AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS

Aquatic Conserv: Mar. Freshw. Ecosyst. (2010)

Published online in Wiley InterScience
(www.interscience.wiley.com). DOI: 10.1002/aqc.1120

Effect of type of bait on pelagic longline fishery–loggerhead turtle interactions in the Gulf of Gabes (Tunisia)

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ABSTRACT

1. Sea turtles may migrate vast distances from their feeding areas to home rookeries where they nest. During these migrations sea turtles are subject to many threats, among which are interactions with pelagic longlines.
2. This gear is used frequently in the summer period in the Gulf of Gabes targeting mainly the sandbar shark (*Carcharhinus plumbeus*). Hooks are baited with mackerel (*Scomber scombrus*) or pieces of stingray (*Dasyatis pastinaca*).
3. Twenty-one fishing trips (48 sets with a total of 35 950 hooks deployed) were conducted using onboard observers in the south of the Gulf of Gabes during the months of July, August and September in 2007 and 2008. Stingray and mackerel bait were used in 19 and 29 sets, respectively.
4. In total, 29 loggerhead sea turtles (*Caretta caretta*) were captured; the majority of them were juvenile and active. Turtles were caught at a statistically greater frequency on sets with hooks baited with mackerel than on sets with hooks baited with pieces of stingray.
5. The type of bait also affected the catch of the target species by increasing the efficiency when pieces of stingrays were used.
6. These results encourage further research into new baits to mitigate turtle catch by longline fisheries without affecting the catch of target species. Copyright © 2010 John Wiley & Sons, Ltd.

Received 13 October 2009; Revised 18 February 2010; Accepted 8 March 2010

KEY WORDS: pelagic longline; loggerhead turtle; Gulf of Gabes; bait; catch rate

INTRODUCTION

Six of the seven species of sea turtles living in the world's oceans are listed as either critically endangered or endangered (IUCN, 2003) and international trade of these species is prohibited (CITES, 2003). Populations of sea turtles are considered to be under human threat worldwide.

Three species of sea turtles are observed regularly in the Mediterranean Sea: the loggerhead turtle (*Caretta caretta*), the green turtle (*Chelonia mydas*) and the leatherback turtle (*Dermochelys coriacea*). Only two of them, the loggerhead and the green turtle, nest in this area, and nesting is confined almost exclusively to the eastern basin (Kasparek et *al*., 2001; Margaritoulis *et al*., 2003).

These reptiles frequent oceanic and neritic zones, in which they feed on pelagic and benthic prey. During their life, turtles can be affected by different threats, including by-catch, which is one of the most significant issues affecting fisheries management today.

In the Mediterranean, there is no specific fishery or type of fishing gear that directly targets sea turtles. Trawls (Casale *et al*., 2004; Jribi *et al*., 2007), set nets (Lazar *et al*., 2006; Casale, 2008; Echwikhi *et al*., in press) and longlines (Deflorio *et al*., 2005; Camiñas *et al*., 2006; Casale *et al*., 2007a; Casale, 2008; Jribi *et al*., 2008) are gears known to interact with sea turtles.

The loggerhead turtle, the most abundant sea turtle in the Mediterranean, is common in Tunisian waters and particularly in the Gulf of Gabes area. This vast area, located in the south of Tunisia, is an important neritic habitat, foraging zone and wintering area for loggerhead turtles (Margaritoulis *et al*., 2003; Casale *et al*., 2008).

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In this area, and particularly in the southern part, a fleet of Tunisian pelagic longliners operates in summer and early autumn targeting the sandbar shark (*Carcharhinus plumbeus*) and the swordfish (*Xiphias gladius*), and results in significant incidental captures of sea turtles (Jribi *et al*., 2008). Turtles are generally hooked in the mouth or in the digestive tract with only a few hooked externally or entangled in the fishing lines.

Recent experiments have shown that simple alterations in gear configurations and bait can reduce turtle by-catch (Watson *et al*., 2005; Gilman *et al*., 2006; Yokota et *al*., 2009). The specific factors that attract sea turtles and target fish to longline gear and bait are not well understood, but multiple sensory cues are probably involved (Southwood *et al*., 2008). The use of different types of bait was identified as a promising tool to reduce the interaction rates with sea turtles in some shallow-set pelagic longline fisheries (Gilman *et al*., 2006; Yokota et *al*., 2009).

The aim of the present study is to gain further insight into by-catch of sea turtles by pelagic longline in the south of Tunisia by (i) providing estimations of catch rates, mortality and related parameters, (ii) testing the effect of different baits on both sea turtles and target species, and (iii) formulating recommendations to efficiently protect sea turtles, as endangered species, while avoiding any negative socio-economic impact on fishermen.

MATERIALS AND METHODS

Fishing operations and gear characteristics

At sea, observations were carried out during 21 trips (48 sets) on board Tunisian-flagged longline vessels based in Zarzis, Djerba and El Ketf, located in the south of the Gulf of Gabes (Figure 1). Trips took place from July to September 2007 and during the same period in 2008, corresponding to the fishing season of target species. The regions of study are known to be traditional fishing areas for the Tunisian coastal pelagic longline fleet.

The basic fishing gear comprises a 20 to 35 km mainline, with a series of branchlines (8 m length) suspended horizontally from the surface by a series of floats. Each branchline is terminated with a baited J hook. The distance between hooks is around 40 m and hook size is 111 mm length, 57 mm width. The gear is set at sunset and the retrieval begins just before sunrise. Gear deployment took approximately 3 h, while hauling operations took approximately 6 h.

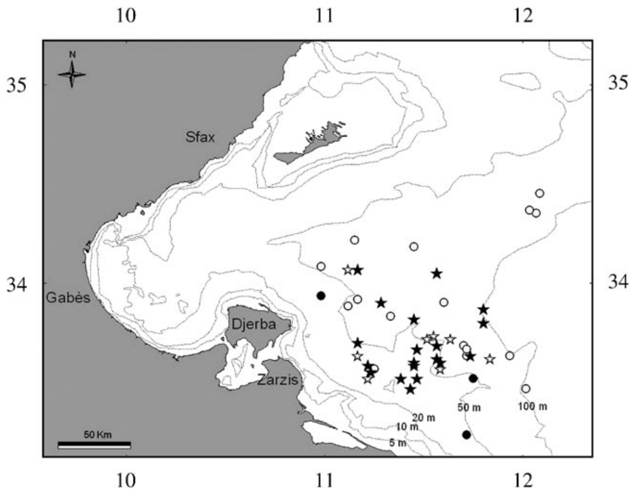

Figure 1. The Gulf of Gabes. Locations of pelagic longline sets. Stars: sets with mackerel baited hooks (★; incidental capture, ☆; no capture), Circles: sets with stingray baited hooks (●; incidental capture, ○; no capture).

In the study area, whole mackerel (*Scomber scombrus*) was typically used as bait as it was most readily available. This bait can stay fresh for a long period in the sea and presents the best economic return for fishermen. However, when mackerel is not available, fishermen use other baits such as fragments of stingrays. During the study, 29 fishing sets were carried out using mackerel bait and 19 using stingray.

Data collection

For each set, information concerning the fishing operation (number of hooks, gear setting and hauling times), and weather (atmospheric and sea conditions) were recorded. All sea turtles that were captured were brought on board. Data on sea turtles included species, geographical position, curved carapace length notch to tip (CCL_{n-t}) (Bolten, 1999) and physical condition, which was classified as active (lively movements), comatose (dazed and apparently dead but eyes or cloacae responding to touch after a few hours on board) and dead (no sign of breathing; eyes not responding to touch). Before the release of active turtles or turtles recovered from a comatose state, an attempt was made whenever possible to unhook the turtle, otherwise the branchline was cut as close to the mouth as possible and the turtle was released with a hook in the mouth or in the digestive tract.

Statistical analysis

In order to compare catch rates within and between studies, catch rate, $\hat{R}1$, which is catch per unit of effort (CPUE), was calculated as the number of turtles caught per 1000 hooks. To show the effect of changing bait on sea turtle captures $\hat{R}1$ was calculated in the two cases when hooks were baited with mackerel and with stingray.

To estimate total turtle catch from the total fishing effort, another catch rate, $\hat{R}2$ (turtle/fishing trip) was calculated and total catch of sea turtles was estimated by applying $\hat{R}2$ to the total fishing effort H (total number of trips), for the whole longline fleet operating in the study area.

The direct mortality p is the proportion of turtles recovered dead. Total direct mortality was calculated by applying total captures to p.

The basic unit of effort of longline (the hook) can have only two possible conditions: capture/no capture (0, 1). The 95% confidence intervals of longline standard catch rates were calculated with the method for binomial distributions (Zar, 1999).

To show the effect of type of bait on the principal target species *Carcharhinus plumbeus* (in recent years, other species such as *Xiphias gladius* have been captured in only small quantities in the Gulf of Gabes pelagic longline fleet), another catch rate $\hat{R}3$(number of specimens of target species captured per 1000 hooks) was calculated. This catch rate was calculated for the total and separately for the use of either type of bait.

SPSS 13.0 software was used for statistical analysis. The Mann–Whitney U test was performed to verify the importance of the factor 'type of bait' of sea turtles and sandbar shark CPUEs.

RESULTS

Sea turtle

In total, 35 950 hooks were set during 21 trips. Altogether, 29 sea turtles (all loggerheads) were caught which represent a catch rate $\hat{R}1$ of 0.806 (95% confidence interval (CI) 0.802–0.810) turtles per 1000 hooks (Table 1) and $\hat{R}2$ of 1.381 (0.945–1.923) turtles per trip. The estimated fishing effort in the study area during the study period was 316.5 trips per year (Source DGPA: General Directorate of Fishing and Aquaculture) giving a total captures estimate of 437.086 (299.092–608.629).

In most cases, only a single turtle was captured on any given set, but on five occasions two turtles were caught on a single set and on one occasion three turtles were caught on a single set. Twenty-six specimens were captured by 22 150 hooks baited with mackerel and three turtles were captured by 13 800 hooks baited with stingray. Thus, the catch rate $\hat{R}1$ was estimated at 1.173 (95% CI 1.160–1.187) turtle per 1000 hooks baited with mackerel and 0.217 (95% CI 0.210–0.224) turtle per 1000 hooks baited with stingray (Mann–Whitney U test: U = 128.000; $n = 48$; $P = 0.001$).

Of the 29 loggerhead turtles taken on board, 24 specimens (82.8%) were captured by hooking (19 in the mouth and four deep in the digestive tract and one in the flipper) and five turtles (17.2%) were entangled in the fishing line (Table 2). Before releasing, the hooks were easily removed from six specimens (20.68%), but 11 turtles (37.93%) were active and released with hooks in the mouth or inside their digestive tracts after cutting the branchline.

At the time when brought on board, 20 turtles were active, six were dead, two in a comatose state and one was injured (Figure 2), leading to 20.68% direct mortality. Consequently, the total direct sea turtle mortality for the longline fleet operating in the zone was estimated at 90.390 (76.026–103.480). Turtles released with hooks and lines in their digestive tracts have a so-called 'delayed' mortality which cannot be estimated. Consequently, the mortality estimated in this study must be considered as a minimum. Casale *et al.* (2007b) reported that the average mortality of a turtle caught by a drifting longline is probably much higher than 30%. Among 26 specimens captured using mackerel as bait, 18 were active, six were dead, one injured and one in a comatose state, for the three specimens captured using stingray as bait, two were active and one in a comatose state.

$CCL_{n\text{-}t}$ of captured loggerheads ranged between 42 and 77 cm, the mean carapace length was 58.103 cm (SD = 9.22; $n = 29$). Only one adult turtle ($CCL_{n\text{-}t}$ = 77 cm) was captured, classified as female following the sexing methodology of Casale *et al.* (2005) (Figure 3).

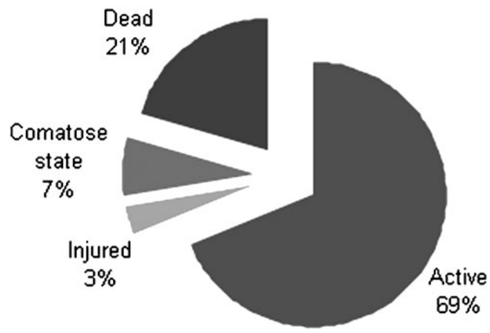

Figure 2. Physical conditions of sea turtles captured.

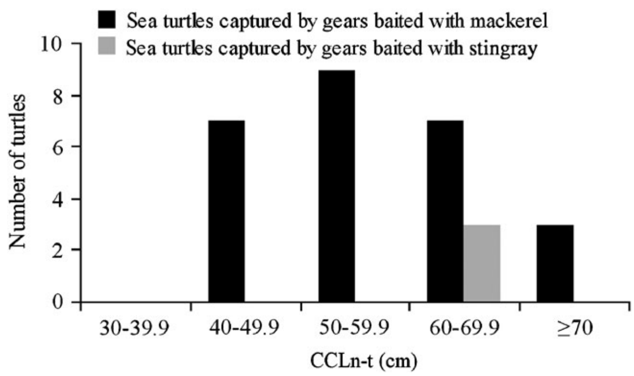

Figure 3. Distribution of curved carapace length ($CCL_{n\text{-}t}$) frequencies of loggerhead turtles captured by pelagic longline with hooks baited with mackerel ($N = 26$) ■ and with stingray (N = 3).

Table 1. Fishing effort and catch rates for sea turtles

	Number of hooks	Number of sets	Number of sea turtles captured	$\hat{R}1$	Turtle/set
Hook baited with mackerel	22 150	29	26	1.173 (1.160–187)	0.896 (0.726–0.978)
Hook baited with stingray	13 800	19	3	0.217 (0.210–0.224)	0.157 (0.030–0.395)
Total	35 950	48	29	0.806 (0.802–0.810)	0.604 (0.452–0.742)

Table 2. Capture mode of turtles with different baits

	Specimens hooked in the mouth	Specimens hooked in digestive tract	Specimens hooked in the flipper	Specimens entangled
Gear baited with mackerel	18	4	1	3
Gear baited with stingray	1	0	0	2
Total	19	4	1	5

Table 3. Numbers and CPUEs ($\hat{R}3$: number of specimens per 1000 hooks) for each species captured (species are listed in decreasing capture order)

Species	Captured specimens			$\hat{R}3$		
	Total	Hooks baited with mackerel	Hooks baited with stingray	Total	Hooks baited with mackerel	Hooks baited with stingray
Carcharhinus plumbeus	547	291	256	15.215±1.769	13.137±2.234	18.550±0.168
Carcharhinus brevipinna	22	13	9	0.611±0.4163	0.586±0.694	0.652±0.171
Xiphias gladius	4	3	1	0.111±0.127	0.135±0.518	0.0725±0.177

Target species

Besides loggerheads, 22 specimens of *Carcharinus brevipinna*, four specimens of *Xiphias gladius* and 547 specimens of sandbar sharks (*Carcharinus plumbeus*) which is considered the principal target species were also captured. The catch rate $\hat{R}3$ for this latter species was significantly greater for hooks baited with stingray (18.550±0.168 specimens per 1000 hooks) than with mackerel (13.137±2.234 specimens per 1000 hooks) (Mann–Whitney U test: U = 152.000; $n = 48$; $P = 0.009$) (Table 3).

DISCUSSION

The present study confirms that pelagic longline is a major source of human-induced mortality for loggerhead sea turtles (see also Casale *et al*., 2007a; Casale, 2008; Jribi *et al*., 2008). The high catch rate recorded in this study is similar to a previous study carried out in Zarzis (part of the study area) with CPUE estimated at 0.823 (95% CI 0.568–1.158) turtles per 1000 hooks (Jribi *et al*., 2008) and among the highest recorded in the Mediterranean Sea (Table 4).

Mackerel and pieces of stingray were the two types of bait used during this study. These types of bait can stay fresh for a long time in the water, and attract the target species either by visual or olfactory (because of bleeding) stimuli. Although stingrays are not available in large quantities, fishermen can collect the necessary amounts to enable them to bait their hooks. A difference in CPUE between the two types of bait is foreseen as a result of differences in their colour and shape; mackerel is a steel blue fish, whereas pieces of stingrays are generally maroon and have a cubic form.

The sandbar shark, the principal species targeted by pelagic longline in the study area, as with sharks in general, is a highly visual predator attracted by bright colours (Gruber, 1977) but can also sense the presence of blood in water even when diluted to one part in ten million (Parker, 1914; Mathewson and Hodgson, 1972). The examination of 130 stomach contents of sandbar sharks captured in the Gulf of Gabes showed that this species mainly feeds on fishes (osteichthyans and chondrichthyans) (Saidi *et al*., 2007). The catch rate of this species registered with stingrays bait is a little higher than that registered with mackerel bait. This could be attributed to the attraction of sandbar sharks caused by the stingray bait's blood release.

The type of bait affects also the catch rate of loggerhead turtles. Vision and chemoreception play an important role in attracting sea turtles to baited hooks. The difference between the two catch rates of sea turtles when mackerel (1.173 turtles per 1000 hooks) or stingray (0.217 turtles per 1000 hooks) were used as bait may, on the one hand, be related to both the colour and the unusual form of pieces of stingrays, and on the other hand, to the mackerel (*Scomber* spp.) bait smell. In fact, Southwood *et al*. (2008) reported that visual cues are of primary importance for foraging success in sea turtles and that chemical cues play a secondary role. This is supported also by Luchetti and Sala (2009) who indicated that chemical cues can play a key role in the sea turtle bite/no bite decision once a food item has been visually located. Piovano *et al*. (2004) showed that even a small piece of mackerel is enough to make a lure attractive, and increase the frequency at which turtle's take such bait.

Table 4. Standard catch rates of sea turtle with pelagic longline from different areas in the Mediterranean

	Turtles per 1000 hooks	C I	Sources
Lampedusa	0.977	0.787–1.200	Casale *et al*., 2007a
North Ionian sea	0.128	0.086–0.183	Deflorio *et al*., 2005
South Ionian sea	0.446	0.357–0.552	Deflorio *et al*., 2005
Spain	1.141	—	Camiñas *et al*., 2006
East Ionian sea/Aegean	0.172	0.108–0.261	Kapantagakis, 2001
West Mediterranean sea	0.847	0.803–0.893	Caminas and Valeiras, 2001
The Strait of Sicily	1.137	—	Piovano *et al*., 2009
Tyrrhenian sea	0.255	0.083–0.595	Guglielmi *et al*., 2000
South Mediterranean sea	0.154	0.090–0.246	Guglielmi *et al*., 2000
Zarzis (Gulf of Gabès)	0.823	0.568–1.158	Jribi *et al*., 2008
Gulf of Gabes	0.806	0.802–0.810	Present study

CI: Confidence interval.

Fisheries targeted at sharks and swordfish species in depths shallower than 100 m pose a serious threat for the loggerhead turtle population which is concentrated at these shallower depths (Gerosa and Casale, 1999). Loggerhead turtles appear to spend almost all their time at depths less than 100 m and more than 90% of the time at depths less than 60 m (Polovina *et al*., 2003).

The relatively high mortality observed in the present study can be explained by the fact that captured turtles were unable to reach the surface to breathe for two reasons: (i) they were pulled back to the bottom by the weight of captured target fish species on adjacent hooks; and (ii) the specific traditional design of Tunisian pelagic longline, which does not include as high a number of floatlines and baskets as the longline used in the north of the Mediterranean Sea (Laurent *et al*., 2001).

RECOMMENDATIONS AND CONCLUSION

This study shows that pelagic longlines in the Gulf of Gabes pose a serious problem for the Mediterranean and Atlantic loggerhead populations (Casale *et al*., 2008). Until now, the best way to protect marine turtles from longline fisheries has been to conduct awareness campaigns aimed at fishermen. The role of professional fishermen is certainly of fundamental importance in sea turtle conservation programmes. Hooks that are lodged externally (i.e. jaw) are easily detected by fishermen and can be removed relatively easily especially if equipped with dip nets and dehookers (Gerosa and Aureggi, 2001).

It appears possible to mitigate turtle interactions with a longline fishery by altering bait type, while still maintaining and even improving catch rates of targeted species. Recent studies have indicated that loggerheads are more likely to feed on squid than on mackerel when both are used simultaneously as bait (Watson *et al*., 2005; Yokota *et al*., 2009). These results go beyond this and demonstrate that other baits such as pieces of stingrays (Dasyatidae) can reduce the catch rate of loggerhead turtles compared with mackerel. Stingrays, however, are considered vulnerable and further research is necessary to identify a more abundant species for use as an alternative bait.

This study provides new possible solutions to reduce by-catch of marine turtles based on differences in sensory behaviour of turtles and target species. Identification of differences in sensory capabilities of sea turtles and pelagic fishes, as well as potential sensory attractants or repellents for these animals, could guide efforts to refine fishing techniques to target more specifically desired species and to reduce the capture of sea turtles.

The efficiency of sensory-based deterrents may be strongly influenced by numerous factors, and techniques that prove useful in reducing sea turtle by-catch in one fishery, may not work as well in another. Factors to consider when evaluating the feasibility of incorporating a sensory-based deterrent in a longline fishery would include the oceanographic region where fishing occurs, time of day when gear is set, target species, age and size class of sea turtles interacting with fishing gear, and diurnal and seasonal variations in sensory capacities.

In addition, there are recent experiments to mitigate sea turtles based essentially on such simple alterations to gear configurations as the use of circle hooks instead of J form (Watson *et al*., 2005; Piovano *et al*., 2009) and the setting of the gear as deep as possible to minimize interactions with turtles (Beverly and Robinson, 2004).

ACKNOWLEDGEMENTS

This paper was made possible thanks to the invaluable efforts of many individuals: fishermen, volunteers, crews, scientists and onboard observers who have participated in this work.

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