Impact of trawl fishery on marine turtles in the Gulf of Gabès, Tunisia

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The aim of this study, carried out during 2001 and 2002, was to assess the interaction between turtles and bottom trawls in the Gulf of Gabès, which is considered an important wintering and foraging area for the loggerhead in the Mediterranean. Catch rates are estimated at 0.01142±0.00292 turtles/haul with a total catch of 5458±1652 turtles/year. However, the total mortality is low (182±55/year), probably due to the short haul duration. Captures occur mainly during winter, spring and summer, with significantly higher rates at depths of less than 50 m.

Key words: bottom trawling, bycatch, *Caretta caretta*, loggerhead, Mediterranean Sea

INTRODUCTION

Marine turtles, and especially the loggerhead *Caretta caretta*, the most common turtle species in the Mediterranean, interact with numerous fisheries in many countries (Laurent, 1990; Laurent et al., 1990; Margaritoulis et al., 1992; Bradai, 1992). The impact of accidental catch on the populations of these reptiles is one of the most urgent problems to be solved in order to ensure the survival of these species all over the world (Gerosa & Casale, 1999). In the Mediterranean, fishing activity is considered a major threat to sea turtle populations (Casale et al., 2004). The conservation of these reptiles requires an identification of the structure of the Mediterranean stock, an evaluation of accidental captures and fishing-induced mortality and the development of an adequate protective strategy that takes into account all these parameters.

In this study, we contribute to the assessment of the impact of bottom-trawling activity on the sea turtle population in the Gulf of Gabès (Tunisia), a zone presumed to be a foraging zone and an important wintering area (Argano et al., 1992; Margaritoulis, 1988; Laurent et al., 1990; Laurent & Lescure, 1994; Gerosa & Casale, 1999; Bradai et al., unpublished data) in the Mediterranean. Bottom trawling in this zone is very developed, causing bycatch of loggerhead (Bradai, 1992). The aim of this two-year study (2001–2002) was the evaluation of turtle catch rate, mortality rate and total catch induced by the Tunisian trawl fleet in the Gulf of Gabès, in order to assess the importance of the threat of this fishery to sea turtle conservation.

METHODS

The Gulf of Gabès is the most important fishing area in Tunisia; it contains about 50% of the Tunisian fishing fleet and lands about 50% of the national fish production. The number of fishing boats recorded in this area is 6892 (Anonymous, 2001).

The trawler fleet is made up of 270 vessels targeting mainly shrimp, cephalopods (mostly *Sepia officinalis*) and benthic fish; 98% of the trawler fleet operating in the Gulf of Gabès is connected to the port of Sfax (Anonymous, 2001). These trawlers had a rest period from mid-July until the end of August during 2001 and 2002, corresponding to a biological rest period. Trawling is forbidden during this time. During 2001 and 2002, there was an average of 6640 trips per year.

For this study, we worked on board trawlers connected to the port of Sfax and operating in the Gulf of Gabès. These trawlers are representative of the whole trawling fleet because they target the same species and have the same fishing protocol. For each haul we recorded date, coordinates at the beginning and end of each haul, haul speed, haul duration, bottom depth and number of turtles caught. When turtles were captured, we measured the Standard Curved Carapace Length (SCCL) and classified their condition as follows: healthy (lively movements), injured (healthy but with wounds), comatose (dazed and apparently dead but eyes or cloaca responding to touch after a few hours), or dead (no sign of breathing; eyes not responding to touch). Four different catch rates *R* were calculated. In order to estimate total turtle catch from the total fishing effort *H* (available as fishing trips), the number of turtles per trip was calculated and 95% confidence intervals were derived. In order to compare catch rates within this study as well as between this and other studies, a standardized catch rate was calculated following the standardization of the net size, based on a standard headrope (the upper of the two horizontal ropes of the net's opening) of 30.5 m, and of the haul duration (60 min) used by Henwood & Stunz (1987) and Laurent et al. (2001): turtle/$h_s * d_s$, where h_s is the headrope length/30.5 m and d_s is the haul duration/60 min.

Annual total catch of marine turtles by bottom trawlers was estimated by applying catch rate *R* (turtles/fishing trip) to the total fishing effort (number of trips) for all the trawling fleet operating in the Gulf of Gabès. Annual total catch with 95% confidence interval was calculated as:

$$H\left[R \pm 1.96\sqrt{V(R)}\right]$$

where *V(R)* is the standard error of *R*.

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Table 1. Estimation of fishing effort of all the trawlers operating in the Gulf of Gabès.

Fishing effort	2001	2002	Average 2001–2002
Number of trips	6103	7178	6640.5
Number of days	41,550.6	48,869.4	45,210
Number of hauls	439,416	516,816	478,116

Direct mortality is the proportion of turtles found dead in trawl operations. It is globally estimated from the total observed turtle catch during fishing operations. Confidence intervals for total direct mortality were calculated using the formula:

$$(H\left[R \pm 1.96\sqrt{V(R)}\right])p$$

Four seasons were considered in this study: December–February (winter); March–May (spring); June–mid-July (summer) and September–November (autumn).

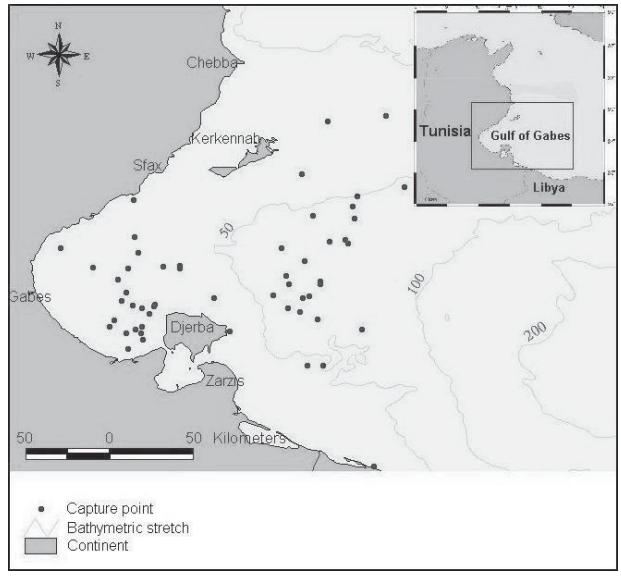

Fig. 1. Geographic distribution of different captures.

RESULTS

During 2001 and 2002, a total of 5256 hauls were carried out on board the trawlers. In 2001 these trawlers completed 3325 hauls during 44 trips; in 2002 they completed 1931 hauls during 29 trips.

The evaluation of fishing effort for the trawler fleet of the Gulf of Gabès is given in Table 1. The number of trips was obtained from the General Direction of Fishing and Aquaculture, and the number of days and hauls were estimated according to our data by multiplying the number of trips by respectively the average of day/trip and the average of haul/trip of trawlers used in this study.

During this study, the average trawling speed was 2.64 knots (SD=3.16; range 2.2–3.4; *n*=1772). Mean haul duration was 86.83 min (SD=11.40; range 40–120; *n*=4422). This important factor affecting turtle mortality depends on the depth of fishing zone (zone, ground, bottom nature, etc.): generally, the haul durations were shorter in depths less than 50m. The frequency of hauls/day, which is dependent on the haul duration, was 10.38 (SD=2.11; range 6–18; *n*=4422).

Sixty loggerheads *Caretta caretta* were accidentally captured during 59 hauls (37 in 2001 and 23 in 2002): 58 hauls captured one turtle and one haul brought back two turtles together. Figure 1 shows the geographic distribution of different captures recorded during this study. These appear to be random.

The minimum depth of hauls in which turtles were found was 7 m; the maximum was 64 m. The mean carapace length of turtles was 57.46 cm (SD=13.30; range 36.5–84.5; *n*=57). The frequency distribution of lengths is shown in Figure 2.

The majority of the captured turtles were healthy (95%). Only one turtle was in a coma (1.67%) and two dead (3.33%) on opening the net on the deck. According to the captains and fishermen, captured turtles are generally in good condition and are released immediately.

Sixty turtles were captured over the two years, 37 in 2001 and 23 in 2002. The highest catch rates were observed in winter during 2001 (0.0069±0.0038 turtles/h.d.) and in summer during 2002 (0.0201±0.0145 turtles/h.d.). The lowest catch rates were observed in autumn in both years: 0.0049±0.0035 turtles/h.d. in 2001 and 0.0022 turtles/h.d. in 2002 (Table 2).

The estimated average fishing effort for the trawler fleet operating in the Gulf of Gabès was 6640.5 trips/year. The total catch resulting from this fishing effort was estimated at 5458±1652 (95% C.I.). Observed direct mortality was 3.33% (*n*=60) and potential mortality (assuming that the comatose turtle would die too) was 1.67% (*n*=60). Consequently, the total direct mortality and the potential mortality were estimated respectively at 182±55 and 91±28 turtles (95% C.I.). The rest of the turtles were in good condition and no injured or decomposed turtles were observed. Mortality rates and total mortality from other studies are shown in Table 3 for comparison.

Table 2. Trawl sampling effort and turtle catch rate with 95% confidence intervals (2001–2002). Winter: Dec–Feb; spring: Mar–May; summer: Jun–mid-Jul; autumn: Sep–Nov.

Season	Turtles	Trips	Days	Hauls	h.d.	Turtles/trip	Turtles/day	Turtles/haul	Turtles/h.d.
Winter	15	16	121	1256	2325.3	0.9375±0.5208	0.1239±0.0711	0.0119±0.0060	0.0064±0.0032
Spring	22	22	143	1478	2633.3	1.0000±0.5158	0.1538±0.0682	0.0149±0.0064	0.0084±0.0036
Summer	9	7	45	476	922.2	1.2857±1.3330	0.2000±0.1474	0.0189±0.0122	0.0098±0.0065
Autumn	14	28	188	2046	3601.1	0.5000±0.2364	0.0745±0.0404	0.0068±0.0036	0.0039
Total	60	73	497	5256	9481.9	0.8219±0.2488	0.1207±0.0332	0.0114±0.0029	0.0063

Table 3. Mortality rate and total mortality from other studies.

Fishing zone	Mortality rate	Total mortality (turtles/year)	Source
France (continental)	0.03	-	Laurent, 1991
Corsica	0.04	-	Delaugerre, 1987
Tunisia (South)	0	-	Laurent, 1993
Greece	0.03	-	Margaritoulis et al., 1992
Greece (Ionian Sea and North Aegean)	0	0	Laurent et al., 2001
Italy (North Adriatic Sea)	0.094	402*	Casale et al. 2004
USA (Atlantic coast)	0.21	6745±577	Henwood & Stunz, 1987
USA (Gulf of Mexico)	0.29	3129±1001	Henwood & Stunz, 1987
Florida	0.45	-	Wibbels, 1989
Tunisia (Gulf of Gabès)	0.033	182±55	This study

*Calculated from data in the text: not reported as such by the authors.

DISCUSSION

If the catch rate of turtles remains constant, and the turtle population increases, the total turtle catch will increase. Catch rate is high in the Gulf of Gabès, suggesting a high density of marine turtles in the region. The catch rate (turtles/haul) is comparable to others in important areas in the Mediterranean and worldwide (Table 4).

The high marine turtle density in the Gulf of Gabès can be explained by the fact that this region is an important wintering and foraging area for marine turtles in the Mediterranean (Argano et al., 1992; Margaritoulis, 1988; Laurent et al., 1990; Laurent & Lescure, 1994; Gerosa & Casale, 1999; Bradai et al., unpublished data).

The high water temperatures in the region also attract turtles, especially in winter. Many turtles tagged in Greece and Italy have later been recorded in the Gulf of Gabès in winter (Margaritoulis, 1982; Jribi, 2003). The monitoring of a male loggerhead from the Gulf of Gabès via satellite telemetry showed that the turtle started moving eastward and arrived in April at Kyparissia bay (Greece). By the end of September, the turtle had returned to the Gulf of Gabès. It is worth mentioning that the turtle was moving from the Gulf of Gabès to Greece along isotherms and stayed within a narrow temperature range of 15–20.5 °C (Bradai et al., unpublished data).

In the Gulf of Gabès, marine turtles are captured throughout the year. The winter, the spring and the summer are periods when the catch rates are higher in contrast with the autumn where this rate is lower ($P<0.01$; Table 2). The highest catch rate occurs during the summer period, although in 2001 there were more captures during the winter. This indicates a difference in the distribution and maybe in the behaviour of turtles according to the time of year. It appears that marine turtles migrate from their nesting area to their feeding grounds (Adriatic and Gulf of Gabès) in winter. The high catch rates registered in these areas and the small number or the absence of nesting sites confirm this fact. In summer, the catch rate remains high in the Gulf of Gabès. This can, in turn, be explained by the fact that juveniles, and females who do not go to nest, stay in the area where an important source of food can be found. The decrease in the catch rate in the autumn remains unexplained and needs further investigation. Could it be possible that a particular behaviour or a possible inverse migration takes place during this season?

The present study shows that trawlers have a large impact on sea turtles in the Gulf of Gabès. The total catch is among the highest in the Mediterranean and it exceeds previous estimates: 3500–4000 (Laurent et al., 1990) and 2000–2500 (Bradai, 1992). This reflects the protective effort in Tunisia that includes the prohibition on fishing for and commerce in turtles enforced since 1990.

Although the catch rate is high, the recorded mortality (direct and potential) shows quite a low number of deaths in comparison with other regions in the Mediterranean (14.3% in north Adriatic) and in the world (29% in the Gulf of Mexico and 45% in Florida) . This fact may be explained

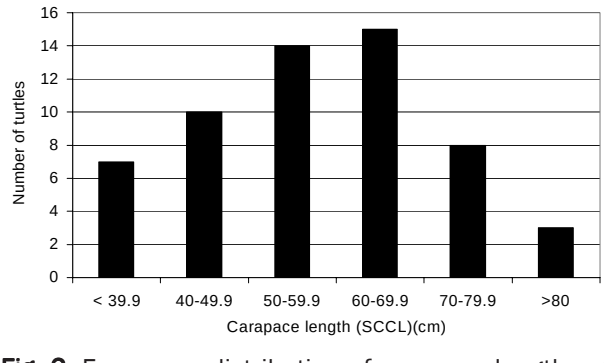

Fig. 2. Frequency distribution of carapace lengths of captured turtles.

Table 4. Catch rates from this and other studies.

Area	Catch rate (turtles/haul)	95% C.I.	Source
Gulf of Gabès	0.0114	±0.0029	This study
North Adriatic Sea	0.0195	±0.0054	1
Northwest Atlantic	0.0456	±0.0039	2
Gulf of Mexico	0.0025	±0.0008	2

Sources: 1) Casale et al., 2004; 2) Henwood & Stunz, 1987.

essentially by the shorter haul duration in the Gulf of Gabès. A close relation has been noticed between duration of haul and mortality, due to the fact that the trawls work within temporal ranges that include the turtle's tolerance of apnea (Henwood & Stunz, 1987). Consequently, the use of loophole systems such as the TED (Turtle Excluder Device), which diverts a turtle entering the net toward a special exit, has not attracted interest in the Gulf of Gabès. This is because this expensive system is needed in cases of high mortality due to long haul duration, which is not the case in the Gulf of Gabès. Further, it is designed for the shrimp trawl fishery (not usually the case in the Gulf of Gabès) and it would exclude the larger commercial specimens too.

The best way to protect marine turtles is to conduct awareness campaigns aimed at fishermen. These explain how to treat captured turtles and especially how to apply recovery techniques to comatose turtles, and the need to avoid fishing in shallow water less than 50 m in depth.

This study shows that recorded captures involve turtles ranging in size from 50 to 70 cm. Adults and small juveniles are less well represented. The bell-shape frequency distribution of the specimens caught (Fig. 2) can be explained by a decrease in the number of adults due to a natural mortality of big specimens and the fact that bottom trawl catches those specimens that have affected or are about to affect the transition between the pelagic phase and the demersal one. Consequently, specimens below a certain size are not caught.

As for depth, it is known that *Caretta caretta* mostly frequents bottoms less than 50 m deep, more rarely deeper ones (Gerosa & Casale, 1999). In fact captures during this study were more numerous in depths of less than 50 m (0.0076 turtles/h.d.) than beyond this (0.0054 turtles/h.d.). This phenomenon has been noted before in the Gulf of Gabès (Bradai, 1992) and in several regions of the world, e.g. South Carolina (Epperly et al., 1995) and the Gulf of Mexico (Henwood & Stunz, 1987; Caillouet et al., 1991).

CONCLUSION

The present results show the importance of the Gulf of Gabès for marine turtles. This area with its characteristics (shallow waters and high biodiversity) is likely to be one of the most important areas in the whole Mediterranean. In spite of the important interaction between marine turtles and the bottom trawlers the induced mortality remains weak, which should be reassuring for the population in the region. It would, of course, always be preferable to reduce the accidental captures and the mortality to the maximum of our ability.

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