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Incidental catch of the loggerhead turtle *Caretta caretta* off the Balearic Islands (western Mediterranean)

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Abstract

A survey, which included questionnaires for fishermen and the placement of observers onboard fishing vessels, was conducted to assess turtle catch off the Balearic Islands. The survey focused on those fishing vessels whose base port was in the archipelago and, hence, the catch of South-eastern Spain longliners moving in summer to the archipelago was not considered. The fishermen's perception was that the stock of loggerhead turtles is declining in the archipelago and that fishing activities are at least partially responsible for this trend. The observer reports indicated that the figures produced by the interviewees for catch per unit effort (CPUE) were reliable. Therefore, on the basis of these figures we calculated a total catch of 373 (95% CI: 365–308) loggerheads for 2001. Most turtles were caught in lobster trammel nets (196; 95% CI: 269–123) or drifting longlines (102; 95% CI: 111–93). Although the CPUE was much lower for the former, total catch was greater because of a larger fleet. Moreover, most loggerheads caught in lobster trammel nets were found dead when nets were hauled in, while no immediate mortality was observed in individuals caught in drifting longlines. This observation highlights the threat of trammel nets to loggerhead turtle populations. The estimated impact of the catches on the turtle population depends on the origin of the individuals inhabiting the region, which is yet to be established.

Keywords: Artisanal fisheries; By-catch; Marine turtles; Trammel net

1. Introduction

The loggerhead turtle *Caretta caretta* is the most common marine turtle in the western Mediterranean (Broderick et al., 2002). In these waters, specimens from Atlantic and eastern Mediterranean rookeries apparently share foraging areas (Laurent et al., 1993, 1998; Laurent and Lescure, 1995; Casale et al., 2002). This anti-tropical species, with highly fragmented populations, inhabits regions that are greatly disturbed by humans (Pritchard, 1997) and has declined throughout its entire distribution range in recent decades (NRC, 1990). Thus, the loggerhead turtle is included in most international wildlife conservation treaties (Eckert et al., 2000), and Groombridge (1990) recommended that the species be considered as critically endangered in the Mediterranean Sea.

Demographic studies indicate that the loss of late juveniles (straight carapace length from 30 to 80 cm) and adults has a more dramatic impact on populations than the loss of younger individuals (eggs, hatchlings and younger juveniles) (Crouse et al., 1987; NRC, 1990). Therefore, although rookery protection is a priority for marine turtle conservation, this measure will be unsuccessful without effective protection of large juveniles and adults. Boat collision, ingestion of debris, and chemical pollution are potential threats for larger size classes at sea (Lutcavage et al., 1997), but available data clearly indicates that fishing is the largest cause of mortality. Indeed, several declining populations have rapidly recovered once mortality caused by this activity was reduced (NMFS-SEFSC, 2001).

Large numbers of late juvenile loggerhead turtles can be observed off the Balearic Islands all year round (Mayol et al., 1988; Camiñas and de la Serna, 1995;

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Mejías and Amengual, 2001). The archipelago supports a large fishing fleet (Iglesias and Martorell, 1990), which is reinforced throughout the warm season with longliners from south-eastern Spain (Camiñas and de la Serna, 1995). Incidental catch of loggerhead turtles has been reported in other heavily fished areas around the world where drift-nets, bottom trawling and drifting longlines are used (Aguilar et al., 1995; Nichols et al., 1999; Silvani et al., 1999; Witzell, 1999). Other fishing gear also produces potential by-catch (Delaugerre, 1987; Laurent, 1991; Goodley et al., 1998; Nichols et al., 1999), but information on these operations is still scarce. This study aims: (i) to identify the fishing gear, used by locally based fishing boats, involved in loggerhead turtle by-catch in the Balearic Islands, and (ii) to establish the total number of these turtles caught and killed in fishing activities.

2. Material and methods

Information was collected from two independent sources: interviews with professional fishermen, and data collected by observers onboard fishing vessels.

2.1. Interviews

A survey was conducted from May to August 2002 in all the fishing harbours of the Balearic archipelago. A questionnaire that was specially designed to identify conflicts between fishermen and turtles was used. The survey was stratified in accordance with the information supplied by the Fisheries Office of the Balearic Islands (*Direcció General de Pesca del Govern de les Illes Balears*), which registers all professional fishing vessels with their base harbour in the archipelago and classifies them into four categories: bottom trawlers, drifting longliners, purse-seiners and artisanal boats. Fishermen on at least 25% of the vessels of each category from each harbour were interviewed; however, to avoid pseudoreplication only one individual per boat was given the questionnaire. Sampling effort was increased for categories of fishing gear used by only a few vessels. Bottom trawlers, drifting longliners and purse-seiners use the same fishing gear throughout the year and hence stratification based on the data of the official register was easy. This was not true for artisanal vessels, as they often alternate several fishing gears year round. Thus, stratification based on the data of the official register might be useless if fishing gears were used unevenly in the archipelago. Fortunately, the results of the questionnaire revealed that three types of trammel nets and bottom long-lines were widely used in all harbours and that stratification based on the official register properly sampled them. Results were grouped for analysis by island, though the data from the southern islands (Ibiza and Formentera, known as Pitiüses) were pooled as the fishermen share the same grounds. Fishermen from boats from South-eastern Spain operating in the area were not interviewed.

The survey included 41 questions (a copy in Spanish is available on request), of which the main ones were:

- Which fishing grounds did you visit last year (Fig. 1)?
- On a monthly basis, which grounds did you use last year?
- On a monthly basis, which gear did you use?
- In your opinion, what is the status of the turtle population (declining, stable, increasing)? If declining, what are the causes?
- When do you think turtles are more often observed and caught, on a monthly basis?
- How many turtles did you accidentally catch last year? In which months did this occur? What kind of fishing gear was involved? Were the turtles released dead or alive?

The fishing effort carried out per vessel in the previous year (2001) was recorded as the number of months the vessel operated. When it visited more than one fishing ground in the same month, the effort was assumed to be distributed evenly and, hence, effort was divided by the number of grounds visited. When a vessel used several fishing gears in the same period, effort was divided by the number of distinct types of gear, again assuming an even fractionation. Thus, total fishing effort with gear a in ground z (E_{za}) was calculated as:

$$E_{za} = \sum_{i=1}^{i=n} E_{zai}$$

where E_{zai} is the effort supported by fishing ground z from vessels from the ith harbour operating with gear a. In its turn, E_{zai} was calculated as follows:

$$E_{zai} = E_{ozai} \frac{n_{ai}}{n_{oai}}$$

where E_{ozai} is the effort reported by the interviewed fishermen from harbour i operating in zone z with gear a, n_{ai} is the number of registered vessels with base in harbour i that used gear a, and n_{oai} the number of vessels from harbour i that used gear a whose crew was interviewed.

Total turtle catch in ground z with gear a (C_{za}) was calculated as:

$$C_{za} = C_{oza} \frac{E_{za}}{E_{oza}}$$

where C_{oza} is the number of turtles caught, as reported by fishermen, in ground z with gear a; E_{za} is the total

fishing effort with gear a supported by zone z; and E_{oza} is the effort reported by fishermen in zone z with gear a. Consequently, the CPUE in each ground for a given gear was calculated as:

$$CPUE = \frac{C_{za}}{E_{za}}$$

2.2. Validation of the CPUE calculated from the questionnaires

Loggerhead turtles are legally protected in the study area. Consequently, it was feared that fishermen might understate the frequency and number of incidental catches. To validate the reliability of responses, we placed observers onboard fishing vessels in a few fishing grounds off Majorca and/or Minorca, compared their data with those reported by fishermen operating in the same fishing grounds, and extrapolate the conclusion about reliability or unreliability of answers to the other fishing grounds. Table 1 provides details of the fishing operations surveyed.

2.3. Aerial surveys

Two aerial surveys were conducted off the Balearic islands in March 2002 and September 2002. The strip transect method was used (Marsh and Sinclair, 1989), with the transects following a systematic saw-tooth pattern over the continental shelf (Gómez de Segura et al., 2003). Surveys were taken from a high-wing aircraft (Cessna-172) that allowed a side-viewing platform.

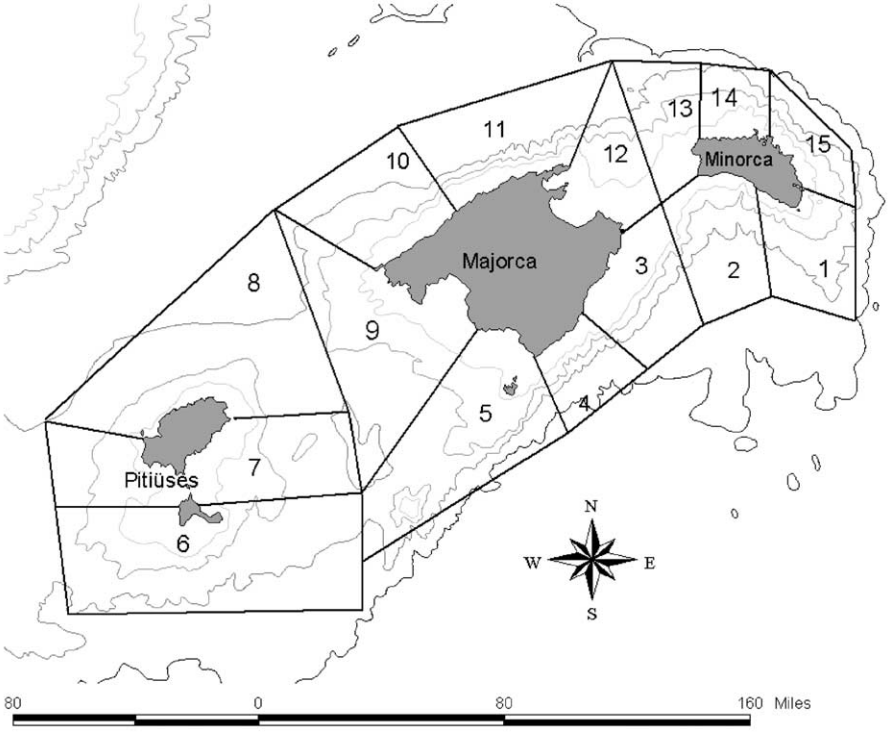

Fig. 1. Main fishing grounds off the Balearic Island.

Table 1
Summary statistics of the fishing operations surveyed by onboard observers. Fishing ground codes as in Fig. 1

	Fishing grounds validated	Number of fishing vessels surveyed	Number of operations surveyed	Average number of operations per month	By-caught turtles
Drifting longlines	5, 7, 8, 9	2	30	10.6	13
Purse-seines	5, 9	6	54	18.0	0
Bottom-trawls	5, 9, 12	6	100	19.1	0
Lobster trammel nets	3, 12, 13, 14	13	250	7.0	7
Bottom longlines	3, 4, 5	6	32	7.2	0
Red mullet trammel nets	2, 12, 13	10	162	10.8	1
Cuttlefish trammel nets	2, 12, 13	11	117	14.0	0
Fish-aggregating devices	9, 5, 12	5	50	8.2	0

Survey altitude was maintained at 500 feet and transects were flown at a groundspeed ranging from 140–156 km h^{-1}. The crew included two pilots and two observers, seated behind the pilots on each side of the plane. Six days were needed for completing each survey and surveys were conducted only in Beaufort (wind scale) <3, because sightability of turtles decreases in bad weather conditions (Marsh, 1990).

Once a turtle was observed, the location of the plain (obtained from a GPS) and the vertical angle of the sighting line (obtained from a clinometre) were recorded. This angle was then used for calculating the distance of the turtle to the flying line. Those turtles outside of a 200 m wide strip were not included in the calculations, as visibility decreases beyond such a distance (Marsh and Sinclair, 1989).

2.4. Statistics

The Kruskal-Wallis test (Cuadras, 1983) was used to assess differences in the perception of turtle abundance (sightings and catches) among fishermen from the three islands. The same test was applied to examine monthly differences in sighting and catch rates in each island.

The chi-square test (Cuadras, 1983) was used to check whether the turtle catch in the various grounds was distributed similarly to fishing effort. When statistically significant differences were observed, Ivlev's electivity index (Ivlev, 1961, quoted by Crowder, 1990) was calculated to identify the areas where turtle catch was higher or lower than expected. The Ivlev's index was calculated as:

$$I = (p_t - p_e)/(p_t + p_e)$$

where p_t is the percentage of turtles caught in a given area and p_e is the percentage of turtles expected to be caught according to the fishing effort deployed there. Confidence intervals were calculated, following Strauss (1979), as:

$$E_c = \left(2 - \left(\frac{2p_e}{(p_e + p_t)}\right)\right) \times \left[1 \pm 1.96 \sqrt{\left[\frac{2n_t p_t (1-p_e)(p_t+p_e)^2 + p_t(1-p_t)n_e}{+ p_e \dfrac{(1-p_e)}{n_t n_e (p_t+p_e)^2}}\right]}\right] - 1$$

where n_t is the number of turtles, and n_e is the total number of fishing grounds.

Onboard observers only monitored vessels from a few fishing grounds (Table 1). Thus, the CPUE data reported by them were compared with the CPUE data reported by the fishermen operating in the same fishing

Table 2
Number of registered vessels using the distinct types of fishing gear, fishermen interviewed and gear coverage

	Registered fishing vessels			Fishermen interviewed			Coverage
	Majorca	Minorca	Pitiüses	Majorca	Minorca	Pitiüses	
Artisanal boats	219	90	107	71	123	18	26.92%
Bottom-trawlers	41	7	13	18	7	13	62.3%
Drifting longliners	3	0	0	2	0	0	66.67%
Purse-seiners	10	1	0	6	1	0	63.64%

Table 3
Accumulated fishing effort (E_{za}) expressed as total fishing months on a yearly basis

Fishing gear	Majorca	Minorca	Pitiüses	TOTAL	%
Lobster trammel nets	462.10	417.65	269.40	1149.15	23.22%
Cuttle-fish trammel nets	584.41	107.11	377.52	1069.04	21.60%
Bottom longlines	359.62	307.43	169.75	836.80	16.91%
Bottom-trawls	411.33	134.66	194.40	740.39	14.96%
Red mullet trammel nets	270.85	179.35	154.28	604.48	12.22%
Fish and squid lures	98.72	38.18	14.00	150.90	3.05%
Purse-seines	120.00	12.00	*	132.00	2.67%
Fish-agregating Devices	115.33	*	*	115.33	2.33%
Gill-nets	25.50	*	27.50	53.00	1.07%
"Jonquillera"	38.81	*	3.25	42.06	0.85%
Traps	5.60	21.60	*	27.20	0.55%
Drifting longlines	14.00	*	1.00	15.00	0.30%
Pound nets	13.00	*	*	13.00	0.26%
TOTAL	2519.27	1217.98	1211.10	4948.35	

*Not used in the island.

grounds and not with the average CPUE in the whole archipelago. The conclusion about the reliability of fishermen's answer about by-catch was then extrapolated to the whole archipelago. The average number of fishing operations per month and vessel (Table 1) was used to transform the CPUE data reported by onboard observers (reported as turtles caught per fishing operation) to the unit used in the fishermen questionnaires (turtles caught per month and vessel). As data were not normally distributed, the Mann-Whitney test (Cuadras, 1983) was used to assess differences in the CPUE reported by fishermen for each kind of gear and those recorded by observers.

The 95% confidence intervals of estimated turtle catch with each fishing gear for the whole archipelago (ΣC_{za}) were calculated with the procedure detailed by Greenwood (1996) for stratified sampling.

3. Results

162 fishermen were interviewed from May 2002 to August 2002. This implies that information was collected from 32% of the vessels based in the Balearic Islands (Table 2). Because the purse-seiners, bottom-trawlers and drifting longliners fleet was smaller, coverage was proportionally higher.

Fishermen reported using 13 kinds of fishing gear, although purse-seines, bottom-trawling, drifting longlines and three types of trammel nets accounted for most of the fishing effort. Extrapolation of fishing effort by gear (Table 3) was easy once information on the number of artisanal boats (official records) and gear use (questionnaires) is known. Geographical distribution of effort within the archipelago was uneven (Table 3), as most of the bottom-trawling, purse-seining and drifting longline took place off Majorca.

In all islands, fishermen reported that sightings of turtles peaked from late spring to late summer, (Kruskal-Wallis test; $P < 0.05$ for all the islands) (Fig. 2). The same pattern was observed for turtle catch (Kruskal-Wallis test; $P < 0.05$ for all the islands) (Fig. 2). Monthly differences between islands were not statistically significant either for sightings or catches (Kruskal-Wallis test; $P > 0.05$).).

Most fishermen (56%) felt that turtles were declining in abundance and that fishing was at least partially

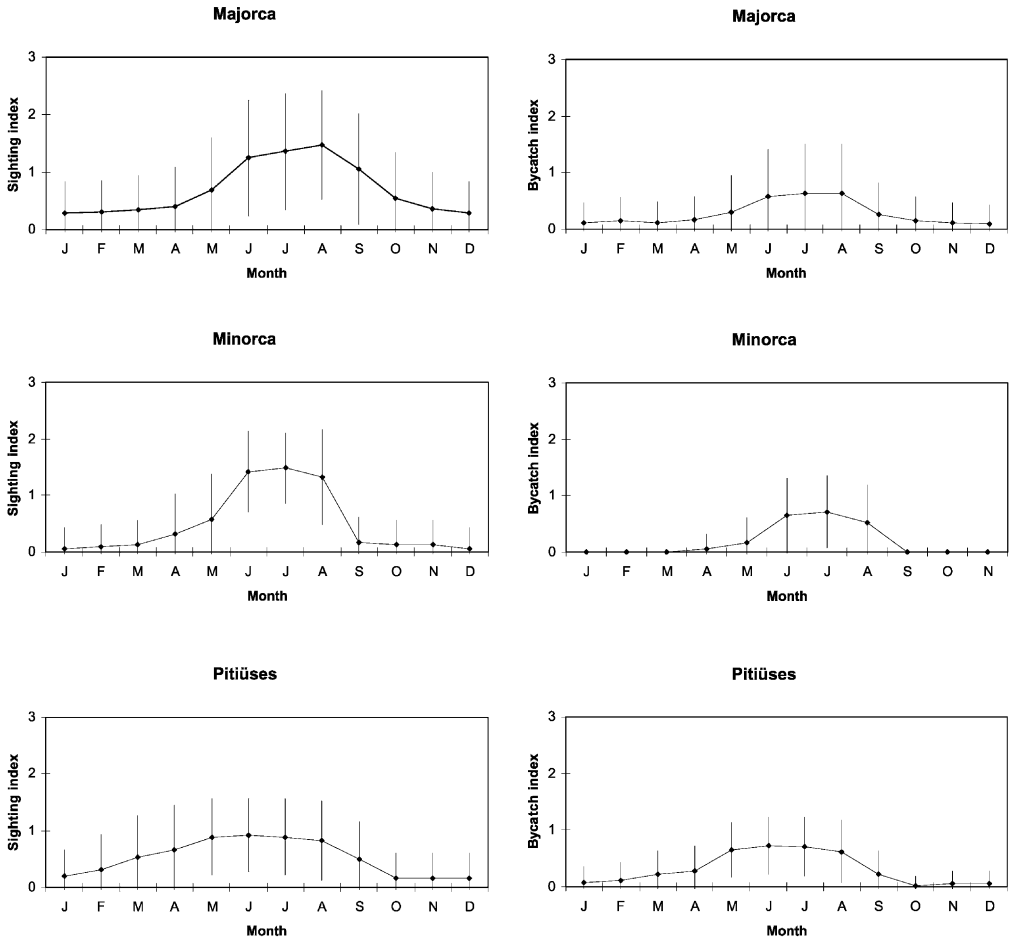

Fig. 2. Temporal distribution of loggerhead turtle sightings and by-catch off the Balearic Islands. The sighting and the by-catch indices range from 0 (no turtles) to 3 (many turtles).

Table 4
Average number of turtles caught monthly per vessel in 2001 according to fishermen's responses (CPUE) and number of turtles by-caught (C_{za}) off the Balearic Islands by professional fishing vessels based in a port in the archipelago

	CPUE	Majorca	Minorca	Pitiüses	Total	95% CI
Bottom-trawls	0.018	11	0	2	13	21–5
Purse-seines	0.039	5	0	*	5	8–3
Drifting longlines	4.665	96	*	6	102	111–93
Bottom longlines	0.010	8	*	0	8	24–0
Lobster trammel nets	0.170	39	152	4	196	269–123
Cuttlefish trammel nets	0.007	3	0	5	8	19–0
Red mullet trammel nets	0.009	2	4	0	6	15–0
Fish-aggregating devices	0.000	0	0	0	0	–
Traps	0.000	0	0	0	0	–
Gill-nets	0.000	0	0	0	0	–
"Jonquillera"	0.000	0	0	0	0	–
Pound nets	0.000	0	0	0	0	–
Fish and squid lures	0.000	0	0	0	0	–
Total		164	156	17	337	365–309

*Not used in the island.

responsible for this trend (59%). Turtles were a common by-catch around the archipelago; 33 fishermen reported an accumulated catch of 143 turtles in 2001. The combination of the data about fishing effort (Table 3) and the CPUE values calculated from the questionnaires (Table 4) suggests that 377 turtles (95% CI: 365–309) were by-caught in 2001 (Table 4). Although several kinds of fishing gear were involved in incidental catches, most turtles had been taken by drifting longlines (Majorca) or lobster trammel nets (Minorca) (Table 4). No statistically significant differences for any of the gear was found between the CPUE values calculated from the questionnaires and those from the observer's reports (Table 5). Therefore, we assume that the results of the questionnaire survey are an accurate reflection of by-catch rates in the validated fishing grounds, that fishermen data are reliable, and that the above reported value is a reliable estimate of turtle by-catch for the whole archipelago.

Table 5
Average number of turtles caught monthly per vessel in the fishing grounds validated according to fishermen's responses (CPUEf), average number of turtles caught monthly per vessel in the same fishing grounds according to observer's records (CPUEo) and results of the Mann-Whitney test (*P*-value)

	CPUEf	CPUEo	*P*-value
Drifting longlines	4.665	4.588	>0.05
Lobster trammel nets	0.326	0.144	>0.05
Purse-seines	0.017	0.000	>0.05
Bottom-trawls	0.070	0.000	>0.05
Bottom longlines	0.012	0.000	>0.05
Red mullet trammel nets	0.042	0.000	>0.05
Cuttlefish trammel nets	0.003	0.000	>0.05
Fish-aggregating devices	0.000	0.000	>0.05

The distribution of turtle by-catch observed among grounds differed significantly from that expected on the basis of the distribution of the fishing effort with lobster trammel nets, bottom longlines, and red mullet trammel nets (Table 6). This observation indicates that the vulnerability of turtles to fishing gear varies between areas. Given that only a few turtles were caught in bottom longlines and red mullet trammel nets, we focused on ascertaining the cause of this unevenness for the lobster fishery. Results showed that Ivlev's electivity index was much higher for most of the grounds off Minorca than for the other areas (Fig. 3), indicating a proportionally greater vulnerability of turtles to lobster trammel nets around this island.

Most turtles were dead when lobster trammel nets were hauled in, whereas the opposite was true for drifting long-lines (Table 7).

Table 6
Turtles by-catches reported by fishermen from each island (o), expected number of turtle by-catch from each island assuming that by-catch volume is proportional to fishing effort, as shown in Table 3 (e), and results of the Chi-square test (*P*-value). The values for the fishing grounds off each island have been pooled in the table, but the statistical analysis was conducted on the original data

	Majorca		Minorca		Pitiüses		
	o	e	o	e	o	e	*P*-value
Drifting longlines	64	65	0	0	6	5	0.940
Lobster trammel net	39	79	152	71	4	46	<0.001
Purse-seines	5	5	0	1	0	0	0.364
Bottom-trawls	11	7	0	2	2	3	0.566
Bottom longlines	8	3	0	3	0	1	<0.001
Red mullet trammel nets	1	2	4	2	0	1	<0.001
Cuttlefish trammel nets	2	4	0	1	5	3	0.397

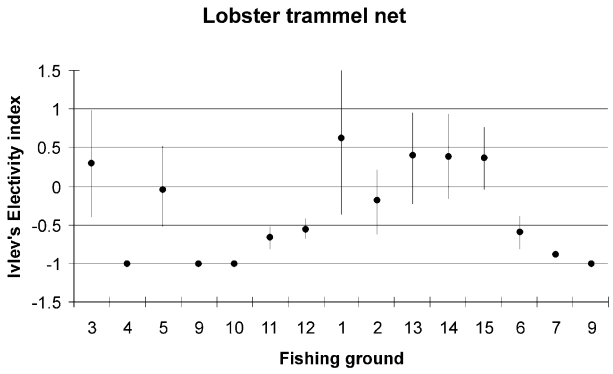

Fig. 3. Vulnerability of loggerhead turtles to lobster trammel nets in several fishing grounds off the Balearic Islands, as indicated by Ivlev's electivity index. Vertical lines show confidence intervals (95%). Fishing ground coding as in Fig. 1.

Table 7
Immediate mortality of loggerhead turtles caused by incidental catch. n: sample size. –: no data

	Fisherman reports		Onboard observer reports	
	n	Mortality (%)	*n*	Mortality (%)
Drifting longlines	70	0.0	13	7.7
Lobster trammel nets	45	77.7	7	100.0
Purse-seines	2	0.0	–	–
Bottom-trawls	6	50.0	–	–
Bottom longlines	3	0.0	–	–
Red mullet trammel nets	2	50.0	1	0
Cuttlefish trammel nets	–	–	–	–

Each aerial survey covered 329.03 km^2 (1645.15 km×0.2 km), i.e., 4.23% of the total surface of the continental shelf of the archipelago (7773.7 km^2). On average, 18.5±3.5 turtles were observed in each survey, which suggests that 437.1±41.7 turtles occurred simultaneously on the water surface over the continental shelf.

4. Discussion

Onboard observers have been widely used in fishery surveys (King, 1995) as they supply detailed and reliable data on by-catches. From surveys such as these, drifting longlines and bottom trawling were identified long ago as significant threats to marine turtles (Camiñas, 1988; Aguilar et al., 1995). One of the advantages of onboard observers is that they can detect incidental turtle catches in only a few trips when catch per unit effort is high. However, observers usually fail to detect these catches when they occur at low frequency, unless many fishing operations are surveyed. Furthermore, when the number of fishing operations per month is low, as is the case for artisanal vessels in the Balearic Islands, a long time is needed for surveying a large number of fishing operations. In this situation, questionnaire-based surveys provide the most practical method to assess the extent of the problem (Godley et al., 1998), although data may be poor or biased. In this survey, we validated fishermen answers with data directly collected by observers onboard fishing vessels.

Loggerhead turtles are found in the Balearic Islands mainly in the summer, as indicated by higher sighting rates throughout the warm season. Drifting longlines and lobster trammel nets are the most widely used fishing gear in late spring and summer and, hence, are a major cause of incidental catch from locally based boats. Drifting longlines have been identified as a threat for marine turtles in the western Mediterranean, where about 15.000 turtles are thought to be caught yearly (Mayol et al., 1988; Aguilar et al., 1995; Camiñas, 1988), but information on incidental catch of turtles with lobster trammel nets is scarce.

Delaugerre (1987) and Laurent (1991) were the first to report on the risk of entanglement in lobster trammel nets in the western Mediterranean; however, they considered the number of captures low, although no supporting figures were produced. On the basis of a questionnaire-based survey, Godley et al. (1998) concluded that lobster trammel nets might be a threat for marine turtles in the eastern Mediterranean but they did not validate their results. Moreover, the size of the fleet operating in their study area was not established and hence, total catch was impossible to estimate.

In the present study, in most cases we were able to precisely determine fleet size and validate the CPUE values reported through information collected by observers. Unfortunately, a calculation of total by-catch by longliners in these islands is unfeasible because of the absence of reliable data on the number of drifting longliners that move from mainland Spain to the archipelago in pursuit of migrating schools of swordfish *Xiphias gladius* in the warm season (Camiñas and de la Serna, 1995). However, there is little doubt that the total take is much larger than the 100 individuals by-caught by the three longliners based in ports in Majorca. In spite of this shortcoming, and the fact that a questionnaire survey does not generate reliable estimates of by-catch but just provide evidence on the general extent of the problem (Lien et al., 1994), these results show that lobster trammel nets are a major cause of incidental catch of loggerhead turtles off the Balearic Islands from locally based boats.

The data from the aerial surveys provide a minimum population size for turtles over the continental shelf of the Balearic Islands. However, the actual population size should be larger, as turtles are known to spend more than 50% of their time submerged (Gómez de Segura et al., 2003). Unfortunately, as the actual percentage of time that turtles remain at surface while off the Balearic Islands is unknown, absolute population

size cannot be calculated (Marsh et al., 1989). Despite this shortcoming, aerial survey data stress the relevance of lobster trammel nets as a threat for turtle conservation in the area, because turtle by-catch and turtle population size are roughly at the same order of magnitude. The aerial surveys covered only the continental shelf and hence are uninformative about turtle abundance off-shore, where drifting longlines are deployed.

The relevance of lobster trammel nets becomes even more evident when the high mortality rate of loggerhead turtles entangled in the gear is considered. Fishermen and onboard observers coincided in that most of the turtles entangled in these nets were found dead, whereas those hooked by drifting longlines were released alive. Similar results were reported by Delaugerre (1987), Laurent (1991) and Aguilar et al. (1995). Although some post-release mortality is likely, this is usually considered to be low (Polovina et al., 2000), with long-term survival chances that probably exceed 50% (Aguilar et al., 1995; NMFS-SEFSC, 2001). The combination of a survival rate of 50% (Aguilar et al., 1995) with an annual catch of 15.000 turtles by longliners (Mayol et al., 1988; Aguilar et al., 1995; Camiñas, 1988) yields an annual absolute mortality in the whole western Mediterranean of about 7.500 turtles. On the other hand, lobster trammel nets kill about 152 specimens in the Balearic Archipelago, which suggests that a few thousands are killed yearly by lobster trammel nets in the whole western Mediterranean. The conclusion is that lobster trammel net may be the second most relevant mortality cause in the basin.

Although detailed information about loggerhead stock size in the whole western Mediterranean is required to assess the relevance of the mortality due to by-catch, precise data on the origin of the turtles is relevant as well. Genetic data indicate that the turtles in the western Mediterranean originate from North-American and eastern Mediterranean rookeries (Laurent et al., 1993, 1998; Laurent and Lescure, 1995; Casale et al., 2002). In this scenario, the Balearic Islands may act as a sink for the population that nests in the eastern Mediterranean because of its small size (Broderick et al., 2002), whereas the impact of by-catch mortality on the much larger North-American population (NMFS-SEFSC, 2001) is probably negligible. However, this conclusion is premature, as haplotypic frequencies observed to date in the western Mediterranean may also be explained by an Atlantic origin alone. Further genetic research is needed to clarify the actual impact of the catches.

An intriguing result is the uneven vulnerability of turtles to fishing gear within the archipelago. Loggerheads are taken in larger numbers in south-eastern Majorca and south-eastern Minorca because of greater populations in these areas, as indicated by relative density data obtained trough the aerial surveys. However, the above-average vulnerability observed in the remaining grounds off Minorca cannot be explained by greater densities as no turtle was recorded there by the aerial surveys, hence suggesting that these grounds have a small stock of turtles. Although the loggerheads can dive deeper than 200 m, they usually remain at much shallower depths (Lutcavage, 1997; Houghton et al., 2002). Trammel nets are usually deployed deeper than 100 m off Majorca and the Pitiüses, while off Minorca they are usually set as shallow as 50 m, thus favouring the take of turtles. Detailed information on diving behaviour of the loggerhead turtle off the Balearic Islands is needed to investigate this hypothesis.

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