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Interactions between small cetaceans and the purse-seine fishery in western Portuguese waters

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SUMMARY: Marine mammal interactions with Portuguese purse-seine fisheries operating in four different ports (Figueira da Foz, Sesimbra, Setúbal, Sines) were studied (July-October 2003). Observers accompanied commercial fishing vessels and monitored 48 fishing trips. An interview survey of skippers was also carried out (n = 36). Three species of marine mammals were observed in 31 sightings during the commercials trips but only the species *Delphinus delphis* and the category Delphinidae were observed to interact with fishing activities. Small cetaceans were observed to sink, gather or disperse school fishes and damage gear. Mean CPUE and fishing effort values did not change significantly in the presence of dolphins (H = 0.06 and H = 0, both p>0.05). Results from Figueira da Foz indicate that cetaceans are attracted to fishing grounds with a high abundance of their prey-species. Fishermen reported three by-catch events off Figueira da Foz. Compared with other fisheries, purse-seine fishing does not seem to be among the most damaging to marine mammals.

Keywords: purse-seine, fishing activity, marine mammals, interaction.

RESUMEN: Interacciones entre mamíferos marinos y la pesca de cerco en aguas Portuguesas. – En este trabajo ha sido estudiada la interacción de los mamíferos marinos con la flota de cerco Portuguesa de julio a octubre de 2003, en cuatro puertos pesqueros (Figueira da Foz, Sesimbra, Setúbal, Sines). Los observadores acompañaron los barcos de pesca de cerco y supervisaron 48 viajes de pesca. Una encuesta por entrevista a los capitanes fue también realizada (n = 36). Tres especies de mamíferos marinos han sido observadas en 31 avistamentos durante los viajes de pesca, aunque sólamente la especie *Delphinus delphis* y la familia Delphinidae han interaccionado con las actividades de pesca. Los pequeños cetáceos fueron observados hundiendo, juntando o dispersando los cardumes de peces y a veces dañando las redes. Los valores del esfuerzo de pesca y de CPUE no cambiaron perceptiblemente con la presencia de delfines (H = 0.06 and H = 0, both p>0.05). Los resultados de Figueira da Foz indican que los cetáceos son atraídos a zonas de pesca con una elevada abundancia de sus especies presas. Los pescadores registraron tres acontecimientos de by-catch en Figueira da Foz. Cuando se compara con otras industrias pesqueras, la pesca de cerco no parece estar entre las que más dañan a los mamíferos marinos.

Palabras clave: arte de cerco, actividad pesquera, mamíferos marinos, interacción

INTRODUCTION

Many fisheries around the world have significant interactions with marine mammals (Northridge, 1991; STECF, 2002). By-catches and incidental mortality of small cetaceans associated with fishing activities are the best-known and best-documented part of these interactions (e.g. Harwood, 1983; Read, 1996). Gillnets and pelagic trawls are responsible for most of the incidental mortality of cetaceans in European waters, although by-catch events have been reported for the majority of fishing gears (Northridge, 1991; STECF, 2002). Another aspect of cetacean-fisheries interactions is the inter-

ference of cetaceans with fishing activities, which can negatively affect fisheries by resulting in loss of bait, damage to fishing gear, decreased catches and increased time spent in fishing operations (Meyer *et al*., 1992; Wickens *et al*., 1992; Nitta and Henderson, 1993; Kobayashi and Kawamoto, 1995; Morizur *et al*., 1999; Silva *et al*., 2002; STECF, 2002; López *et al*., 2003).

In Portuguese continental waters, data on stranding records and fishermen's reports indicate that incidental capture of small cetaceans and other operational interactions take place mainly in gillnet fisheries (Sequeira *et al*., 1997; STECF, 2002). However, fisheries such as purse-seining for small pelagics (Parente, 2000; Stratoudakis and Marçalo, 2002) provide an opportunity for operational interactions with small cetaceans for two main reasons: (i) purse-seiners target the main prey species of small cetaceans (Northridge, 1991; Pauly *et al*., 1998; Silva, 1999; Santos *et al*., 2004; Santos *et al*., 2007) and (ii) they operate within their distribution area (Sequeira and Ferreira, 1994; Silva and Sequeira, 2003). Landings from the Portuguese purse-seine fishery (around 70000 t per year from 135 vessels, ICES, 2006) are composed mainly of sardine (*Sardina pilchardus*), an important prey species of the common dolphin (*Delphinus delphis*) (Silva, 1999; Santos *et al*., 2004), which is the small cetacean most frequently observed off the Portuguese continental coast (Sequeira *et al*., 1997; Silva and Sequeira, 2003). Fishing activity takes place within the coastal waters of the continental shelf, mainly below the 100 m depth contour (Parente, 2000; Stratoudakis and Marçalo, 2002). In addition, purse-seiners operate mainly from sunset to sunrise, coinciding with the feeding period of dolphins (Waring *et al*., 1990; Aguilar, 1997; Crespo *et al*., 1997) and thus increasing the potential for cetacean-fisheries interactions.

Portuguese purse-seine fishers have repeatedly expressed concern about the adverse effects (for example reducing catches, increasing fishing time) of dolphins on fishing activities, providing some indication that interactions with small cetaceans may be important in this fishery. To address this hypothesis, data were collected on the occurrence of cetaceans during purse-seine fishing activities by observers onboard commercial fishing vessels and through interviews to skippers. Vessels were registered in four ports on the western Portuguese coast (Fig. 1), which contribute 29% of the annual purse-seine sardine landings in the total area. Observations were carried out between July and October 2003, coinciding with the period of most intense fishing activity of the purse-seine fleet. Rates of cetacean attendance and interference with the fishing activities are presented and the effects of the presence of cetaceans during fishing activities on the fishing effort and catch rate are described.

METHODS

Onboard observer trips

Data were collected by observers on board commercial purse-seiners from four ports off the northern (Figueira da Foz), central (Sesimbra and Setúbal) and southern (Sines) regions of the west Portuguese coast (Fig.1). Observations were carried out continuously and the observation effort within each phase of the fishing trip (steaming to or from the fishing areas, searching for fish schools and fishing) was recorded. Observers noted information on the presence, behaviour and by-catch events of cetaceans (hour, position, species, and number of individuals) and types of interference with the fishing activities. Cetaceans were considered to be present during a fishing event whenever an individual was sighted in the vicinity of the vessel. The behaviour of fish schools was observed with the help of the boat's equipment, sonar and echosounder, but unfortunately neither printing nor electronic recording devices were available on the vessels to store the observations. Cetaceans were considered to interfere with the fishing activity when the behaviour of fish schools was different from that usually observed during fishing operations. These unusual reactions were generally abrupt changes in fish schooling behaviour and were classified as scattering (shoal "explodes" and individual fish become scattered), sinking (shoals dive towards the sea bottom) or clustering (shoals become more compact and cohesive). Observers also recorded whether any damaging of the nets occurred.

Sighting rates for each species of cetacean were calculated as the number of groups sighted per hour of observation for each fishing trip. Mean sighting rates where then calculated for each species for each fishing trip and, in the case of the common dolphin, mean sighting rates were also calculated for each area. Sighting rates of the common dolphin were

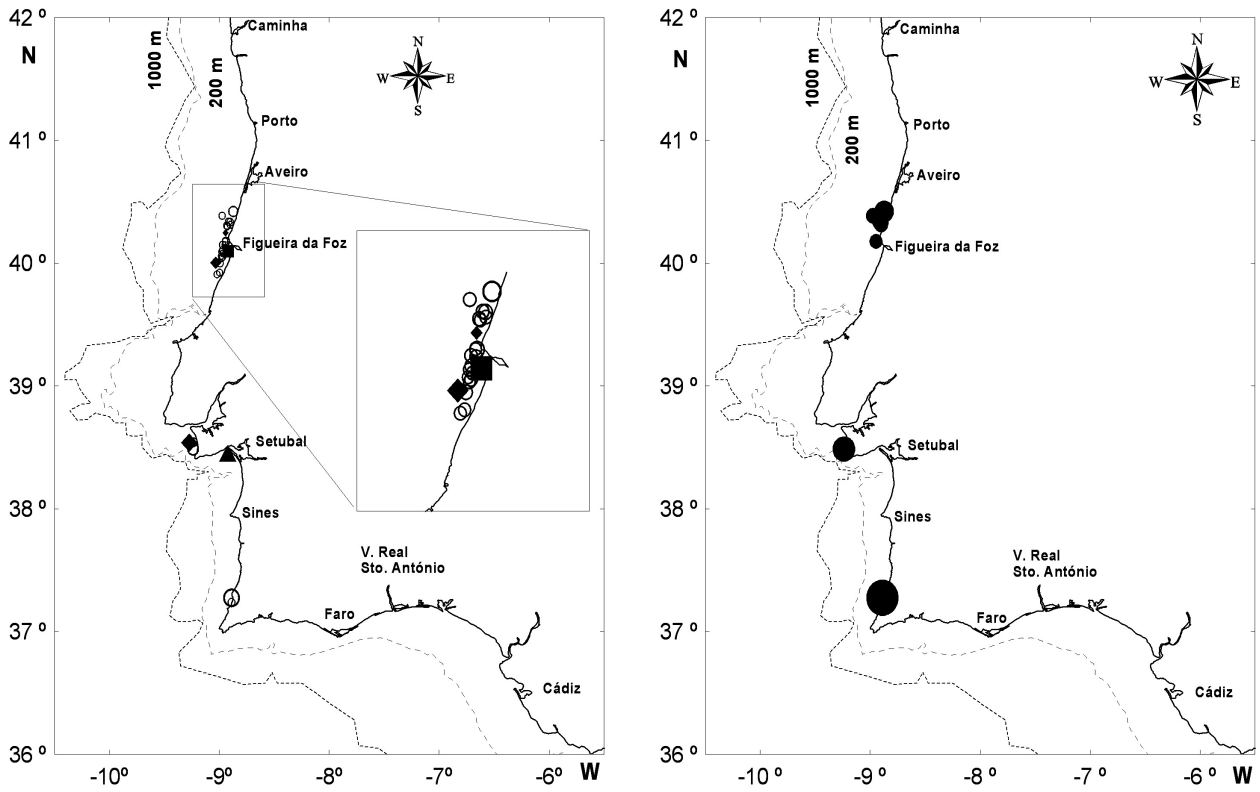

FIG. 1. – Distribution of recorded sightings of *Delphinus delphis* (○), *Tursiops truncatus* (▲), *Phocoena phocoena* (■) and Delphinidae (◆) (A). Distribution of recorded sightings of *Delphinus delphis* during fishing events (B). Point size is proportional to group size of the cetaceans.

compared among areas using Kruskal-Wallis tests (Zar, 1999).

The total catch biomass and species composition per fishing set (visually estimated by the skipper) was recorded. Fishing effort was calculated as the sum of the time spent searching and fishing per fishing trip, as both affect catch rates (Hilborn and Walters, 1992). The catch-per-unit effort (CPUE) was calculated as the catch biomass per unit of fishing effort. Fishing effort and CPUE were compared among fishing trips carried out in the presence and absence of cetaceans using a Kruskal-Wallis test. Only data from the northern region (Figueira da Foz) were analysed as the majority of fishing events attended by cetaceans occurred in this region.

Interview survey

Interviews were carried out by the observers during fishing trips and focused on the skippers' last trip (usually the day before). They were intended to provide information comparable to direct observations, although necessarily less complete. Data on the number of fishing sets, catch biomass and species composition of fishing sets, presence and by-catch events of cetaceans (hour, position and species) and interference with the fishing activity were collected for each fishing trip. As skippers were generally not able to distinguish cetacean species, their sightings were classified by the observers according to the description provided.

RESULTS

Purse-seine fishing practices were similar among ports. Vessels usually left simultaneously from the port and the fishing areas rarely extended beyond one degree of latitude to the north or to the south of their home port, although they could vary considerably between days. Fishing trips took around 9 hours; steaming comprised 7-15% of the trip time, while the remaining time was split between searching and fishing operations. The net was generally set once or twice per fishing trip at sunset or at sunrise. The main target species varied according to their local abundance and vessel characteristics. Sardine was the target species of vessels from Figueira da

TABLE 1. – Summary information of the monitored fishing trips off the Portuguese west coast, June-October 2003.

Area	No. vessels Fleet	Sampled	No. Trips Fleet	Landings (t)	On-board observers Observation effort (hours)	No. trips	No. sets	Catch (t)	CPUE (kg/hour)	Interviews No. trips	No. sets	Catch (t)
North	9	1	701	2809.8	115 h 12 min	18	19	73.6	1109.6	14	18	112.9
Centre	16	8	1806	2107.2	178 h 06 min	23	44	22.7	153.9	19	41	49.3
South	6	2	375	1609.2	63 h 18 min	7	9	35.8	1362.3	3	6	27.8
Total	31	11	2882	6526.2	356 h 32 min	48	72	132.1	-	36	65	190

TABLE 2. – Species, number and percentages of sightings, mean sighting rate and number of individuals observed off the Portuguese west coast, June-October 2003 (observer data).

Species	Sightings Number	%	Mean sighting rate (groups/hour)	No. ind.
Delphinus delphis	25	80.7	0.72	183
Tursiops truncatus	2	6.5	0.03	10
Phocoena phocoena	1	3.2	0.01	2
Delphinidae	3	9.7	0.03	6
Total	31	-	0.89	201

Foz and Sines, while the fleets from the central area directed their effort towards horse-mackerel (*Trachurus trachurus*) and demersal species. Sardine comprised 72% of the total catch biomass within the study period, followed by Spanish-mackerel (*Scomber japonicus*) and horse-mackerel (around 5% each).

Observer trips

On-board observers monitored 48 fishing trips during which 72 fishing sets yielding 132 t of fish were recorded (Table 1). In a total of 356 h 32 min of observation (53.4% between sunset and sunrise) there were 31 sightings of cetaceans, corresponding to 201 individuals and a mean sighting rate of 0.89 groups/hour (Table 2). 42% of the sightings took place during navigation while the remaining ones occurred almost equally during fishing operations and while vessels were searching for schools of fish.

Three cetacean species were recorded: the common dolphin, the bottlenose dolphin (*Tursiops truncatus*) and the harbour porpoise (*Phocoena phocoena*). The common dolphin was sighted across the study area and showed the highest frequency of occurrence (80.7%) and relative abundance (mean sighting rate = 0.72 groups/hour) of the three species (Table 2; Fig. 1). Sighting rates of the common dolphin were higher in the north, intermediate in the south and lower in the central regions but significant differences were observed only between the northern and the central region ($Q = 1.75$, $p<0.015$) (Table 3). The size of common dolphin groups ranged from 1 to 60 individuals (median = 7.6 individuals). Bottlenose dolphins and harbour porpoises were sighted twice (0.09 groups/hour) and once (0.03 groups/hour), respectively (Fig. 1).

During fishing operations, most of the sightings occurred after the net started to be set and all individuals identified to the species level were common dolphins. Overall, common dolphins attended 12.5% of the fishing sets, being considerably more frequent during fishing operations off the northern (Figueira da Foz; 31.6%) and southern (Sines; 22.2%) regions than in the central region (Setúbal/Sesimbra; 2.3%) (Table 3). Interactions were observed in 4% ($n = 3$) of the fishing events: fish schools were observed to sink and scatter (2 cases) and to cluster (1 case). Except for the assembling effect on fish, which facilitated encircling of the school, interactions were considered to negatively affect the fishing activity. Observers also regis-

TABLE 3. – Sightings of *Delphinus delphis* (observer data) by area.

Area	No. sightings	Mean sighting rate (groups/hour)	Group size Mean	SD	Occurrences during fishing events (%)	Interactions
North	21	1.56	7.4	13.3	31.6	2
Centre	2	0.20	7.3	13.4	2.3	0
South	2	0.39	33.0	38.2	22.2	1
Total	25	0.72	-	-	12.5	3

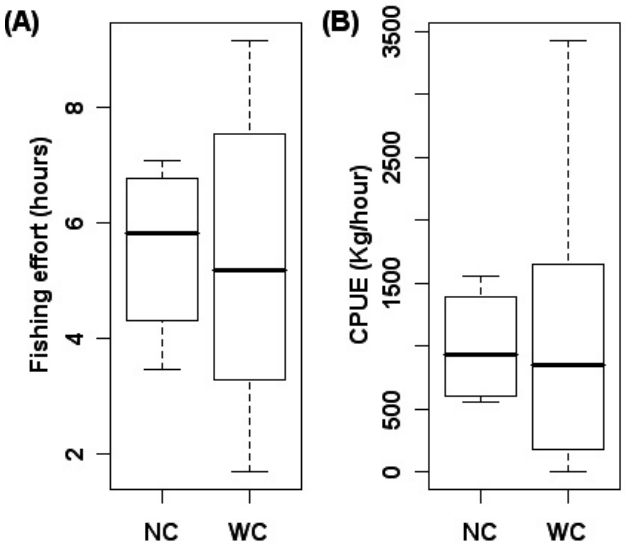

FIG. 2. – Boxplot of (A) fishing effort and of (B) CPUE of fishing trips without (NC) and with (WC) the presence of small cetaceans. Boxes are drawn with width proportional to the square-roots of the number of observations in the groups. The box stretches from the 25th percentile to the 75th percentile. The line across the box represents the median. The ends of the vertical line indicate the minimum and maximum data values.

tered some opportunities for fishing events aborted due to the presence of dolphins. In fact, although skippers know about the association between sardine and dolphins, they believe that dolphins are one of the major predators of sardine and responsible for reducing catches, so they tend to avoid them.

The mean CPUE was substantially higher in the southern (Sines, 1362 kg/hour) and northern regions (Figueira da Foz, 1110 kg/hour) than in the ports of the centre (Sesimbra/Setúbal, 154 kg/hour). In the northern region, fishing effort and CPUE were not significantly different between fishing trips attended by small cetaceans (n = 12, 5.4 ± 2.6 h, 1148.5 ± 1145.9 kg/hour) and fishing trips not attended by small cetaceans (n = 4, 5.6 ± 1.6 h, 992.8 ± 480.6 kg/hour) (H = 0.06 and H = 0, both $p>0.05$). However, catch rates were more variable in the presence of small cetaceans (Fig. 2), although no significant differences were found (F = 2.62 and F = 5.68, both $p>0.05$). Onboard observers registered no accidental captures of cetaceans.

Interview survey

A total of 36 fishing trips were monitored, during which 65 fishing sets yielding 190 t of fish were recorded (Table 1). Skippers reported 18 sightings of small cetaceans (all classified in the category Delphinidae). Half of the sightings occurred during fishing operations, 39% during navigation and 11% during searching for fish schools. Cetaceans attended 9 (13.8%) of the total number of the fishing sets, affecting fishing operations on 8 occasions (12.3% of the fishing sets). Skippers reported that cetaceans appeared after the net started to be set and disturbed fishing operations by causing fish schools to sink (4 cases) or scatter (1 case) and by damaging the fishing gear (1 case). In two cases, in which dolphins clustered the fish school, cetaceans were considered not to affect the fishing activity, whereas the other six interactions were considered to negatively affect the fishing activity. Both the number of sightings per trip and the rates of attendance and interaction with fishing operations were considerably higher off the northern than off the central area (Sesimbra/Setúbal), supporting the data from onboard observers (Table 4). The limited number of trips sampled off Sines precludes a meaningful comparison among the three regions.

TABLE 4. – Sightings of Delphinidae (interview data) by area.

Area	No. sightings	Occurrences during fishing events (%)	Interactions
North	14	44.4	7
Centre	3	2.4	1
South	1	0	-
Total	18	13.8	8

Skippers reported three events of accidental catches of cetaceans (eight individuals being caught) off the northern area, corresponding to 4.6% of the fishing events. All individuals were released by lowering the head rope of the net. One of the animals died *in situ* but it was impossible to ascertain whether the others survived the interaction or whether any injuries occurred that might have caused death after release.

DISCUSSION

Small cetaceans were frequently sighted within the operation area of the Portuguese purse-seine fishery, as shown by data collected by on-board observers. Three cetacean species were recorded: the common dolphin, the bottlenose dolphin and the harbour porpoise. Bottlenose dolphins were sighted in the Sado estuary near Setúbal, where there is a resident population (dos Santos *et al*., 1998), and harbour porpoises were sighted in the Figueira da

Foz area, where there is also evidence of the existence of a resident population (Ferreira, 2000). Cetaceans were recorded in 31 out of 48 fishing trips (65%) accompanied by observers. The common dolphin showed the highest sighting rate, 0.72 groups/hour, and accounted for 80% of the sightings. Common dolphins attended 12.5% of the fishing sets and, in all cases, were detected after the net started to be set. The presence of common dolphins was observed to negatively affect fishing operations in 3% (n = 3) of the net sets by causing the fish schools to sink and scatter. Although most interactions were judged to negatively affect the outcome of the fishing activity, neither the CPUE nor the fishing effort changed significantly in the presence of cetaceans during fishing trips. However, catch rates were more variable in the presence of cetaceans. No by-catches of small cetaceans took place when the observers were on board. The highest interaction rates were observed in the northern and southern regions, where the highest catch rates were also registered, suggesting that both cetaceans and fishers are attracted to fishing grounds with high abundance of the prey/target species.

Data collected during interviews with skippers of purse-seine vessels showed that small cetaceans (Delphinidae) were sighted on 50% of fishing trips and attended 13.8% of the net sets, mostly in the northern region, generally supporting observer data. However, skippers reported higher interference rates (12.3%) than on-board observers and, in addition to sinking or dispersing fish schools, small cetaceans were reported to damage the fishing gear. Skippers reported small cetacean by-catches (8 individuals) in 3 of the 65 fishing events. Although seven individuals were released alive it is impossible to know whether they survived the interaction. The reason for the different interference rates is unclear but it is possible that the occurrence of by-catch events is responsible for this difference. The fact that skippers reported by-catch events makes us believe that they did not fear sanctions and that probably no occurrence of cetacean by-catches was concealed. Interview surveys, although not necessarily a reliable source of quantitative data, provide a means of obtaining minimum estimates of fishing sets attended by cetaceans, by-catches of cetaceans and cetacean interference with fishing activities.

Purse-seining is mostly dependent on detection and location of fish schools by hydroacoustic instruments (Misund, 1997 *in* Fréon and Misund, 1999) and is conducted on fish aggregated in dense shoals normally during night-time (Pitcher, 1983 *in* Fréon and Misund, 1999). Field studies of fish behaviour are performed under uncontrolled conditions and therefore provide contrasting results. Also, fish schools' behaviour is affected by several external factors, such as sound stimuli from vessels, visual stimuli of the net and the presence of predators (Fréon and Misund, 1999), so it is difficult to identify a single cause of changes in their behaviour. However, there is evidence indicating that the swimming speed of schooling herring and mackerel increases in the presence of an active vessel (Misund, 1994), and that they tend to avoid them by moving horizontally but remain at about the same swimming depth during circling and pursing (Misund, 1993). More abrupt changes in schooling behaviour like splitting, escaping and panic swimming of the schools may indicate that visual stimuli from the gear or the presence of predators have a stronger effect on their behaviour than the sound stimuli from the vessel (Misund, 1993; Schwarz, 1985 *in* Misund, 1994). On the other hand, the majority of net sets registered by onboard observers occurred between sunset and sunrise, when fish schools seem to show little avoidance of the net. Misund (1993) reported that mature, shoaling herring in the spawning grounds off western Norway show little avoidance of the net in the winter darkness but, in contrast, in the North Sea summer daylight, the herring schools often avoid the net and escape in about 35% of the sets. In fact, in purse-seine fisheries along the Norwegian coast, shoaling herring seldom escape capture at night (Misund, 1990 *in* Misund, 1994). We therefore consider that, most probably, changes in fish schooling behaviour during net sets attended by cetaceans, as reported by observers, were due to fish schools' awareness of the presence of a predator. Predators are known to not only change the microdistribution of their prey, which usually react by increasing their packing density and school splitting and avoidance, but can also cause a large decrease in abundance in the area due to long distance flight by the prey (Fréon and Misund, 1999). In acoustic surveys of *Sardinella aurita* in Venezuela, Fréon and Misund (1999) observed that fish disappeared when dolphins arrived in the area.

By-catches of cetaceans provide ample evidence that interactions with small pelagic fisheries have a high probability. Our results showed that

Delphinidae are accidentally caught in the Portuguese purse-seine fishery in accordance with data collected from similar fisheries in neighbouring areas off northwest (Galician waters, López *et al*., 2003) and southern Spain (southeastern Mediterranean waters, Aguilar, 1991) and across Mediterranean waters (Tudela, 2004). Although cetacean-fishery interactions are known to affect fisheries, few studies have been specifically dedicated to the evaluation of cetacean interference with fishing operations. The types of interference observed in this study are comparable to those reported by purse-seine fishermen in Galician waters (northwest Spain), where dolphins were observed to scare and eat fish and to damage the fishing gear (López *et al*., 2003). The observed rate of cetacean attendance (12.5%) to nets sets is considerably higher than that reported for pelagic trawling on the coast of Scotland (4%), where, additionally, no interactions were observed (Pierce *et al*., 2002). Interestingly, both attendance and interaction (3%) rates have comparable magnitude to those reported for the tuna fishery in the Azores (northeast Atlantic, Silva *et al*., 2002). In this fishery, cetaceans were present in <10% of the fishing events and interfered with fishing in <5% of the cases by causing the fish schools to sink and feed on live bait. Small pelagic fish may mediate interactions in tuna fisheries since these are the prey species of both tuna and cetaceans.

Most of the observed interactions took place in the northern region of the Portuguese coast (Figueira da Foz) and involved the common dolphin. This pattern is consistent with the distribution of cetaceans in Portuguese waters, since the common dolphin is the predominant species and shows a decreasing abundance from north to south along the coast (Silva and Sequeira, 2003). It also agrees with the overall distribution of sardine, the most abundant small pelagic fish in Portuguese waters and the target of the purse-seine fishery. Data collected during acoustic surveys between 1997 and 2002 (Marques *et al*., 2003) show that 34-88% of estimated sardine (in numbers) was distributed in northern Portuguese waters (between 39º and 42ºN). Interactions in this fishery may be partly explained by prey-predator relationship between sardine and the common dolphin, since sardine is an important food resource for the common dolphin across Iberian waters (Silva, 1999; Santos *et al*., 2004). Silva (1999) reports that 63% of stranded and 96% of accidentally caught common dolphins off the Portuguese coast contained mainly juvenile sardine in their stomachs, corresponding to 24% and 56% of stomach content biomass. The fact that the northern region is the main recruitment area of sardine, and that young-of-the-year (<16 cm) are usually observed in the autumn, when most observations were carried out, may have contributed to higher interaction rates in the area.

A total of 84 fishing trips (on-board observers and interviews) and 137 fishing sets were monitored within this study, as a first attempt to describe cetacean interference with the Portuguese purse-seine fishery. Observations covered 4% of the fishing trips and 5% of the landings of the fleet operating at the observed ports during the study period. In spite of the substantial observation effort, this study reports information from a short period that may not be representative of the average situation, so generalisation of interference or by-catch rates was not attempted. The low frequency of interactions and apparently stable catch rates do not support the hypothesis that small cetaceans are harmful to the Portuguese purse-seine fishery. However, additional data is needed to account for temporal and spatial variability of interactions, and estimates of fishing effort and cetacean abundance are required to assess the importance of by-catches in this fishery.

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