along the entire coast of the Gulf of Venezuela. However, interactions with sea turtles have been more intense in the south region. The southern region of Zapara Island (10°58'58"N - 71°33'45"W) supports approximately 150 fishermen, of which about the 70% use longlines. This fishery is often used at depths between 15 and 25 m, with 5/0 “J” hooks approximately 6,000 to 16,000 m off shore. Five species of sea turtles have been reported for the Gulf of Venezuela: green, hawksbill, loggerhead, olive ridley and leatherback. The loggerhead is the most common turtle species in Zapara Island. Because of their carnivorous feeding habits in this zone, loggerhead turtles interact the most with this type of fishery, which uses a variety of fishes as bait. Between the years 2005 and 2008, the “Grupo de Trabajo en Tortugas Marinas del Golfo de Venezuela” (GTTM-GV) carried out interviews and surveys to fishermen and inhabitants of Zapara Island. We were able to identify the sea turtle species impacted by longlines in the study area. Bait type, hook depth, salinity, and substrate are the main factors affecting loggerhead bycatch in bottom-set longline fisheries in the southern region of the Gulf of Venezuela. The vast majority of loggerhead interactions with longline fisheries (95.23%), were of juveniles and subadults (n=21). This was the highest interaction value for any life stage of a sea turtle in the study area. Loggerhead mortality caused by longline fisheries was between 147 and 490 individuals per year (3 to 10 turtles per gear). This demonstrates the importance of the Gulf of Venezuela for loggerhead sea turtles’ populations, and the urgent need to implement viable mitigation methods that will allow fishermen and loggerhead sea turtles to coexist.

Key words: longline fishery, loggerhead turtle, Zapara Island, by-catch.

Introduction

Over the last decades, worldwide sea turtle populations have considerably decreased, mainly as a result of habitat destruction, and the intentional and incidental catch in fisheries (Lutcavage *et al.*, 1997). Interactions between sea turtles and artisanal fisheries are an issue of particular importance. Among the artisanal fishing gears in use, longlines are considered one of the most dangerous for sea turtles, causing the greatest number of incidental captures and highest mortality of loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*) (Godley *et al.*, 1998; Hall *et al.*, 2000; Pinedo *et al.*, 2003). One of the characteristics of the longline is its selectivity, which lies in the size and design of the hook, as well as in the bait that is employed (Watson *et al.*, 2003).

The artisanal fishery is the principal source of food and income for the inhabitants of Zapara Island, located at the south region of the Gulf of Venezuela. The longline is among the most common and important fishing gears for this community (Barrios-Garrido *et al.* 2002). Our objective is to conduct a systematic analysis of longline fishing in Zapara Island, its characteristics and direct impacts to local loggerhead sea turtle populations. "Does the longline fishing gear at Zapara Island represent a threat to subadult loggerhead sea turtles?"

Methods

The study area was focused in Zapara Island (10°58'58"N - 71°33'45"W), located in the southern of the Gulf of Venezuela (Figure 1). During 2005-2008, we conducted semi-structured interviews of 70 fishermen of the region. All information was corroborated by direct observation of the fishing process, including the assembling of the hooks and the preparation of the captured animals for their subsequent trade. The conversations were focused on the gear, their fishing practices, and their knowledge of sea turtles (sightings, abundance, and species characteristics, among others).

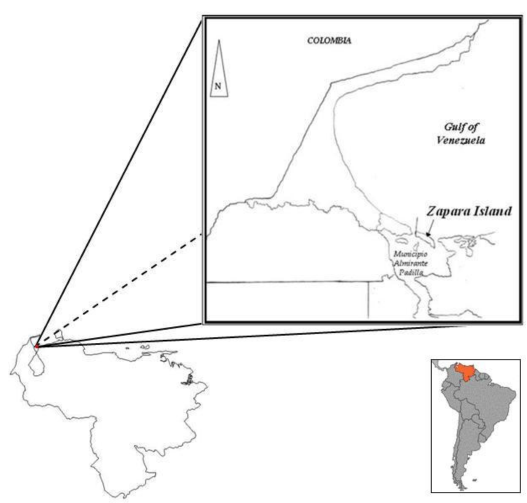

Figure 1. Geographic location of Zapara Island

Results and Discussion

Based on the fishermen's testimonials, the estimated annual catch rate of sea turtles in Zapara Island was between 147 and 490 individuals (Table 1). Sea turtle bycatch studies in

Cyprus carried out by Godley *et al.* (1998) indicated that 179 artisanal longline vessels caught a moderate amount of sea turtles (4.0 turtles/year/vessel). The number caught near Zapara Island is considerably higher. For only 49 vessels, the catch rate was nearly 7 turtles/year/vessel. Also, we estimated the total annual catch rate in Zapara island at 319 turtles/year (Table 1). This result is comparable to the values obtained by Peckham *et al.* (2007) (680 turtles/year in artisanal bottom-set longline fishery), corroborating the importance of the necessity of a sustainable management of the artisanal fisheries.

Table 1. Specifications of the longline fishing gear at Zapara Island.

COMPONENTS	DESCRIPTION
Fishing fleet number	49 vessels (3 fishermen per vessel) distributed throughout 10 ports
Fishermen participating	≈ 150
Vessel size	7.80 x 1.62 m (standard) 10 x 2 m (bigger size)
Fishing departure time	6 am (winter season: 5 am)
Fishing duration hours	Minimum: 4-6 h; Maximum: 12 h
Optimum fishing season	March to October (Winter)
Target species	Catfish (*Arius proops*) Bonefish (*Albula vulpes*) Northern red snapper (*Lutjanus campechanus*) King mackerel (*Scomberomorus cavalla*) Stingray (*Dasyatis sp.*) Spotted eagle ray (*Aetobatis narinari*) Blacktip shark (*Carcharhinus limbatus*) Scalloped hammerhead (*Sphyrna lewini*) Common snook (*Centropomus undecimalis*)
Common bait	Round Sardine (*Sardinella aurita*) Atlantic cutlassfish (*Trichiurus lepturus*) Horse crevally (*Caranx sp.*) Gilded catfish (*Brachyplatystoma rousseauxii*) Mullet (*Mugil curema*)
Interactions with other species	Brown pelican (*Pelicanus occidentalis*) Royal stern (*Sterna maxima*) Magnificent frigatebird (*Fregata magnificens*) Olivaceous Cormorant (*Phalacrocorax olivaceus*)
Distance from the coast	6000 – 16000 m
Depth	15 - 25 m
Main line longitude	1800 m (distributed between 3 sets of 600 mts)
Branch line longitude	0.75 mts
Distance between branch lines	1.5 mts
Hook's number on Main line	1600-1900 hooks
Hook's depth	15-25 mts
Hook type	"J" 4/0, 5/0, 6/0
Weights per set (600 mts)	Large: 2 units / 10-15 kg Medium: 2 units / 500 gr Small: 6 units / 200 gr
Sea turtles captured/year/vessel	3 to 10 All vessels: 147 to 490 turtles/year

COMPONENTS	DESCRIPTION
	(Average: ≈319 turtles/year)
***Sizes of Registered Sea Turtles* (N=21)**	20 Subadults: CCL= (52-77)cm 1 Adult: CCL= 80.5 cm

Loggerhead lengths (CCL) indicated that the predominant life stage in the area is represented by the subadults (95.23%). In addition, this region represents an important portion of the transatlantic loggerhead migratory pathways, as evidenced by the recovery of a metallic Tag (P8111) on a subadult (GTTM-GV, 2005) tagged in the Azores (Portugal).

The southern region of the Gulf of Venezuela contains optimal foraging habitats for loggerhead turtles. These include muddy substrates rich with the species that form the turtle's diet (Párraga *et al.*, 2008). Based on these characteristics and the analysis of the longline gear (Table 1), the factors that most favor sea turtle capture are hook type and depth.

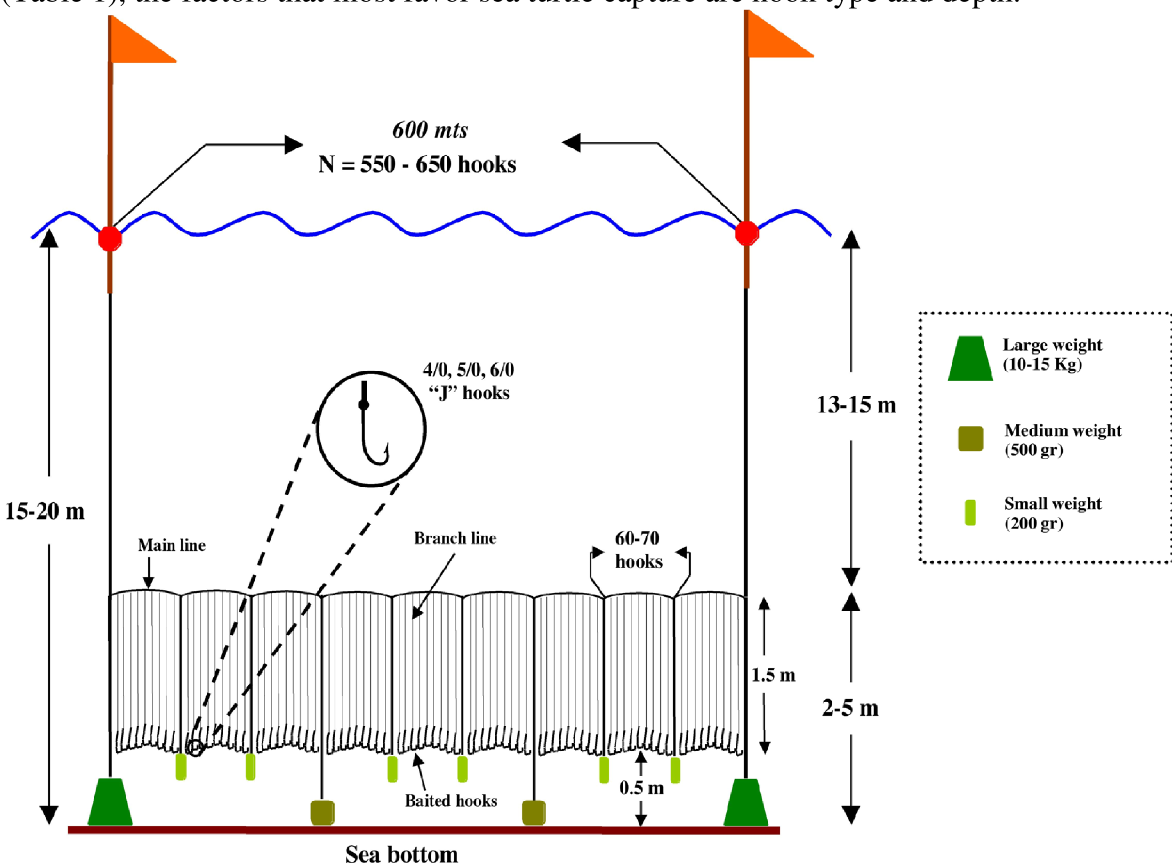

Figure 2. Example of the Longline fishing gear at Zapara Island (Not drawn to scale).

First, "J" hooks are more prone to harm sea turtles, and their small sizes (4/0, 5/0 and 6/0) can be easily swallowed by juvenile and subadult individuals, causing severe internal damage (Watson *et al,*. 2005). Furthermore, the longlines are positioned in zones with depths between 15-20 m. This is the same distance where the fishermen place the hooks (Figure 2), because of the benthic habitat preferences of their target species (catfish, stingray, hammerhead, among others) (Table 1). According to Lutcavage & Lutz (1991), the diving behavior of subadult loggerheads consists of routine dives made between 9-22 m deep, lasting 19-30 min.

Loggerheads spend about 80-94% of their diving time submerged. As a result, there is the possibility that loggerheads interact with longlines, due to the continuous presence of the hooks where the majority of the loggerheads' activities take place. This provides evidence of the negative impacts of longlines on the loggerhead population in the Gulf of Venezuela.

Conclusions

The environmental conditions (substrate and water depth specifically) in the southern region of the Gulf of Venezuela are suitable for loggerhead turtles. The longline specifications that are being used in Zapara Island, mainly the type of hooks and the depth at which they are placed, favor the interactions of the turtles with the longlines, which negatively affect the local loggerhead population.

The annual bycatch rate of loggerhead sea turtles near Zapara Island varies between 147 and 490 individuals. According to the lengths of the captured individuals, more subadults than any other age class are being caught in this area. It is presumed, by the recovery of a metallic Tag (P8111) from a subadult turtle tagged in the Azores, that the Gulf of Venezuela constitutes an important point of the loggerhead's transatlantic migration route. It also could be an important feeding area for subadults. The loggerhead's diet and foraging habitats overlap with longline bait and hook placement which leads to loggerhead by-catch in the longline fishery near Zapara Island. Consequently, it is important to implement a viable conservation plan that will benefit the sea turtles and the local fishermen.

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Prospects and Challenges for Assessing Bycatch from Fishers Interviews: Examples from Caribbean fisheries

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Introduction

Effective wildlife management must be undertaken at spatial scales comparable to the range of the focal species. For migratory marine vertebrates such as sea turtles, managing and mitigating threats such as fisheries bycatch therefore require large-scale assessments. Such analyses are in line with an ecosystem based approach and would, under ideal circumstances, compare bycatch by gear and ecosystem or biogeographic provinces of an ocean basin. Such an assessment would aid managers and policy makers in avoiding errors such as implementing gear or time or area restrictions that result in fishing effort being displaced or transferred to more problematic locations or gears (Hall, Alverson *et al.* 2000)

While there is considerable variability in the quantity and type of bycatch information available around the world, the data for investigating spatial and temporal patterns of bycatch are generally limited to industrial fisheries with observer programs. In contrast, data exist for very few of the thousands of small-scale fisheries especially those in the Tropics. The complexity, numbers of fishers and difficulties in placing observers on small vessels in these types of fisheries renders the cost of gathering information through direct scientific observation prohibitively expensive and time consuming (Berkes, Mahon *et al.* 2001). Consequently, surveys based on interviews with fishers are important sources of information on artisanal fisheries. Here, I describe some of the challenges of using interview-based data to make inferences about sea turtle bycatch and offer general recommendations that I hope will be incorporated into the design and conduct of future surveys of fishers.

In the wider Caribbean region, (excluding the northern Gulf of Mexico and southeastern continental shelf fisheries) approximately fifty percent of the information on sea turtle bycatch rates had been generated from interviews with fishers (TABLE 1). Bycatch information from these studies provides a useful overview of the regional bycatch landscape and indicates important data gaps. These studies have also provided data on the relative frequency of species interaction in major gear types. While loggerheads and leatherbacks are the most common sea turtle species occurring as bycatch in longline fisheries, bycatch in gillnets appears to be more habitat related. Gillnets set for conch or lobsters are set in reef habitat and will catch hawksbills, whereas gillnets set in front of a large leatherback nesting colony will have predominately leatherback bycatch. Fishers' surveys have also revealed a surprising number of cases of small hawksbills captured in fish traps and leatherback entanglement in trap float lines.

In spite of these insights, using interview data for bycatch assessment is challenging. Many studies are conducted during very narrow temporal windows and do not generate estimates for a bycatch rate or seasonal or annual take[3]. This is probably related to the difficulty in obtaining gear or species specific rates. Fishers often deploy multiple gears sequentially or concurrently. Survey questions should avoid obtaining incidental capture rates summed or averaged across all fishing gear. Of interest is the finding of researchers in Trinidad that fishers' recall of catch and effort is most accurate for their primary gear (R. Kishore, pers. comm.).

Another challenging aspect to interview-based bycatch assessment is gathering information on the location of bycatch events. Solutions to bycatch require an understanding of the spatial distribution and overlap of bycatch and fisheries but such data are not easily gathered from interviews, a sharp contrast to observer and fishery-independent data sources. Data on retrospective events such as generated by interviews are likely to provide only broad approximations (tens of square kilometers or greater) of the vicinity where the animal was caught or entangled, in contrast with the fine-scale data obtained when fisheries are directly observed on fishing grounds. However researchers in Mexico's Yucatan Peninsula surveyed fisheries cooperative members to identify the distribution of fishing effort. With the aid of maps displaying bathymetry and important coastal features, fishers were able to identify their fishing grounds and high bycatch areas (Cuevas 2006; Guzman 2006). Including such maps and charts in surveys adds a layer of complexity to interviews and increases the time to conduct interviews The value of such tools may be related to the extent made of navigational equipment and maps by fishers and may be inappropriate in areas where such technological aids are uncommon.

The use of fishers' expertise has ethical implications. Information on bycatch and fishing grounds represents considerable intellectual and proprietary knowledge of the fisher. The data may also implicate the fisher in catching or harming a protected species. Researchers should therefore address these issues in developing and conducting surveys as the accuracy of the information can be negatively impacted if participants perceive probable risks in sharing information on positive bycatch events. There are a number of ways to address this, including ensuring privacy, confidentiality of the responses, explaining the necessity of the information being sought and on insisting that all answers are acceptable (Fowler 2002).

Towards a Best Practices for Interviewing Fishers

Talking to people is a natural and common human activity. Ecologists and biophysical scientists trained in collecting environmental data might not regard interviewing respondents as requiring specific training or insight; or they may be tempted to skip inter-disciplinary collaborations in their efforts to quickly gather information on an endangered taxon. Logic may not suffice to achieve a good and appropriate interview survey protocol. Social, cultural and political factors will influence participation and response to a survey. Understanding and factoring these in the survey process may necessitate securing social science expertise and/or knowledgeable parties. Social science collaboration is especially important when investigating socially sensitive issues including accessing proprietary knowledge such as fishing grounds and illegal activity (e.g.

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[3] For example: Godley *et al.* (2004), Moncada *et al.*Moncada, F. G., L. Font, *et al.* (2003). Bycatch of marine turtles in Cuban shelf-waters. 22nd Annual Symposium on Sea Turtle Biology and Conservation. J. Seminoff. Miami, FL. USA, NOAA Technical Memorandum NMFS-SEFSC-503. 308 pp.**:** 8-9.

Cuevas(2006), Guzman (20006), Lagueux and Campbell Lagueux, C. J. and C. L. Campbell (2005). "Marine turtle nesting and conservation needs on the south-east coast of Nicaragua." Oryx **39**(4): 398-405.

do not estimate bycatch rates.

catching an endangered species). Insufficient attention to these issues may contribute to the frustration expressed by some researchers to us that "fishers' lie" when questioned about bycatch.

All elements of designing surveys to provide factual information can not be covered in the brief overview we provide here. There is an immense body of literature and expertise in surveys and qualitative research methods (Rea and Parker 2005). Those experienced in survey design and implementation can also assist in incorporating methodologies to evaluate and minimize bias in survey responses. We identify the following as areas that are not explicitly addressed in the interview-based assessments

- Questions should be designed so they are easy to administer consistently and with little or no variation in meaning (Fowler 2002) and focus group discussions with key fishers can be very useful in finalizing the survey questions.
- Survey data are plagued by memory effects. There is evidence that past events such as how much bycatch occurred and when, are likely to be recalled as more recent phenomena (Sudman and Bradburn 1973). An event that occurred a week or month prior is more likely to be recalled as a long term average or typical behavior (Fowler 2002)**.** In a similar vein, extreme events will probably have a more accurate recall and questions should probably be structured more broadly, (for example ascertaining high, medium and low values).
- Prior surveys may make a difference. It is useful to identify whether your potential subjects have been interviewed recently and to contact those investigators. Biemer (2004) describes the use of latent class analysis to estimate errors when respondents have answered the same question repeatedly.
- Training and an excellent understanding of the survey goals and objectives are essential. Training should address issues that your team might have (e.g. personal safety), review guidelines for conduct and interaction with potential subjects (including handling non-cooperative subjects) and pre-testing your survey instrument. Typical pre-testing approaches involve administering the questionnaire exactly as it would be attempted during the survey proper (Presser, Couper *et al.* 2004).

Conclusion

Fishers' knowledge of bycatch events can provide important information on the rates, frequency and location of sea turtle bycatch. Rates from interview and observer data for industrial (trawl fisheries) in the Caribbean are of similar magnitude, given the variable nature of bycatch events. Spatial and temporal patterns are harder to ascertain, and the resolution of these data may limit their usefulness. The results of fisher's surveys are not easily integrated with data from traditional scientific sources; Analytical tools (e.g. regression methods) suitable for ecological studies are not easily applied to studies using fishers' knowledge, thereby limiting comparison across knowledge sources.

Most studies of sea turtle bycatch come from the southern sections of the Caribbean basin, leaving large sections of the region with no assessment or recent information. Consideration should be given to whether or not a standardized program of bycatch monitoring from interview data can facilitate an ocean-basin, multi-gear assessment. If so, a regional dialogue on bycatch monitoring on coastal fisheries would be an important step towards developing a standard and cost effective bycatch monitoring protocol from surveys. If it becomes difficult or too costly to sustain continuing direct observation of the fishery, an initial calibration and periodic review would facilitate quantifying the uncertainty around the rate estimates from both knowledge bases.

Recent efforts in Mexico, Martinique, Trinidad and French Guiana to observe small scale fisheries- either through experimental fishing trials or through the placement of observers at portside or on vessels offer opportunities for "calibrating" survey data. While reported values for fisheries data are often lower than observed (for example Lunn and Dearden (2006) found a 42-64% lower estimate of catch from interviews compared with observed estimates of catch), if the direction and magnitude of this difference is consistent, then survey-based estimates can be valuable indices. Examining difference or congruence in results from the two knowledge sources (local ecological knowledge and western science) can help efforts to bring communities, government agencies and researchers together to manage coastal ecosystems.

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Table 1: Sea turtle bycatch studies in the wider Caribbean since 1990. This list does not include the northern Gulf of Mexico and the SE US fisheries.

Gear	Territory	Target species	Bycatch species	RATES	Time frame	Data source	Notes	Reference
Gillnets	Dominican Republic	*Panulirus* spp.	Ei	0.03 turtles/ hr in a 640 m long gillnet	2006	experimental fishing, direct observation, trials and interviews		Aucoin (*in prep*)
Gillnets	Guadeloupe	*Panulirus* spp., conch (*Strombus gigas*),reef finfish (Scarids)	Ei, Cm	1-10 turtles/net/year	2003	interview date for annual estimate		(Delcroix 2003; Delcroix and Chevalier 2006)
Gillnets	Suriname	*Cynoscion* spp., Ariidae	Dc, Cm,Lo	0.031-0.042 turtles/boat day	2006	interview		(Madarie, 2006)
Gillnets	Venezuela	*Scomberomorus cavalla*, *Cynoscion* spp., Ariidae, Mylobatidae	Cm, Dc, Ei	>0.0166 turtles/ boat day	1997-1998	interview data	Calculated from estimates of effort and bycatch numbers. Symposium abstract	H. Guada pers. comm..
Gillnets	French Guiana	*Cynoscion* spp., Ariidae	Dc, Cm, Lo	0.091-0.101 turtles/boat day	2004-2005	interview	Calculated from estimates of effort (20 boat days per month per boat for 6 months) and sea turtle bycatch estimates	(Delamare, 2005)
Gillnets	Trinidad and Tobago	*S. cavalla*, *S. brasiliensis*,	Dc, (Ei, Cm rare)	0.23-0.42 turtles/boat day	2001-2002	interview		(Lee Lum 2006)

Gear	Territory	Target species	Bycatch species	RATES	Time frame	Data source	Notes	Reference
Gillnets	Trinidad and Tobago	*S. cavalla*, *S. brasiliensis*,	Dc, (Ei, Cm rare)	0.004-0.005 turtles/boat day	2005	interview and strandings	Interview and strandings. calculation based on 38 reported captures in 2 months (6944-8680 boat days)	(Gass 2006)
Gillnets	Mexico (Campeche)	*Centropomus, Mugil, Lutjanus* spp.,	Ei , Cm Cc, Lk	0.00016 turtles/boat day		experimental		Vicente Guzman, pers. com
Gillnets	Trinidad and Tobago	*S. cavalla*, S. brasiliensis,	Dc	0.04 turtles/net m hr.	1992	Interviews	Calculated from statistic: 10 Dc in 61 m of net- and average soak time of 4 hrs.	(Eckert and Lien 1999)
Gillnets	French Guiana	*Cynoscion* spp., Ariidae	Dc	0.04 -0.44 turtles/net.km.hr (average= 0.14)		Direct observation		(Chevalier 2001)
Pelagic longlines	Anguilla	Scombrids, *Makaira,* elasmobranches fisheries	Dc	0.037 turtles/'000	1997	experimental fishing trials		(Godley, Broderick *et al.* 2004)
Pelagic longlines	Venezuela	*Thunnus thynnus*, *T. albacares*, *T. alalunga*, *T. obesus*, *X. gladius*	Dc, Cc, Cm, Ei	0.011 turtles/'000 hooks	1993-2006	Observer data		Bjorkland et al (this review)
Pelagic longlines	US	*Thunnus thynnus*, *T. albacares*, *T. alalunga*, *T. obesus*, *X. gladius*, elasmobranches (sharks)	Dc, Cc, Cm, Ei	0.02- 0.15 turtles/'000 hooks	1992-2006	Observer data	Witzell (in Fairfield-Walsh and Garrison)	(Fairfield Walsh and Garrison 2007)

Gear	**Territory**	**Target species**	**Bycatch species**	**RATES**	**Time frame**	**Data source**	**Notes**	**Reference**
Trawls	Belize	Penaeid fisheries	Ei	1 turtle/trawl hr	?	experimental fishing trials		R. Carcamo (pers. com.)
Trawls	French Guiana	Penaeid fisheries	Lo	0.022 turtles/ trawl hour	1992-1993	experimental fishing trials		(Gueguen 2000)
Trawls	Guyana	Penaeid fisheries	Not species specific	0.003- 0.005 turtles/trawl hr	1992	interview data	Calculated from reports (Tambiah, 1994; Reichert *et al.*, 1999; Shepherd and Ehrhardt, 2000; FAO, 2005)	(Tambiah 1994; Reichart, Laurent *et al.* 2003);
Trawls	Venezuela	Penaeid fisheries	Ei,Cm, Cc, Dc	0.0011- 0.00137 turtles trawl hr	1991-1993, 2000	Observer data	Symposium abstract	(Marcano and Alio 2000; Alio, Marcano *et al. In Review*))
Trawls	French Guiana	Penaeid fisheries	Lo and?	?	?	?	Reference needed	Moguedet (1994) cited in Reichert *et al.* (1999)

Eliminating the Incidental Killing of Endangered Leatherback Sea Turtles by Trinidad Coast Gillnet Fisheries

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The island of Trinidad in the southeastern Caribbean Sea supports one of the largest nesting aggregations of Critically Endangered (cf. IUCN Red List) leatherback sea turtles in the world, with 6,000 to 10,000 females nesting on the island each year (S. Eckert, unpubl. data). While this nesting population was once threatened by extensive killing of gravid females on the nesting beaches for sport and meat, this source of mortality has largely been eliminated and a large ecotourism program established in its place. Today, two of the beaches with the largest nesting aggregations support more than 20,000 tourists each year who come to view nesting leatherbacks.

While on-beach mortality of nesting leatherbacks no longer poses a significant survival threat, the accidental killing of adult females in inter-nesting habitats by coastal gillnet fisheries is a growing problem that may reverse many years of effective conservation management at this site.

Recent estimates are that more than 3,000 leatherbacks are entangled each year in the coastal gillnet fisheries of Trinidad (Eckert and Lien, 1999; Lee Lum, 2006). One study suggests that mortality may exceed 30% (Lee Lum, 2006). Such bycatch also significantly threatens the capacity of coastal fishers to sustain their fishery, as entangled leatherbacks damage or destroy nets. Fishers have been known to catch as many as 10 leatherbacks in a single set, effectively destroying the net (Nature Seekers, unpubl. data). Because the leatherback nesting population is growing in Trinidad (Turtle_Expert_Working_Group, 2007), the conflict between gillnet fisheries and nesting turtles shows no sign of abatement.

In an effort to reduce leatherback mortality and increase fisher productivity, a National Consultation (16-18 February 2005) was hosted by the Wider Caribbean Sea Turtle Conservation Network (WIDECAST) and the Ministry of Agriculture, Land and Marine Resources of the Government of the Republic of Trinidad and Tobago (Eckert and Eckert, 2005). Invited participants included stakeholders from the fishing communities in Trinidad and Tobago; non-government conservation organizations; international fishing and conservation experts; and representatives from the government of Trinidad and Tobago's natural resource management agencies, Ministry of Foreign Affairs, and Department of Education.

The objective of the National Consultation was to develop a plan to reduce the interaction of leatherback turtles with the fishery without reducing the ability of fishers to earn a living wage. The output of the Consultation was a plan that describes a series of investigations to be undertaken in bycatch reduction, with the eventual objective that one or more of the reduction methods would be adopted by the fishery. Suggested bycatch reduction methods included the evaluation of new bait types (artificial, dead and non-traditional) to enhance hook and line fishing as a replacement for nets, the use of new technologies or gear modifications (such as power take-up reels) or alternate net materials, Fish Aggregating Devices (FAD), modifications in net fishing methods (such as adjusting the depth of the net to avoid surface swimming turtles), means to repel turtles from nets (such as the use of sonic pingers which are effective on small cetaceans), and the adding of shark silhouettes to the nets (Eckert and Eckert, 2005).

Testing of possible bycatch reduction methods began in 2006. One of the most important aspects of the mitigation testing was the complete integration of stakeholders in the conception and testing process. Fishers were hired to conduct up to 30 fishing trials comparing experimental fishing methods against control methods. Local sea turtle conservation workers were hired to serve as on-board data collectors to record turtle catch data, or to tag and release any sea turtles captured. In-port data collectors were hired either from the local fisher community, or the turtle conservation groups to record catch or other fishing related data.

In this way, two major stakeholder groups that might otherwise have been at odds with each other worked cooperatively together toward developing mitigation measures. Furthermore, using personnel from each of these stakeholders groups allowed each group to maximize (and share) its own particular expertise. Fishers have greater experience and knowledge in optimizing catch, while the turtle conservation groups have greater experience and knowledge at data collection and management (due to many years of experience collecting information on nesting turtles).

Another important aspect of the program was that each stakeholder involved was paid a standard wage for their participation. Fisheries bycatch reduction programs often assume that stakeholder personnel will participate on a volunteer basis in order to achieve a common good. However, such an approach does not recognize that artisanal stakeholder participants are often the least able to give up income, despite the potential for long-term benefit. In the case of the fishers involved in this program, they were not only salaried for their participation, but all the requisite gear was provided and they were allowed to keep or sell the catch after it had been tallied.

Information collected in all experiments included costs of operation (e.g. fuel consumption), time spent fishing, gear purchases, and gear repair costs. Catch was identified to species, number of each species caught and total weight of each species. Fishing location (start of fishing and end of fishing) was noted using Global Positioning System (GPS) receivers. Communication with stakeholders was maintained through weekly visits by an on-site coordinator, as well as regular telephone calls.

The fishing fleet working along the north and east coasts of Trinidad consists primarily of small (6 – 8 m) pirogues powered by single outboard engines. According to 1998 data, there are 17 landing sites along the North and East coasts supporting 223 vessels (Nagassar, 2000). Thirty-three percent of those vessels are used for gillnet fishing (Nagassar, 2000), though it should be noted that fishers may use multiple types of gear during the year so it is difficult to categorize vessels based on gear type. Target species vary widely and include demersal (e.g. catfish), midwater (e.g. shark, snapper) and surface species (e.g. tuna and mackerel). Gillnet configurations also vary, but for the drift-gillnet fishery (which sustains the highest sea turtle bycatch), 4.25 inch mesh, green colored, braided twine is preferred. For demersal fishing, 4.25 inch mesh monofilament net or 9 inch mesh, brown colored, braided twine netting is used.

The amount of net fished varies per boat, but usually ranges from 50 – 150 meshes deep (≈ 5 – 15 m) and 500 to 1000 meters in length. Nets are weighted along the bottom and suspended with integrated floats on the top line. Drift gillnets are usually set in the evening, and fished all night, with one end secured to the boat and the other end drifting. Some fishers prefer to place lighted floats at net ends and possibly at the mid point of the net line to alert other vessels to the presence of the net, while other fishers do not light the nets, reportedly to avoid pirates.

Initial experiments in 2006 were designed to give stakeholders an opportunity to work together and to test whether suspending nets in midwater would change fish catch. Previous research in Trinidad has shown that leatherbacks tend to dive to the bottom after leaving the nesting beach, and likely have a good chance of capture in bottom set nets at this time. However, when they return to the coast to re-nest (leatherbacks will nest up to 12 times per season separated by an average of 10 days), females spend more time near the surface (S. Eckert, unpubl. data) and we hypothesized that they were more prone to capture in surface set nets at that time.

By suspending the nets we hoped that the turtles would be able to travel over, or under, the net. However, if this method also significantly reduced fish catch then it would not readily be accepted by fishers and would not be considered a viable catch reduction method. Because the start of this experiment could not be early in the turtle nesting season when probability of turtle capture was high, the results were useful primarily to test the fishing capability of this methodology.

Results of the 2006 project showed that target species fish catch declined 70.4 – 76.2 % from more traditional methods (Gearhart and Eckert, 2007). Most instructive about this result is that mackerel species catch declined most dramatically, indicating that the highest probability of mackerel catch would occur in the upper 5 m of the water column. Mackerel species, particularly Kingfish (*Scomberomorus cavalla*), have the highest value per weight of any species fished in Trinidad and therefore are highly desired by fishers.

For 2007, we used the information that mackerel species had a higher probability of capture in surface waters to develop another series of bycatch reduction tests. Vessels from north and east coast ports were contracted to compare the fishing effectiveness of traditional nets constructed with 100 meshes deep to experimental nets constructed of only 50 meshes.

Research by Gearhart and Price (2003) in North Carolina had shown that lower profile nets used in a bottom set flounder fishery significantly reduced unintentional sea turtle entanglement. Because a narrower profiled net tends not to billow in the current, we believed it likely that it would hang in the water column more stiffly and provide less opportunity for sea turtle entanglement. Also, by limiting fishing to the area of the water column with higher fish probability, we believed that this alternative would not significantly reduce fish catch.

In addition to experimenting with gillnets, we also introduced Trinidad fishers to modern troll methods. While trolling has been used by Trinidad coastal fishers, it was not considered by fishers as cost effective as gillnets and thus is used only rarely. For this project we outfitted pirogues with trolling gear consisting of outriggers, planers, fish finders and bandit reels.

Results for 2007 were very promising. Surface set gillnets reduced sea turtle bycatch by 32.2% if calculated on an equal area of net fished basis (i.e. catch per area of net deployed). Catch of Kingfish increased slightly and catch of Carite (*Scomberomorus brasiliensis*) declined slightly. Costs of net repair showed that low profile nets had a two and a half-fold reduction in net repair costs due to both lower turtle entanglement rates and lower rates of damage. Fishers reported that turtles entangled in lower profile nets were far easier to untangle, and there were a significant number of turtles that struck the net and "bounced out". When these costs are factored into an economic comparison of the experimental low profile and control nets demonstrate that fishers will average $499 (TT) per day using low profile nets as compared to $334 (TT) per day with traditional nets. Average daily trolling daily income is calculated at $406 (TT).

At the conclusion of the 2007 field tests, fishers were presented with the results of the experiments and asked about their willingness to try these new methods. All (100%) reported that the catch of leatherbacks poses a serious problem for their fishing. 90% reported that they would switch to fishing with shallow set nets (10% said they "might" switch). 90% said they would be willing to switch to trolling and 70% said they would switch to new methods even if they had to bear "some" of the costs of the switch (20% more said they might switch depending on the cost).

Analysis of the most recent experiments suggests that we are well on our way to resolving the bycatch problem in surface-set drift gillnets in the coastal waters of Trinidad. By refining gillnet fishing methods, introducing more modern fishing techniques, fairly and transparently incorporating stakeholders into the process of developing mitigation methods, and responding to fisher feedback, we believe that we can significantly reduce the bycatch of leatherbacks in the nearshore waters of this Caribbean island.

The research will continue in 2008, sponsoring another series of fisher-inspired bycatch reduction experiments, as well as refining the mitigation methods already under development based on results to date.

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Artisanal Bycatch of Turtles in the Union of the Comoros, Western Indian Ocean – Are Gear Restrictions Always Effective?

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Introduction

The Union of the Comoros is a cluster of three volcanic islands: Grande Comore, Anjouan and Mohéli, located to the west of Madagascar in the Mozambique Channel. The islands host a number of ecologically important and vulnerable coastal habitats including coral reefs, mangroves and seagrass (Ahamada *et al.*, 2004; Anasse *et al.*, 2003), which support high marine biodiversity.

Mohéli is one of the most important nesting sites for green turtles (*Chelonia mydas*) (estimated 5000 nesting females) in the world and also hosts a smaller population (< 50 nesting females) of hawksbill turtles (*Eretmochelys imbricata*; Ben Mohadji and Paris, 2000). Smaller numbers of green turtles (<50 nesting females) also nest on Anjouan or Grand Comore (Ben Mohadji and Paris, 2000; Mortimer, 1993). The hunting and trade of marine turtles is illegal in the Comoros, but they continue to be hunted for their meat (Hauzer *et al.*, in press). A National Turtle Conservation Action Plan (Ben Mohadji & Paris, 2000) has been compiled but it has not been fully implemented to date. Although bycatch was not recognized by the Action Plan as a threat, accidental capture of immature turtles in nets has been reported (Mortimer, 1993).

Fishing in the Comoros is exclusively artisanal, using traditional canoes and motorized fiberglass boats; fishing gears include: beach seines, fish traps, gill nets, lines (including trolling, longlines and droplines) and purse seines. A number of legal restrictions have been put in place, prohibiting destructive fishing techniques (dynamite, poison, gillnets) and capture of endangered species, but the enforcement of these restrictions has proved ineffective to date (UNEP, 2002). There is an official ban on gillnets in Moheli Marine Park since 2001 (Gabrie, 2003) and informal bans in other areas enforced by local village associations and fishing syndicates because of the indiscriminate nature of this gear and its damaging effects on to sensitive substrates such as coral reefs. These restrictions on gillnets have been in place for some time, in certain communities since at least 1995 (Ministère de l'Agriculture et de la Pêche, 1995)

Methods

Turtle bycatch in artisanal fisheries in the Comoros was investigated through structured interviews of fishers and a review of existing fishery data. A total of 25 out of 44 landing sites were sampled on Grande Comore and 5 out of 13 sites were sampled on Mohéli (all outside of Mohéli Marine Park). Anjouan was omitted from the sampling because of political unrest. Sites were selected using stratified sampling with strata based on the number of boats at each village (UNEP, 2002) to achieve a geographically representative sample from each island and to include both large (>50 boats) and small (<50 boats) fishing communities.

Fishers were questioned about their boat and gear characteristics, fishing patterns and incidence of bycatch. A total of 409 interviews were conducted out of the estimated 8,500 fishers in the Comoros (Union des Comores, 2005).

Results and Discussion

Lines targeting pelagic fish were the most common fishing gear used on both islands (97% of fishers on Grande Comore and 91% of fishers on Mohéli). On Grande Comore, line fishing was larger-scale with fishers using multiple (up to 180) hooks on each line. Gillnet fishers were rarely encountered during surveys (4.4% of fishers on Mohéli and 2.9% on Grande Comore), probably as a result of the long-established prohibition of this gear in some fishing communities and absence of shallow fishing grounds, particularly around Grande Comore.

Fifty-four percent of Grand Comorian fishers and 28% of Mohélian fishers reported that they had caught turtles, whether accidently or deliberately. Green turtles were the most commonly captured species (76% and 89% of total reported turtle captures on Grande Comore and Mohéli respectively). Fishers reported mortality rates of captured turtles (all species) to be 63% on Grande Comore and 12% on Mohéli although real rates were probably higher.

It was not always clear during interviews as to whether turtles caught were actually bycatch or whether the fisher had caught them intentionally. Turtle meat is extremely popular in the Comoros (Ben Mohadji & Paris, 2000; Mortimer, 1993) explaining the high levels of bycatch mortality, so much of what was reported as bycatch may have actually been caught intentionally. Also, fishers' interpretation of an 'accidental' capture was often ambiguous (e.g., they may have reported turtle capture to be 'accidental' if catching turtles was not the main aim of the fishing trip).

Awareness-raising activities and the prohibition of gillnets associated with the establishment of Mohéli Marine Park in 2001 may have helped reduce bycatch mortality and intentional capture of sea turtles on Moheli, as bycatch rates were lower on that island than on Grand Comore. However, the ban on gillnet fishing in Moheli Marine Park has been poorly received by local fishing communities, with fishers losing significant income in the absence of alternative livelihoods; the ban has also proved logistically difficult and costly to enforce in the absence of sustainable funding mechanisms (Hauzer et al in press).

It is also unlikely that gillnet bans have significantly reduced turtle mortality; since turtles are still caught by the majority of fishers even though almost all of them now fish using lines (the bans may however be effective in the reduction of bycatch of other species such as dugong). Thus the driving force behind fishers catching turtles in the Comoros is not the gear that they are using but their socioeconomic needs. In cases such as this, gear restrictions are likely to only put further pressure on communities that are already extremely poor, leading to further dissatisfaction and lack of interest in conservation.

Awareness-raising in fishing communities may be a stronger force to reduce bycatch of turtles in the Comoros. Awareness-raising can instigate management initiatives at the community level, resulting in self-regulation with higher levels of compliance, particularly in countries such as the Comoros where local capacity and funding availability limits the effectiveness of large-scale attempts at bycatch-mitigation strategies.

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