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Interactions of loggerhead turtle with bottom longline fishery in the Gulf of Gabès, Tunisia

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In the Gulf of Gabès (Tunisia), a fleet of bottom longliners operates in summer and in the beginning of autumn targeting groupers. This fleet interacts with loggerhead turtles. During twenty trips in which 48,020 hooks were deployed, a total of 16 loggerheads were captured, most of them were juveniles, and direct mortality was estimated to be 43.75%. During the fishing operation, the hauling of the gear started one to three hours after and sometimes occurred immediately after setting. Results obtained show that the soak time did not affect the capture of turtles and target species, whereas it influenced the mortality rate of turtles. Bottom longline should be studied more in depth throughout the Mediterranean Sea, as well as parameters related to the interaction with sea turtles. However, mitigation measures to reduce turtle by-catch are urgently needed. In this way, we propose: (i) reducing the fishing soak time; (ii) experimenting with gear modification such as the use of circle hooks; and (iii) conducting an awareness campaign aimed at fishermen to show them how to deal with turtle by-catch.

Keywords: bottom longline, catch rate, loggerhead turtle, mortality, soak time

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INTRODUCTION

The loggerhead turtle, *Caretta caretta*, has a circumglobal distribution (Marquez, 1990), frequenting tropical and temperate zones, oceanic and shallow coastal waters. It is considered as the most common and widespread sea turtle species in the Mediterranean Sea (Groombridge, 1990) and is currently classified as globally endangered by the World Conservation Union (Hylton-Taylor, 2000). During their life, loggerheads inhabit both oceanic and neritic waters in a complex stage-specific pattern (Bolten, 2003). Post-hatchling turtles spend several years in the open sea, drifting passively in the surface currents (oceanic developmental stage) before recruiting to neritic habitats to complete their development (neritic developmental stage) (Carr, 1987). Turtles either may utilize the same neritic developmental habitat all through maturation, or they may move among different areas and finally settle in an adult foraging habitat (Casale *et al.*, 2008a). Due to their amphibious life cycles, loggerhead turtles are adversely affected by a large variety of factors. Human activities such as pollution, habitat degradation of the nesting beaches, incidental catch and intentional killing (for blood and meat), represent the major threats to the survival and to the general decline of marine turtle populations in the Mediterranean Sea (Margaritoulis *et al.*, 2003).

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In recent years, there has been a rising awareness of the global threats posed to sea turtles through incidental mortality as a result of fisheries by-catch (Lewison *et al.*, 2004; Deflorio *et al.*, 2005; Camiñas *et al.*, 2006; Carranza *et al.*, 2006; Casale *et al.*, 2007; Jribi *et al.*, 2008; Lucchetti & Sala, 2009; Echwikhi *et al.*, 2010a).

In the Gulf of Gabès in Tunisia, a part of the North African shelf, considered as neritic foraging area for Mediterranean and Atlantic loggerhead turtle (Margaritoulis *et al.*, 2003; Casale *et al.*, 2008b; Bradai *et al.*, 2009; Lucchetti & Sala, 2009), recent studies have shown that loggerhead turtles in this area interact with fisheries (Jribi *et al.*, 2007; Echwikhi *et al.*, 2010a, b).

Bottom longline exploit fish that inhabit irregular sea bottoms (Hovgard & Lassen, 2000). This fishing gear used in the summer period in the south of the Gulf of Gabès, targeting groupers *Epinepheleus aeneus* and *Epinepheleus marginatus*, affects the loggerhead population (Jribi *et al.*, 2008) generally concentrated in shallow depth (Polovina *et al.*, 2003).

By-catch of loggerheads depends on several factors and parameters related to the fishing gear (number of hooks, length of the mainline, baits used, etc.) and to the fishing operation such as fishing depth, fishing zone and soak time (the time between the start setting and retrieval of a fishing gear). This latter parameter affects the by-catch and mortality of sea turtles with many fishing gears such as pelagic longline (Watson *et al.*, 2005; Gilman *et al.*, 2006) and gillnets (Echwikhi *et al.*, 2010b). In fact, in some cases, when the animal is captured, it cannot reach the water surface to replenish its oxygen stores and unload the cumulated carbon dioxide.

This study aims at: (i) showing the current interaction of loggerhead turtles with bottom longline in the south of the Gulf of Gabès; (ii) analysing the effect of fishing soak time on catch rate and mortality of sea turtles; and (iii) proposing measures to reduce bottom longline–sea turtle interactions.

MATERIALS AND METHODS

Area and period of study

The investigation was carried out during the 2007 and 2008 fishing seasons on-board fishing boats connected to the ports of Zarzis (33°30′00″N 11°07′00″E), Djerba (33°31′50″N 10°41′20″E) and El Ketf (33°11′00″N 11°30′00″E), located in the southern part of the Gulf of Gabès (Figure 1). Data were obtained from records taken by on-board observers during 38 fishing sets from 20 randomly selected trips taking places from July to September 2007 and 2008. The fishing sets represent the average effort of the bottom longline fishery in this area, because the different trips were conducted on-board different boats from different ports.

Gear and fishing operation

Tunisian traditional bottom longline (Figure 2) consists of a 10 to 12 km mainline anchored to the bottom, suspended by a series of monofilament polyamide branch lines separated with a distance of about 7 m, each branch line is 1 m long and 2 mm diameter terminating with a single baited J hook (Mustad model number 92671). The number of hooks ranges from 1200 to 1800 and the hook sizes are 78 mm length and 41 mm width; frozen round sardinella (*Sardinella aurita*) or common cuttlefish (*Sepia officinalis*) are the baits mainly used.

Fishing operations were monitored by an on-board observer. Target and incidentally captured specimens were identified to species level. For each set, information concerning the fishing operation (number of hooks, gear setting and hauling times), and weather (atmospheric and sea conditions) were recorded. Information on sea turtles captured included species, geographical position, curved carapace length notch to tip ($CCL_{n\text{-}t}$) (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 branch line 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.

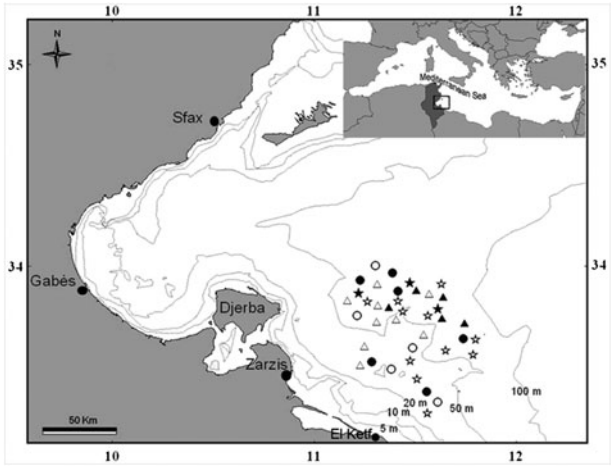

Fig. 1. The Gulf of Gabès: location of bottom longline sets. Stars, sets of class I (★ incidental capture, ☆ no capture); triangles, sets of class II (▲ incidental capture, △ no capture); circles, sets of class III (● incidental capture, ○ no capture).

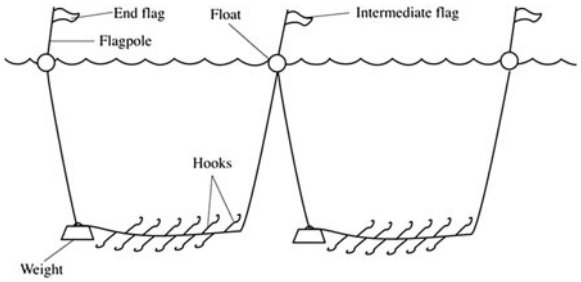

Fig. 2. Tunisian bottom longline (Echwikhi *et al.*, 2006).

During all trips conducted, bottom longline was deployed at any moment of the daylight and retrieval could start immediately or after some hours (the number of sets deployed ranged from 1 to 3 in one single trip). Taking in consideration the soak time, all fishing sets were classified into three classes; sets of class I: the retrieval of the gear began immediately after setting; sets of class II: sets with soak times lasting between 1 and 2 hours; sets of class III: sets with soak times taking more than 2 hours.

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 number of specimens per 1000 hooks. To test for an effect of the fishing soak time on catch rate, we calculated $\hat{R}1$ for the three classes of sets.

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 (number of trips (Source DGPA: General Directorate of Fishing and Aquaculture)).

Anaysis of variance (ANOVA) was applied to verify the effect of the soak time on the capture of turtles and groupers (the principal targets species) CPUEs.

The direct mortality p is the proportion of sea turtle found dead during all the fishing sets. To show the effect of soak time on the mortality rate of sea turtle, we calculate p for the three classes of sets. ANOVA was applied to test for an effect of soak time on the mortality rate of sea turtles. Total mortality was estimated by applying total capture to p.

The basic unit of effort of longline (the hook) can have only two possible conditions: no capture/capture (0, 1). As a consequence, the distribution is exactly binomial and can be easily derived from monitored data. Hence, 95% confidence intervals of longline standard catch rates could be calculated with the method for binomial distributions (Zar, 1998).

RESULTS

All overview species

A total of 794 specimens belonging to 8 species were captured during all the fishing trips. The total numbers of individuals per species captured and corresponding CPUE values are summarized in Table 1. When considering the whole of captured specimens per 1000 hooks, difference between catch rates registered in the three classes of sets was not significant ($F_{2,21} = 0.825$, $P = 0.451$).

Sea turtles

In total, 48,020 hooks were set during 20 trips (38 sets). Altogether, 16 sea turtles (all were loggerhead turtles) were caught which represent a catch rate $\hat{R}1$ of 0.333 (0.190–0.541) turtles per 1000 hooks and $\hat{R}2$ of 0.8 (0.563–0.942) turtles per trip (Table 2). Turtles were captured in 14 sets (48% of the total of sets); generally we recorded one capture in one single set but in two cases, we observed a capture of two turtles in a single set. The mean fishing effort in study area during the study period H was 177.5 trip/year, giving total captures estimated to 142 (99.9325–167.205) (Table 2). $\hat{R}1$ was 0.184 (0.037–0.537), 0.343 (0.126–0.747) and 0.491 (0.197–1.011) turtle/1000 hooks for sets of classes I, II and III, respectively (Table 1). The catch rate of loggerheads was not affected by the soak time ($F_{2,35} = 1.39$, $P = 0.260$).

Turtles were captured throughout the entire zone of study and throughout the three months of the campaigns in the two-year study. The majority of captures occurred between 50 and 60 m, and there was no apparent distinguishing feature in terms of location between sets that did or did not catch turtles. The distribution of fishing efforts depends mainly on target species (Figure 1).

Among the captured turtles, six were in good condition (37.5%), two were in comatose state (12.5%), one specimen presented old scars and specific damages and was classified as injured externally but healthy (6.25%) and seven were dead (43.75%). Total annual direct mortality reflects uncertainty in the capture rate but not in the per-capture mortality rate. It was estimated to 62.125 (43.720–73.152).

We did not record any case of mortality when the retrieval of the gear was immediate. The mortality was estimated to 33.33% for sets of class II and 71.14% for sets of class III (Table 3). The soak time affects the mortality rate of loggerheads ($F_{2,35} = 3.447$, $P = 0.042$).

The way by which the animals were captured differs; seven specimens were hooked in the mouth (43.75%), six were hooked in the digestive tract (37.5%), and three were entangled in the lines (18.75%) before releasing, the hooks were easily removed from 2 specimens (12.5%), but 3 active turtles (18.75%) were released with hooks inside their digestive tracts after cutting the branchline.

The size of captured turtles ranged between 42 and 65 cm with an average of 50.12 cm. On the basis of the size of adult females nesting in the Mediterranean (Margaritoulis *et al.*, 2003) and according to Casale *et al.* (2005), all captured specimens were juveniles (Figure 3).

DISCUSSION

Catch rates recorded and total loggerhead captures estimated show that bottom longline represents an additional threat

Table 1. Numbers and CPUEs (number of specimen per 1000 hooks) for each species captured by different set-classes. Species are listed in decreasing captures order, except *Caretta caretta*.

Species	Captured specimens				$\hat{R}1$		
	Total	Sets of class I (14 sets) 16300 hooks	Sets of class II (11 sets) 17470 hooks	Sets of class III (13 sets) 14250 hooks	Sets of class I	Sets of class II	Sets of class III
Caretta caretta	16	3	6	7	0.184	0.343	0.491
Epinepheleus aeneus	221	68	71	82	4.171	4.064	5.754
Epinepheleus marginatus	181	57	63	61	3.496	3.606	4.280
Rhinobathos cemiculus	167	50	47	70	3.067	2.690	4.91
Carcharinus plumbeus	83	18	24	41	1.104	1.373	2.877
Mustelus punctulatus	62	3	31	28	0.184	1.774	1.964
Mustelus mustelus	53	21	13	19	1.288	0.744	1.333
Carcharinus brevipinna	11	2	4	5	0.122	0.228	0.350
Total	794	222	259	313	13.619	14.854	21.473

Table 2. Fishing effort, catch rates and total capture of loggerhead sea turtles estimated in the study area.

	2007	2008	2007–2008
Number of trips	7	13	20
Number of hooks deployed	12620	35400	48020
Number of turtles captured	8	8	16
Number of turtles/1000hooks ($\hat{R}1$)	0.634 (0.274–1.250)	0.225 (0.097–0.445)	0.333 (0.190–0.541)
Number of turtles/trip ($\hat{R}2$)	1.142 (0.506–2.128)	0.615 (0.315–0.861)	0.8 (0.563–0.942)
Total number of trips	192	163	177.5
Total capture	219.264 (97.152–408.576)	100.245 (51.354–140.343)	142 (99.932–167.205)

Table 3. Physical conditions of loggerhead turtles captured in different class of soak time periods.

Soak time	Turtles captured	Physical conditions				Mortality rate
		Activqe	Comatose state	Injured	Dead	
0 hour	3	3	0	0	0	0%
1–2 hours	6	2	1	1	2	33.33%
>2 hours	7	1	1	0	5	71.14%

affecting sea turtle populations in the Gulf of Gabès an important neritic habitat, foraging zone and wintering area for loggerhead turtles in the Mediterranean Sea (Laurent *et al.*, 1998; Margaritoulis *et al.*, 2003; Casale *et al.*, 2007, 2008b).

The catch rate recorded $\hat{R}1$ (number of turtles caught per 1000 hooks) in this study can be considered as similar to the one registered in a previous study carried out in Zarzis (part of the study area (0.278 turtles per 1000 hooks) (Jribi *et al.*, 2008)) but is lower than that reported in the Strait of Sicily 0.873 (0.436–1.562) (Casale *et al.*, 2007). The extent to which bottom longlines are dangerous clearly depends on the depth at which they are placed. Bottom longline used at a depth of 200–700 m should not arouse concern (Bolten *et al.*, 1994). However, in some fishing grounds such as the study area, this method is used at a much shallower depth, causing numerous captures of loggerhead turtles; this species appears to spend almost all the time at less than 100 m depth and more than 90% of the time at less than 60 m (Polovina *et al.*, 2003). In the Mediterranean Sea, available data suggest that the annual number of captures by Mediterranean bottom longliners may well be above 35,000 (Casale, 2008). It should be taken into account that these are capture events and not individual turtles, because the same turtle can be caught more than one time (Casale, 2008). The most affected marine areas being the North African continental shelf (Tunisia, Libya and Egypt), the Alboran Sea (Morocco), the Levantine basin (Turkey) and the Aegean (Greece) (Table 4).

Specimens captured in our study were juveniles, in neritic stage. Many studies showed that the wide continental shelves of the eastern Mediterranean (Tunisia and Libya; north Adriatic; Egypt; south-east Turkey) and the Gulf of Gabès

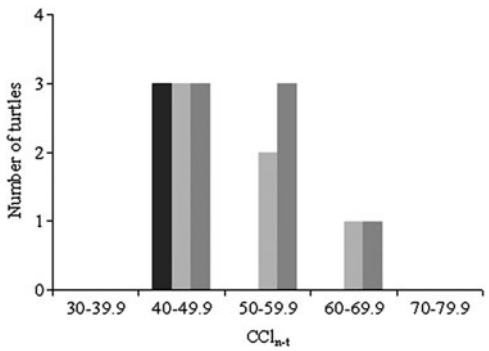

Fig. 3. Distribution of curved carapace length (CCL_{n-t}) frequencies of loggerhead turtles caught in the study area by bottom longlines. Turtles captured in sets of class I (N = 3); ■, turtles captured in sets of class II (N = 6); ■, turtles captured in sets of class III (N = 7) ■.

Table 4. Estimate of total loggerhead turtle captures by bottom longliners in the Mediterranean.

Area	Total capture estimated/year	Sources
Egypt	2218	Nada & Casale, 2008
Lampedusa	257(94–421)	Casale *et al.*, 2007
Greece(Aegean Sea)	6.064	Casale, 2008
Gulf of Gabès	732.89 (469.50–1090.21).	Jribi *et al.*, 2008
Gulf of Gabès	2000	Bradai, 1993
Alboran Sea (Morocco)	3366	Casale, 2008
Levantine basin (Turkey)	5000	Casale, 2008
Current study	142 (99.932–167.205)	-

specially are neritic foraging habitats for loggerhead turtle (Margaritoulis *et al.*, 2003; Casale *et al.*, 2008b). Moreover, some adult turtles frequenting the Gulf of Gabès in winter leave the area during the summer period to reproduce in the north of the Mediterranean Sea (Cyprus, Greece and Turkey), thus increasing the proportion of juveniles in the study area.

Mortality of sea turtles caught is particularly problematic in this fishery component. The direct mortality induced by bottom longlines appears to be higher than that recorded by other gears such as benthic trawl (3.33%) (Jribi *et al.*, 2007) and pelagic longline (20.68%) (Echwikhi *et al.*, 2010a) in the same area, also the delayed mortality is a cause of concern because it is widely unknown and it is suspected to be very high. The post-release mortality strongly depends on the hook's position in different parts of the digestive tract (mouth, oesophagus, stomach, intestine, etc) (Camiñas & Valeiras, 2001). In particular, if the hook is swallowed in the lower oesophagus or in the stomach like the case of this study (three of the six active turtles captured (50%) were released with hooks inside their digestive tracts after cutting the branchline); the turtle has a very low chance of surviving. Jribi *et al.* (2008) stated that bottom longline has the potential to be more harmful than pelagic longlines; this opinion was supported by Casale (2008) who reported that bottom longlines seem to be responsible for a potential mortality (delayed) of about 40% and total mortality is estimated to 14,000 turtles per year in the Mediterranean.

This study shows that the soak time did not affect the capture of loggerhead and target species. This is also supported by Gardner *et al.* (2008) who reported that 'contrary to water temperature, region, and bottom depth, the soak time is not a significant predicator of the number of loggerheads captured by longlines'. The mortality rate of loggerheads was affected by the soak time. In fact, hooks are close to the bottom and the turtles captured are smaller; therefore they might not be able to reach the surface to breathe as a result of forced submergence (i.e. drowning) especially when the gear is set deep and when the soak time passes the apnoea endurance of a sea turtle. Bentivegna *et al.* (2008) showed that in summer, the dive time of loggerhead turtle did not exceed 40 minutes, whereas in winter single dives of up to 120 minutes were recorded.

In conclusion, the current study demonstrates that bottom longliners pose an additional threat to the loggerhead population in the Gulf of Gabès. Compared to those registered with pelagic longline (Jribi *et al.*, 2008; Echwikhi *et al.*,

2010a) and bottom trawl (Jribi *et al.*, 2007), the loggerhead mortality rate recorded with bottom longline in the study area seems to be the highest. Furthermore, turtle mortality seems to be correlated to the soak time: soak time exceeds two hours, the majority of captured turtles die. This parameter should be more studied and fishermen should take it into consideration in their fishing operations to mitigate sea turtle capture.

Actually, no solutions were developed to reduce bottom longline–sea turtle interactions. In this context, we recommend: (1) reducing the fishing soak time, which should be lower than 2 hours; and (2) increasing the number of sets and decreasing the soak time period.

The use of circle hook which is effective for pelagic longline (Watson *et al.*, 2005; Piovano *et al.*, 2009) should be tested with bottom longline. The problem is the typical small size of target species and the small size of the hooks used by this gear so that the feasibility of increasing hook size, to reduce turtle catch rate, is questionable and should be investigated. Furthermore, long term conservation of sea turtles in the Mediterranean Sea requires international cooperation among bordering countries in order to obtain a complete assessment of the scale of the threats of different gears, develop and implement possible national regulations and international agreements and monitor the implementation of measures to protect turtle populations.

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REFERENCES

Bentivegna F., Horchscheid S. and Minucci C. (2008) Seasonable variation of dive time duration of the Mediterranean loggerhead turtle Caretta caretta. *Scientia Marina* 67, 371–375.

Bolten AB. (1999) Techniques for measuring sea turtles. In Eckert K.L., Bjorndal K.A., Abreu-Grobois F.A. and Donnelly M. (eds) *Research and management techniques for the conservation of sea turtles*. Washington, DC: IUCN/SSC Marine Turtle Specialist Group Publication 4, pp. 110–114.

Bolten A.B. (2003) Active swimmers–passive drifters: the oceanic juvenile stage of loggerheads in the Atlantic System. In Bolten A.B. and Witherington B. (eds) *Loggerhead sea turtles*. Washington, DC: Smithsonian Institution Press, pp. 63–78.

Bolten A.B., Bjorndal K.A. and Martins H.R. (1994) Life history model for the loggerhead sea turtle (*Caretta caretta*) population in the Atlantic: potential impacts of a longline fishery. In Balazs G.H. and Pooley S.G. (eds) *Research plan to assess marine turtle hooking mortality: results of an expert workshop held in Honolulu, Hawaii, 16–18 November 1993*. NOAA, National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, Administrative Report H-93-18, pp. 48–54.

Bradai M.N. (1993) *La tortue marine Caretta caretta dans le sud-est de la Tunisie (Pêche accidentelle—utilisation—législation)*. MAP, RAC/SPA, UNEP, 27 pp.

Bradai M.N., Bentivegna F., Jribi I., El Ouaer A., Maatoug K. and El Abed A. (2009) Monitoring of loggerhead sea turtle *Caretta caretta*, in the central Mediterranean via satellite telemetry. In Demetropoulos A. and Turkozan O. (eds) *Proceedings of the Second Mediterranean Conference on Marine Turtles. Barcelona Convention–Bern Convention–Bonn Convention (CMS). Kemer, Antalya, Turkey, 4–7 May 2005*, pp. 54–57.

Camiñas J.A. and Valeiras J. (2001) Marine turtles, mammals and sea birds captured incidentally by the Spanish surface longline fisheries in the Mediterranean Sea. *Rapport de la Commité Internationale de la Mer Mediterranée* 36, 248.

Camiñas J.A., Baez J.C., Valeiras X. and Real R. (2006) Differential loggerhead by-catch and direct mortality due to surface longlines according to boat strata and gear type. *Scientia Marina* 70, 661–665.

Carr A. (1987) New perspectives on the pelagic stage of sea turtle development. *Conservation Biology* 1, 103–121.

Carranza A., Domingo A. and Estrades A. (2006) Pelagic longlines: a threat to sea turtles in the Equatorial Eastern Atlantic. *Biological Conservation* 131, 51–57.

Casale P. (2008) *Incidental catch of marine turtles in the Mediterranean Sea: captures, mortality, priorities*. WWF Mediterranean Marine Turtle Programme.

Casale P., Freggi D., Basso R. and Argano R. (2005) Size at male maturity, sexing methods and adult sex ratio in loggerhead turtles (*Caretta caretta*) from Italian waters investigated through tail measurements. *Herpetelogical Journal* 15, 145–148.

Casale P., Cattarino L., Freggi D., Rocco M. and Argano R. (2007) Incidental catch of marine turtles by Italian trawlers and longliners in the central Mediterranean. *Aquatic Conservation: Marine and Freshwater Ecosystems* 17, 686–701.

Casale P., Abbate G., Freggi D., Conte N., Oliverio M. and Argano R. (2008a) Foraging ecology of loggerhead sea turtles *Caretta caretta* in the central Mediterranean: evidence for a relaxed life history model. *Marine Ecology Progress Series* 372, 265–276.

Casale P., Freggi D., Gratton P., Argano R. and Oliverio M. (2008b) Mitochondrial DNA reveals regional and interregional importance of the central Mediterranean African shelf for loggerhead sea turtles (*Caretta caretta*). *Scientia Marina* 72, 541–548.

Deflorio M., Aprea A., Corriero A., Santamaria N. and De Metrio G. (2005) Incidental captures of sea turtles by swordfish and albacore longlines in the Ionian Sea. *Fisheries Sciences* 71, 1010–1018.

Echwikhi K., Jribi I., Bradai M.N. and Bouain A. (2006) *Interaction of marine turtles with longline fisheries in the region of Zarzis (Gulf of Gabès, Tunisia)*. Presented at the 26th Annual Symposium on Sea Turtle Biology and Conservation, Crete, Greece, 3–8 April 2006.

Echwikhi K., Jribi I., Bradai M.N. and Bouain A. (2010a) Effect of type of bait on pelagic longline fishery–loggerhead interactions in the Gulf of Gabès—south of Tunisia. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20, 525–530.

Echwikhi K., Jribi I., Bradai M.N. and Bouain A. (2010b) Loggerhead turtle–gillnet fishery interactions in the Gulf of Gabès, south of Tunisia. *Herpetological Journal* 20, 25–30.

Gardner B., Sullivan P.J., Epperly S. and Morreale S.J. (2008) Hierarchical modeling of by catch rates of sea turtles in the western North Atlantic. *Endangered Species Research* 5, 279–289.

Gilman E., Zollet E., Beverly S., Nakano H., Davis K., Shiode D., Dalzell P. and Kinan I. (2006) Reducing sea turtle by catch in pelagic longline fisheries. *Fish and Fisheries* 7, 2–23.

Groombridge B. (1990) *Marine turtles in the Mediterranean: distribution, population status, conservation*. Strasbourg: Council of Europe, Publishing and Documentation Service. ISBN 92-871-1864-7.

Hovgard H. and Lassen H. (2000) *Manual on estimation of selectivity of gillnet and longline gears in abundance surveys*. FAO Fisheries and Technical Paper No. 397.

Hylton-Taylor C. (2000) *Red List of Threatened Species*. Gland, Switzerland: IUCN.

Jribi I., Bradai M.N. and Bouain A. (2007) Impact of trawl fishery on marine turtles in the Gulf of Gabès, Tunisia. *Herpetelogical Journal* 17, 110–114.

Jribi I., Echwikhi K., Bradai M.N. and Bouain A. (2008) Incidental capture of sea turtles by longlines in the Gulf of Gabès (South Tunisia): a comparative study between bottom and surface longlines. *Scientia Marina* 72, 337–342.

Laurent L., Casale P., Bradai D.A., Godley B.J., Gerosa G., Broderick A.C., Schroth W., Schierwater B., Levy A.M., Freggi D., Abd El-Mawla E.M., Hadoud D.A., Gomati H.E., Domingo M., Hadjichristophorou M., Kornaraky L., Demirayak F. and Gautier C.H. (1998) Molecular resolution of marine turtle stock composition in fishery bycatch: a case study in the Mediterranean. *Molecular Ecology* 7, 1529–1542.

Lewison R.L., Freeman S.A. and Crowder L.B. (2004) Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. *Ecology Letters* 7, 221–231.

Lucchetti A. and Sala A. (2009) An overview of loggerhead sea turtle (*Caretta caretta*) bycatch and technical mitigation measures in the Mediterranean Sea. *Review of Fish Biology and Fisheries* 20, 141–161.

Margaritoulis D., Argano R., Baran I., Bentivegna F., Bradai M.N., Camiñas J.A., Casale P., De Metrio G., Demetropoulos A., Gerosa G., Godley B., Houghton J., Laurent L. and Lazar B. (2003). Loggerhead turtles in the Mediterranean Sea: present knowledge and conservation perspectives. In Bolten A.B. and Witherington B.E. (eds) *Loggerhead sea turtles*. Washington, DC: Smithsonian Books, pp. 175–198.

Márquez M. (1990) *FAO species catalogue. Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date*. FAO, Rome: FAO Fisheries Synopsis.

Nada M. and Casale P. (2008) *Marine turtles in the Mediterranean Egypt: threats and conservation priorities*. Rome: WWF Italy.

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

Polovina J.J., Howell E., Parker D.M. and Balazs G.H. (2003) Dive-depth distribution of loggerhead (*Carretta carretta*) and Olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific: might deep longline sets catch fewer turtles? *Fishery Bulletin* 101, 189–193.

Watson J.W., Epperly S.P., Shah A.K. and Foster D.G. (2005) Fishing methods to reduce sea turtle mortality associated with pelagic longlines. *Canadian Journal of Fisheries and Aquatic Sciences* 62, 965–981.

and

Zar J.H. (1998) *Biostatistical analysis*. 4th edition. Upper Saddle River, NJ: Prentice-Hall Inc., 929 pp.

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