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Fishery by-catches of marine mammals in Galician waters: results from on-board observations and an interview survey of fishermen

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Abstract

Rates of cetacean by-catch were investigated in Galician waters (NW Spain) using a combination of observer trips on fishing vessels, a carcase recovery scheme and an interview survey of fishermen, carried out over two years (1998–1999). All these data sources are suspected of underestimating by-catch due to the sample of co-operating fishermen being, necessarily, self-selecting. No by-catches were seen during observer trips, although not all sectors of the fishery could be covered. The carcass recovery scheme yielded seventeen cetacean carcases over two years, which compares to around 35 by-caught cetaceans recorded annually by the Galician strandings network. Analysis of interview data suggested that around 200 cetaceans might be caught annually in inshore waters and around 1500 in offshore waters. Confidence limits were wide for all estimates. The highest by-catch rates were estimated for gillnets and offshore trawling. The majority of by-catches are small dolphins, probably mainly *Delphinus delphis*. Smaller numbers of *Tursiops truncatus* and *Globicephala melas* are also reported. Comparing the interview estimates of by-catch rates with minimum estimates of population size, it is suggested that by-catches of *D. delphis* and *T. truncatus* may be unsustainably high and that routine monitoring of fishery by-catches in Galician fisheries is required.

Keywords: Fishery by-catch; Cetaceans; *Delphinus delphis*; *Tursiops truncates*; *Phocoena phocoena*; Galicia (NW Spain)

1. Introduction

Galicia is the main fishing region of Spain and one of the most important in the world. Seasonal upwelling near the coast during April to September, which influences the entire shelf area (Fraga, 1981), sustains high productivity, which, in turn, is expressed in high biodiversity, including nearly 300 species of fish (Solórzano et al., 1988) and 78 species of cephalopod (Guerra, 1992). Galician waters are an important for hake (*Merluccius merluccius*), scad (*Trachurus trachurus*) and blue whiting (*Micromesistius poutassou*), all of which are of high commercial value.

There are 87 fishing ports in Galicia (Fig. 1), used by more than 6000 fishing boats that landed 147,514 metric tons in 1997 (data from the Galician Institute for Statistics). The total annual number of fishing trips by the (full-time) Galician fleet is estimated as being around 1.1 million (Table 1). In inshore waters, small boats target mainly molluscs and crustaceans. The offshore, demersal fishery targets hake, blue whiting, scad, megrim (*Lepidorhombus whiffiagonis*), Norway lobster (*Nephrops norvegicus*) and monkfish (*Lophius piscatorius*), amongst other species, while purse seiners target sardine (*Sardina pilchardus*), scad and mackerel (*Scomber scombrus*). Around 150 Galician vessels, mainly trawlers and long-liners, fish at "Grand Sole", off southwest Ireland. In addition to the full-time commercial sector, around 1500 boats are operated by retired fishermen and use a variety of fishing gears. The activity of this sector is difficult to quantify but is largely confined to the coastal zone.

Resident marine mammal species include common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*) and harbour porpoise (*Phocoena phocoena*), all of which are regularly recorded amongst strandings (López et al., 2002). At least 16 species of

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cetacean and three species of pinniped have been recorded in Galician waters (Fernández de la Cigoña, 1990; Penas-Patiño and Piñeiro-Seage, 1989).

In the 1970s and 1980s, most studies on cetaceans in Galician waters concerned the biology and abundance of species taken by commercial whaling (e.g. Sanpera and Jover, 1985). Systematic recording of stranded cetaceans commenced in 1990 with the establishment of the Coordinadora para o Estudio dos Mamiferos Mariños (CEMMA), a volunteer group which records strandings, conducts land-based sighting surveys, carries out necropsies and provides samples for biological studies (López et al., 2002).

The possible adverse effect of fisheries on marine mammal populations, particularly mortality due to fishery by-catch, is currently a major conservation issue in European waters. The present study aimed to estimate the mortality caused to small cetaceans by fishing

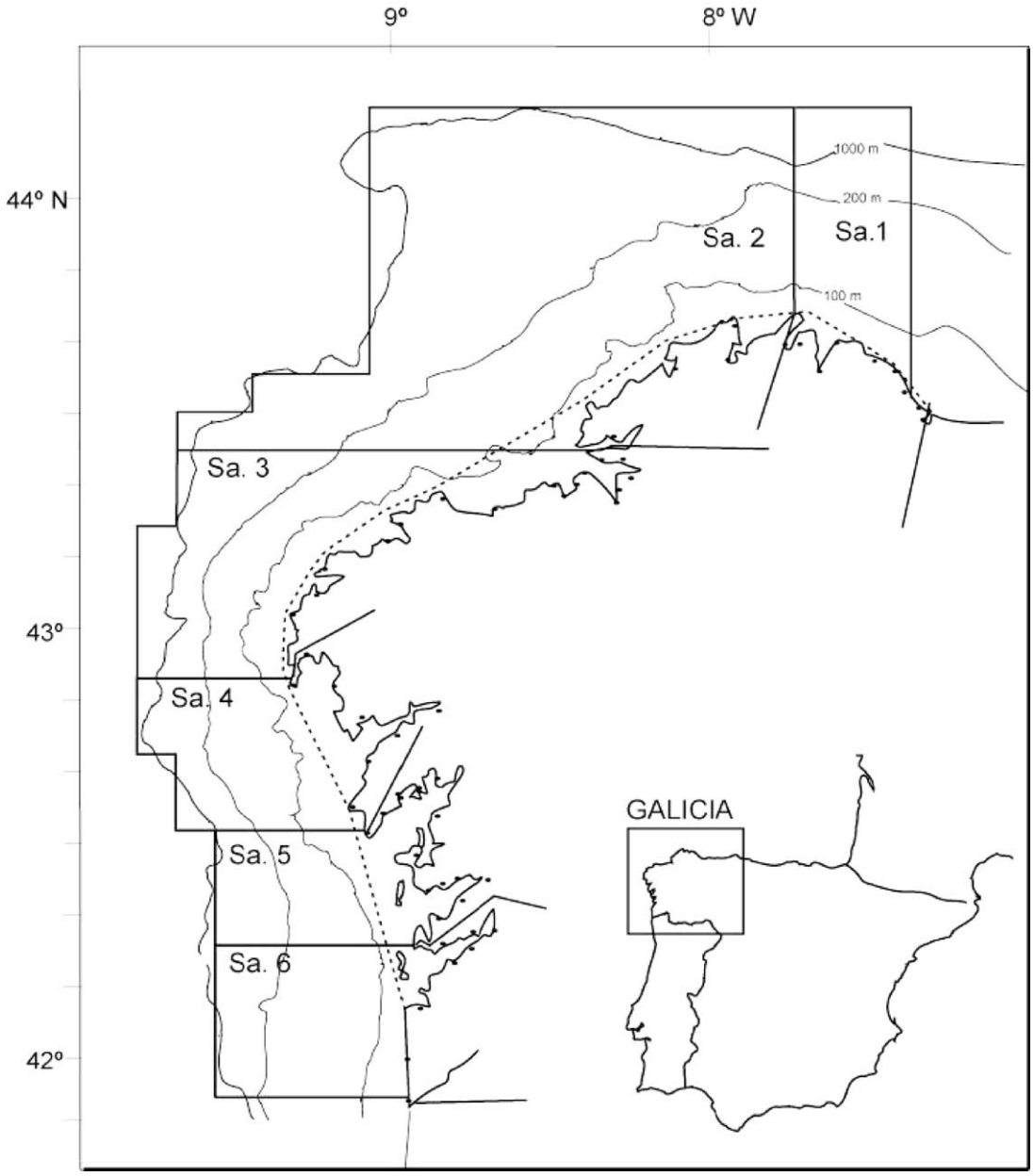

Fig. 1. The study area, which consists of Galician coastal waters from the shore to the 1000 m isobath. By-catch data were analysed separately for inshore (interior) and offshore waters. The inshore zone is delimited by a minimum complex polygon joining the outermost points of the coast, and thus encompasses mainly areas with <100 m depth. For the interview survey, the area was divided, from northeast to south, into six sub-areas (Sa 1–6). The map also shows bathymetric contours (100, 200, 1000 m) and the locations of ports along the coast (small circles).

Table 1
The main sectors of the Galician fishery, showing number of boats, the approximate number of fishing trips monthly, the number of interviews conducted, the number of interviews reporting cetacean by-catches and estimated overall numbers of cetaceans (all species) by-caught annually (derived from interview data on numbers caught over a 10-year period)[a]

Fishing area	Gear	Boats	Estimated fishing trips			Interviews		Annual cetacean by-catch		
			Monthly per boat	Monthly total	Annual total	Total	With cetacean by-catch	Mean per boat	Fleet total	Mean per 1000 trips
Inshore	Gillnet	1068	19.3	20 608	247 298	54	7	0.178	190	0.77
	Line	401	17.9	7161	85 928	7	2	0.029	12	0.14
	Seine	–	–	–	–	1	1	0.100	–	–
	Traps	1153	18.8	21 727	260 726	32	2	0.006	7	0.03
	Trawl	250	19.8	4947	59 367	19	1	0.005	1	0.02
	All gears	2872		54 443	653 318	113	13	0.073	210	0.32
Offshore	Gillnet	535	18.8	10 064	120 767	97	31	1.785[b]	955	7.91
	Line	306	18.0	5522	66 261	23	1	0.004	1	0.02
	Seine	259	19.4	5025	60 295	6	1	0.500	130	2.15
	Trap	628	19.2	12 077	144 925	109	8	0.028	18	0.12
	Trawl	243	17.7	4306	51 669	69	28	1.707	415	8.03
	All gears	1971		36 993	443 916	304	69	0.770	1518	3.42
All Galicia	All gears	4843		91 436	1 097 234	417	82	0.357	1728	1.57
Grand Sole	Gillnet	10	1.4	14	165	9	3	1.778	18	107.76
	Line	63	1.9	118	1418	24	3	0.013	1	0.58
	Trawl	82	1.7	142	1707	49	17	4.043[b]	332	194.19
	All gears	155		274	3290	82	23	2.259	350	106.43
All areas	All gears	4998		91 710	1 100 524	499	105	0.416	2078	1.89

[a] The fishing areas are inshore and offshore waters off Galicia and "Grand Sole", to the southwest of Ireland. Notes: Although no boats working inshore waters with seine nets had been previously identified, the interview results included one example.
[b] Two by-catch values were strongly influenced by outliers in the interview data-set.

activities in coastal waters of Galicia during 1998–2000, and to identify any areas, fleets and cetacean species associated with high levels of by-catch.

The most reliable method for collecting information on cetacean by-catches is the placement of observers on-board fishing vessels (e.g. Goujon et al., 1993b; Morizur et al., 1999). Within the European Union, the Habitats Directive (92/43/EEC), Article 12, requires Member States to establish a system to monitor the incidental capture and killing of animals such as cetaceans. However, neither national nor European legislation places any requirement on fishermen to co-operate with on-board observation schemes, so samples are inevitably self-selecting. Furthermore, the high level of fishing activity in Galicia, coupled with the diversity of fishing areas and gears, means that adequate sampling of fishing trips is simply not feasible using on-board observers alone.

The study period coincided with that for a second project which involved interviews with fishermen to obtain data on catch rates. Thus, by adding questions about marine mammal sightings and by-catches to the questionnaire it was possible to obtain a second data set. While interview surveys are not necessarily a reliable source of quantitative data (see Lien et al., 1994 for a detailed critique), especially if fishermen wish to conceal the occurrence of cetacean by-catches, the interview survey offers a means of obtaining a minimum estimate for by-catch frequency. Based on available data on the resident common dolphin population, we also derive figures for the number of observer trips required to check whether by-catch is below an acceptable level (no more than 2% of the population removed annually, as recommended by the second Meeting of Parties to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS).

2. Methods

2.1. Study area

The study area encompasses approximately 20 700 km^2 of the Galician continental shelf and adjacent waters, from the coast to the 1000 m isobath (Fig. 1).

The Galician shelf is relatively narrow, with a maximum width of 20–35 km. The coastline is characterised by the presence of a series of inlets or rías, formed when the sea inundated coastal valleys of moderate depth. To ensure that boats from ports all along the Galician coast were sampled, the study area was divided in six strata for the interview and observer programmes. For analysis, boats were assigned to one of the two fishery administrative divisions, designated here as "inshore" and "offshore" waters. The inshore zone is delimited by a minimum complex polygon joining the outermost points of the coast, and thus encompasses mainly areas with <100 m depth (Fig. 1).

2.2. Data collection

2.2.1. Observer trips

Observers were placed on-board fishing vessels throughout the period March 1998–February 2000, covering as many strata as possible—the major gear types, the six sub-areas and both inshore and offshore waters. Although fishermen working on boats deploying gillnets participated in interviews, it was not possible to obtain agreement with skippers to put observers on board. Records were obtained from 67 fishing trips. Observers recorded any by-catches of cetaceans as well as noting their presence in the vicinity of the boat.

2.2.2. Interview survey

The interview survey of skippers and fishermen took place at ports throughout Galicia over the period of the project (March 1998–February 2000), covering the main fishing area/gear combinations. Interviews were conducted as part of a wider study on fishery catches and fishing effort. All interviews were carried out at the ports, in person, by an experienced interviewer with extensive knowledge of the fishing sector. Although the main focus is on Galician waters, some of the fishermen interviewed worked on boats fishing at Grand Sole (SW of Ireland) and data for this area are also presented (see Table 1).

Fishermen were asked to recount a summary of their experiences over the last 10 years. Questions on marine mammals related to: (a) Sightings of marine mammals in ports, during trips to fishing grounds and on the fishing grounds; and (b) Interactions with fishing: problems caused by the small cetaceans and the incidence of cetacean by-catches; the frequency of such interactions and species of cetaceans involved.

Only complete interviews were included in the analysis (eight interviews were excluded due to incomplete specification of either fishing areas or gear used).

2.2.3. Ancillary data

Skippers and fishermen contacted during the interview and observer programmes were asked to provide carcasses of any by-caught cetaceans.

2.3. Analysis of by-catch rates

2.3.1. Observer data

Since no by-catches of cetaceans were directly observed during observer trips (see below) analysis was restricted to estimation of the 95% confidence limits of the underlying by-catch rate and a retrospective power analysis. As noted above, adequate observer coverage of Galicia's enormous fishery sector is effectively impossible within the scope of a short-term project but we aim to specify requirements for a long-term monitoring programme.

Assuming that catching a single cetacean in a net can be modelled as a Poisson process, if λ is the mean by-catch per sampled unit of fishing effort and X is the number of by-catches, the probability of seeing r by-catches during a single sampling unit is given by:

$$P(X = r) = e^{-\lambda}\lambda^{r}r!$$

Since the terms λ^r and $r!$ are both equal to 1 for $X=0$, the probability of observing at least one by-catch during N observed units of fishing activity is simply:

$$P\left(\sum_{N} X > 0\right) = 1 - P\left(\sum_{N} X = 0\right) = 1 - \left(e^{-\lambda}\right)^{N}$$

Based on a bootstrap re-sampling procedure (Buckland, 1984; Efron and Tibshirani, 1993) and assuming a Poisson distribution, confidence limits for observed by-catch were estimated for a range of sample sizes and underlying by-catch rates.

This approach is also used to assess the number of observer trips needed to test whether the by-catch rate exceeds what might be regarded as the permitted Potential Biological Removal (PBR) for the population. The only population size estimates available are minimum estimates from sightings surveys in Galician waters (López et al., in preparation). The population estimate for common dolphins is 8100 animals. Since there are no data on reproduction and mortality rates, the figure for maximum permitted by-catch may be set at 2% of the population (as recommended by ASCOBANS), i.e. 162 animals. Assuming that animals were always caught singly, common dolphin by-catch events should not exceed this figure. Given the estimate of 1.1 million trips per year, this is a by-catch event rate of 0.00015, or 0.15 events per 1000 trips.

2.3.2. Interview data

Interview data were analysed to estimate a "minimum" by-catch rate. Data were first divided into strata on the basis of gear type and fishing area (see Table 1). Of 499 interviews, 105 indicated the occurrence of by-catches of marine mammals. Within each stratum, the

boats sampled are assumed to be representative, i.e. the proportion of boats reporting by-catch and the calculated by-catch rates can be raised to give estimates for the fleet.

Not all of the interview information on accidental capture was fully quantitative. To facilitate analysis of the full data set, some simple assumptions were made: (a) When the by-catch was said to be "a few" or "some" animals, or a generic answer such as "dolphins" was given, the conservative figure of two animals was used, and this figure is applied to all species mentioned by the interviewee (11 interviews); (b) For records referring to "many" animals, the by-catch rate was set to the annual maximum for other boats in the same sampling stratum (two interviews, both for trawlers in offshore waters—the maximum for this stratum was 14 cetaceans caught per year); (c) when a figure was given for the total number of individual cetaceans by-caught in a specified time-period and more than one species was mentioned, the total was divided equally between the species (one interview).

The species by-caught was often not identified but most fishermen distinguished between bottlenose dolphins and other small cetaceans, and between dolphins and whales. The large bottlenose dolphin is well known. However, fishermen generally did not distinguish between common dolphins and porpoises, using the two names interchangeably. Nevertheless, porpoises appear be relatively rare and are mainly seen in inshore waters in the area of ría de Pontevedra (Martínez and Benavente, 1995) whereas the common dolphin is the most common species in the area (Aguilar, 1997; López et al., 2002). Thus, most of the by-catches of small "dolphins" were probably common dolphins. Most whales appear to have been long-finned pilot whales (*Globicephala melas*), with occasional mention of sperm whales (*Physeter macrocephalus*).

For each stratum, the average by-catch per boat per year is given by the total number of animals caught per year divided by the number of interviews. Separate totals were estimated for each species and the composite categories "small cetaceans (dolphins)", "large cetaceans (whales)" and "all cetaceans". Numbers for the composite categories will be more complete and thus more reliable. By-catch rates for the fleet are estimated using the number of boats in each stratum as a raising factor. Interviews also included information on the number of fishing trips undertaken monthly. These data were used to derive expressions of average by-catch per trip.

Since the most frequently reported number of by-catches by a boat was zero, the data are neither normally distributed nor transformable to normal. Confidence limits for numbers of by-catches were therefore estimated using a bootstrap procedure. A purpose-written BASIC programme was used to simulate the data collection procedure, repeatedly re-sampling with replacement from the set of N interviews in a stratum to generate multiple sets of N interviews. In the present application 2000 repeats were used, each yielding an estimate of the number of by-caught cetaceans in the stratum, raised to the level for the fleet. The 2000 estimates are then sorted, and the 51st and 1950th values represent the 95% confidence limits (i.e. only 5% of values are more extreme). Interviews were stratified by gear and by fishing area (inshore, offshore, Grand Sole) and confidence limits derived separately for each stratum and overall. The sensitivity of these results to outliers in the data set was also examined. Using a version of the bootstrap programme, and actual interview data for the fleets, expected confidence limits for the total number of cetaceans captured annually were simulated for different numbers of interviews, including extrapolation to larger numbers of interviews than were actually carried out (5–500). We also estimate the number of observer trips needed to corroborate the interview findings on the by-catch rate.

3. Results

3.1. Observed by-catch

No by-catches of marine mammals took place when the observers were on board during any of the 67 fishing trips, although one skipper mentioned an interaction taking place the day before the observer was on board. Assuming the trips to have been representative, we can be 95% certain that the overall by-catch rate is less than 0.045—i.e. less than one occurrence per 20 trips. Since the fleet makes more than 1 million individual fishing trips each year, this indicates only that there are fewer than 50 000 incidences of marine mammal by-catch annually.

3.2. Carcase recovery scheme

Over 2 years, skippers of fishing boats handed in 17 by-caught cetaceans. These comprised six common dolphins; two harbour porpoises, two bottlenose dolphins, two long-finned pilot whales, one Risso's dolphin (*Gnampus griseus*) and four unidentifiable (due to their condition) dolphins.

3.3. By-catch rates estimated from interview data

Cetacean by-catches are reported in all three main fishing zones, although both the proportion of boats with some cetacean by-catches (Fig. 2) and the mean numbers of cetaceans by-caught per boat.year (Table 1) were greater in offshore waters and at Grand Sole than in inshore waters. Variation between boats was high, as reflected in the wide confidence limits (Table 2). Boats deploying trawls and gillnets in offshore waters and

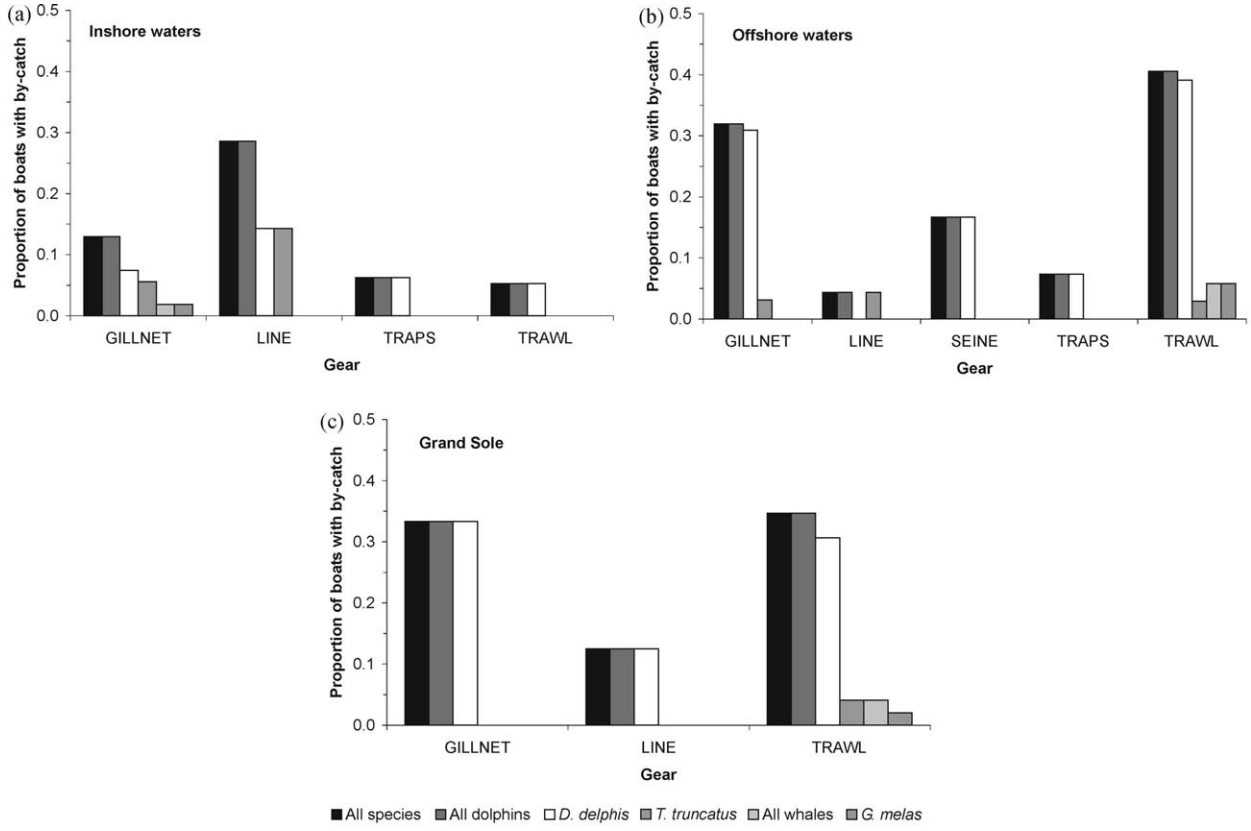

Fig. 2. Proportion of interviews reporting non-zero by-catches for fishing activities in (a) inshore waters, (b) offshore waters and (c) Grand Sole.

Table 2
Estimated annual numbers of cetacean by-catches for the Galician fleet, with bootstrap estimates of 95% confidence limits: Galician waters and Grand Sole (SW of Ireland)[a]

Fishing area	Gear	Boats	Numbers of cetaceans by-caught annually						
			All species	All dolphins	Small dolphins	*Tursiops*	All whales	*Globicephala*	*Physeter*
Inshore	Gillnet	1068	190 (8–522)	111 (8–295)	87 (2–251)	24 (0–67)	79 (0–237)	79	0
	Line	401	12 (0–23)	12 (0–23)	6 (0–17)	6 (0–17)	0	0	0
	Traps	1153	7 (0–18)	7 (0–18)	7 (0–18)	0	0	0	0
	Trawl	250	1 (0–4)	1 (0–4)	1 (0–4)	0	0	0	0
	All gears	2872	210 (23–556)	131 (23–313)	101 (10–272)	29 (2–81)	79 (0–237)	79 (0–237)	0
Offshore	Gillnet	535	955 (81–2639)	955 (81–2639)	935 (69–2628)	20 (0–56)	0	0	0
	Line	306	1 (0–4)	1 (0–4)	0	1 (0–4)	0	0	0
	Seine	259	130 (0–389)	130 (0–389)	130 (0–389)	0	0	0	0
	Trap	628	18 (3–42)	18 (3–42)	17 (2–44)	0	0	0	0
	Trawl	243	415 (214–649)	394 (208–601)	392 (196–610)	3 (0–8)	20 (0–53)	20 (0–53)	0
	All gears	1971	1518 (464–3375)	1498 (435–3453)	1474 (420–3278)	24 (2–68)	20 (0–53)	20 (0–53)	0
All Galicia	All gears	4843	1728 (588–3794)	1629 (539–3536)	1575 (486–3723)	53 (9–114)	100 (3–285)	100 (3–285)	0
Grand Sole	Gillnet	10	18 (0–44)	18 (0–44)	18 (0–44)	0	0	0	0
	Line	63	1 (0–2)	1 (0–2)	1 (0–2)	0	0	0	0
	Trawl	82	332 (27–911)	328 (25–910)	55 (12–129)	12 (0–32)	4 (0–11)	0	3 (0–10)
	All gears	155	350 (43–904)	346 (37–903)	74 (21–157)	12 (0–32)	4 (0–11)	0	3 (0–10)
All areas	All gears	4998	2078 (791–4184)	1975 (722–3888)	1648 (557–3537)	65 (19–131)	103 (5.6–282)	100 (3–273)	3 (0–10)

[a] All-gears, all-species and all-areas by-catches are derived from separate runs of the bootstrap procedure and the figures will therefore not necessarily be exactly equal to the sum of figures from runs using data from single gears, species or areas. For example, not all by-caught cetaceans were identified to species and some categories (e.g. small dolphins) are subsets of more general categories (e.g. dolphins).

Table 3
Revised by-catch estimates excluding outliers

Fishing area	Gear	Numbers of cetaceans by-caught annually		
		All species	All dolphins	Small dolphins
Offshore	Gillnet	144 (79–218)	144 (79–218)	124 (63–196)
	All gears	707 (412–1058)	687 (408–1033)	663 (370–1021)
All Galicia	All gears	917 (520–1447)	817 (488–1197)	764 (447–1154)
Grand Sole	Trawl	104 (26–205)	100 (25–910)	55 (12–129)
	All gears	123 (40–233)	119 (27–223)	74 (21–157)
All areas	All gears	1039 (638–1531)	936 (607–1315)	838 (515–1222)

Grand Sole appear to be especially important causes of by-catch, mainly of small cetaceans. Common dolphins were most frequently identified (by fishermen) as the species caught, although bottlenose dolphins were also cited as being caught, particularly in inshore gillnets.

The total annual mortality due to accidental capture of cetaceans in fishing gear is estimated at around 1730 cetaceans in Galician waters, with a further 350 taken at Grand Sole (Table 1). However, results for both of the strata with the highest by-catch rates (offshore gillnets and trawling at Grand Sole) are influenced strongly by single records, of annual catches of 150 and 156 dolphins respectively, well outside the typical range of values (see below). If these extreme values are replaced by the next greatest values in the respective strata, the revised totals for annual by-catches in Galician waters and Grand Sole come down to 917 and 123 respectively (see Table 3).

3.4. Power analysis

The interview data indicate an overall annual by-catch for all cetacean species of 1730 animals (920 excluding outliers), i.e. around 1.6 (or 0.8) by-catches per 1000 trips. Treating results for inshore and offshore fisheries separately and using the higher figures (0.3 cetaceans per 1000 inshore trips; 3.4 per 1000 offshore trips), the probabilities of observing any cetacean by-catches during 67 trips would have been 0.02 (inshore trips) or 0.20 (offshore trips). In fact, since boats using gillnets were not sampled during the observer programme, the real probabilities could have been considerably lower.

Assuming the estimate for annual by-catch of small dolphins in inshore + offshore waters to be applicable to the common dolphin, this corresponds to by-catch rates per trip of 0.0014 (or 0.0007 excluding outliers) dolphins. To be 95% confident that the by-catch rate did not exceed 1.4 by-catch *events* per 1000 trips, given that no by-catches were seen during trips, up to around 2000 observer trips would be required annually (Fig. 3a). However, based on the minimum population estimate of around 8000 common dolphins, the acceptable annual by-catch is approximately 160 dolphins (or 0.15 by-catches per 1000 trips). Following the same logic, as many as 20 000 observer trips would be needed to confirm that by-catch rate did not exceed this number of events (Fig. 3b). See Fig. 3c for the general relationship between number of trips and the probability of seeing zero by-catches for a given underlying by-catch rate.

The above figures consider the interpretation of seeing zero by-catches. Perhaps more useful is to consider the number of trips required to obtain a reliable estimate of the by-catch rate. If the true by-catch rate is low, sampling few fishing operations will tend to underestimate the by-catch rate (as indicated by the median values) and confidence limits will be wide. As the underlying by-catch rate increases, the sample size required to accurately estimate the average by-catch falls, but continued gains in precision are achieved up to very large sample sizes. For an underlying by-catch rate of 1 event per 1000 trips, the by-catch estimate stabilises after around 1000 trips while confidence in the estimate continues to increase up to 2000 trips (Fig. 4a). For an underlying by-catch rate of 10 events per 1000 trips, the estimate stabilises after 500 trips, while an appreciable improvement in confidence continues up to 1000 trips (Fig. 4b).

Assuming that the level of variability in reported catches in the actual interviews is realistic, simulation results indicate that estimated cetacean by-catch and associated 95% confidence limits begin to stabilise after around 50 interviews (per stratum). Reduction of confidence limits is seen for up to at least 200 interviews (Fig. 5). However, even for higher numbers of interviews, 95% confidence limits remain around $\pm 100\%$ of the estimated value.

3.5. Other information on marine mammals reported by fishermen

3.5.1. Sightings

Interview results indicated that the most frequently sighted marine mammals were small dolphins, generally thought to be common dolphins, which were seen more frequently in offshore waters and at Grand Sole than in inshore waters. Bottlenose dolphins were seen mainly in inshore waters. Larger cetacean species (including long-finned pilot whales, sperm whales and killer whales

Orcinus orca) were reported infrequently and were mainly seen in offshore waters and at Grand Sole (Fig. 6). Some fishermen, mainly those fishing at Grand Sole, also mentioned seeing pinnipeds.

Small dolphins (common dolphins or porpoises) were occasionally sighted in ports and frequently sighted in transit and on the fishing grounds. Considering only records for Galician waters (i.e. excluding records from Grand Sole), the frequency of sightings from boats with home ports in sub-areas 4 and 5 was lower than in the other areas (Fig. 7). Boats from ports in each sub-area will tend to fish more in their "home" sub-area and it can thus it can be concluded that common dolphins are less frequently seen in sub-areas 4 and 5.

Bottlenose dolphins were the second most commonly sighted category of cetacean in Galician waters and, as noted above, were mainly seen in inshore waters. Bottlenose dolphins were less commonly seen in the north of the study area (Fig. 8).

3.5.2. Interactions with fishing activities

Fishermen reported various problems caused by marine mammals, including entanglement in nets (interrupting or slowing down fishing activities), damage to the gear, consumption of captured fish and scaring fish (Fig. 9). The proportion of fishermen who reported that marine mammals caused some kind of problem for fishing activities was lower at Grand Sole than in Galician waters. Fishermen working in inshore Galician waters most commonly cited gear damage as a problem, whereas offshore fishermen also reported marine mammals becoming entangled in gear and some stated that the presence of marine mammals scared fish away from their nets. The apparently high impact of marine mammals on seine net fishing in offshore waters is possibly misleading since it is based on a sample size of only eight interviews. Two interviewees commented that the presence of cetaceans was beneficial to fishing, one of these also reporting the highest by-catch rate (10–15

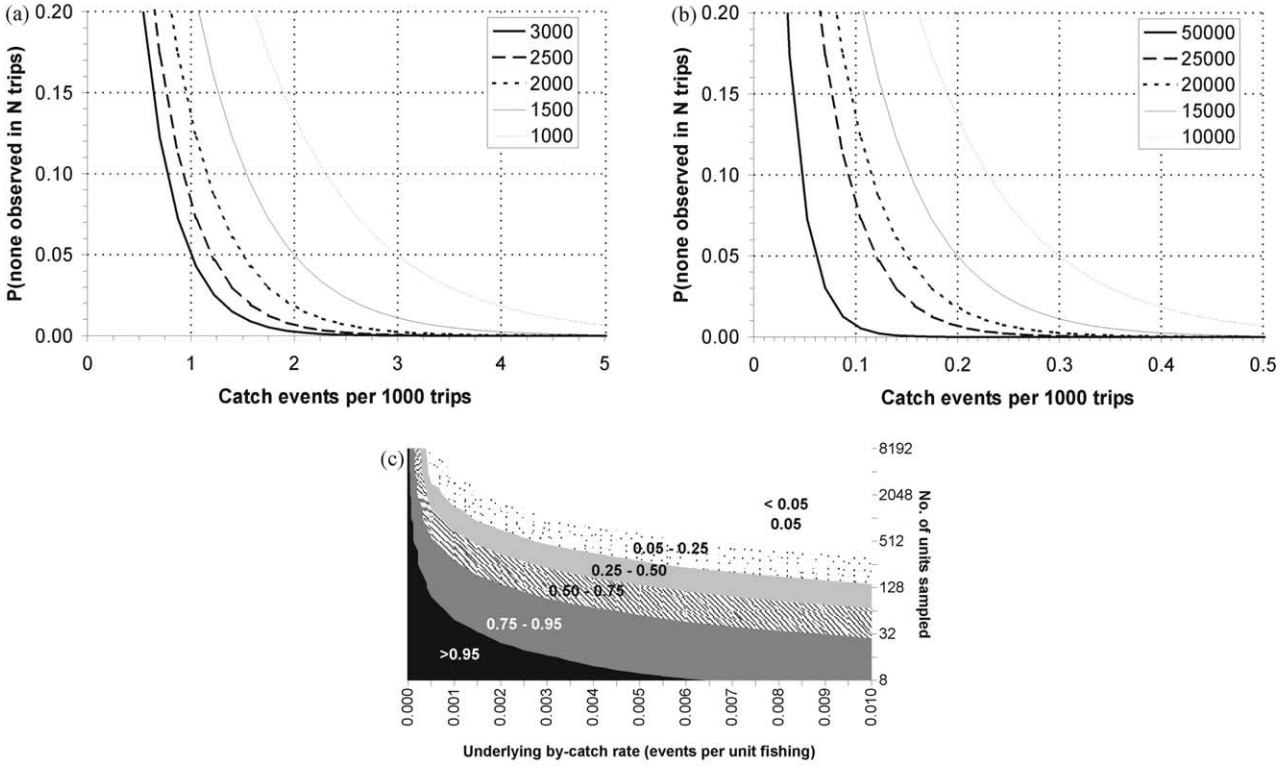

Fig. 3. Probability of seeing zero marine mammal by-catch events as a function of the underlying true rate of by-catch and the number of observer trips, assuming a Poisson distribution of by-catch events. (a) Probabilities of observing no by-catches for underlying by-catch rates of 0–5 events per 1000 observer trips. Interview survey data suggested a figure of around 1.4 dolphins captured per 1000 fishing trips in Galician waters. It would be necessary to place observers on around 2000 trips in order to be 95% confident that by-catch did not exceed this rate. (b) Probabilities of observing no by-catches for underlying by-catch rates of 0–0.5 events per 1000 trips. The estimated permissable Potential Biological Removal (PBR) for common dolphins in Galician waters is 0.15 by-catch events per 1000 fishing trips. It would be necessary to place observers on around 20 000 trips in order to be 95% confident that by-catch did not exceed this rate. (c) The general relationship between the probability of seeing zero cetacean by-catches in relation to the underlying "real" rate of by-catch and the number of fishing trips observed. Probability bands <0.05, 0.05–0.25, 0.25–0.50, 0.50–0.75, 0.75–0.95 and >0.95 are illustrated.

dolphins per month). Species causing damage to fishing activities were rarely named: bottlenose dolphins were mentioned on nine occasions and sperm whales once, the latter at Grand Sole.

The interview data also yielded information on uses of marine mammals. Sixty-nine interviewees referred to cetaceans being used for human consumption. Some interviewees admitted to eating marine mammals (variously taking fillets or the liver), while others commented that the Basques, Portuguese or French ate cetaceans. The use of cetaceans for bait, animal food and as a source of fat was also mentioned.

4. Discussion

By-catches in fisheries are widely recognised as one of the major threats to the conservation of cetacean populations world-wide (IWC, 1994; Kuiken et al., 1994; Kock and Benke, 1996; Dawson et al., 1998). The present study suggests that substantial numbers of small cetaceans, probably mainly common dolphins, are being caught in fisheries in Galician waters. The results also implicate Spanish trawlers as a cause of common dolphin mortality at Grand Sole (SW Ireland), consistent with studies on other European fishing fleets in the area (Couperus, 1997; Tregenza and Collet, 1998; Morizur et al., 1999).

The present study had access to three sources of new data: on-board observation, a voluntary reporting scheme and an interview survey. The Galician strandings scheme offers a fourth source of information (López et al., 2002). All these data sources will tend to underestimate the rate of cetacean by-catch.

Although the strandings data are thought to be a reliable record of animals found ashore, not all by-caught cetaceans wash up on the coast. López and Valeiras (1997) found that around 22% of stranded cetaceans in Galicia showed evidence of by-catch mortality while López et al. (2002) showed that 23% of stranded common dolphins and 14% of bottlenose dolphins were fishery by-catches. This corresponds to an

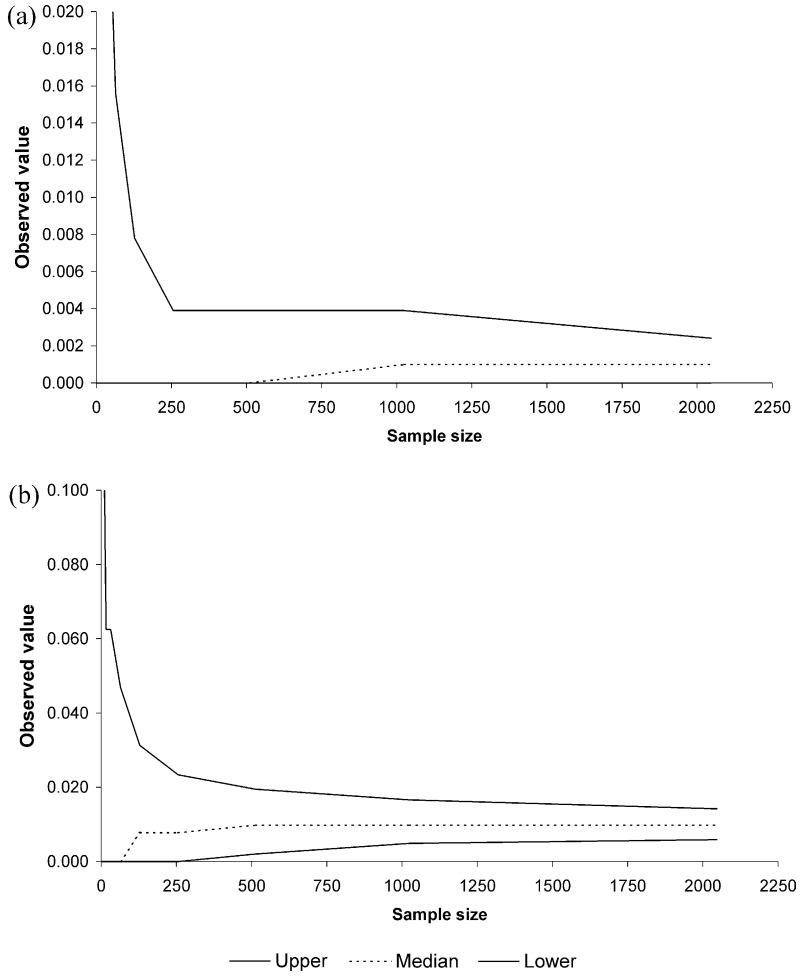

Fig. 4. Accuracy and precision of marine mammal by-catch estimates from observer trips in relation to number of simulated fishing trips observed. Median estimated by-catch rate and 95% confidence limits, in relation to the number of observer trips, for underlying marine mammal by-catch rates of: (a) 1 event per 1000 trips; (b) 10 events per 1000 trips.

annual average of 15.5 common dolphin strandings and 2.2 bottlenose dolphins being diagnosed or known by-catches. The greatest number of by-caught cetaceans recorded in a single year by the strandings scheme was 58 in 1996. Since then the number has averaged around 35 animals per year (López et al., 2002).

The fishermen who collaborate with by-catch recording schemes are a self-selecting sample. Ultimately, documentation of a significant cetacean by-catch problem could lead to constraints being imposed on fishing practices, which gives fishermen who catch cetaceans in their nets an incentive not to report it. The Marine

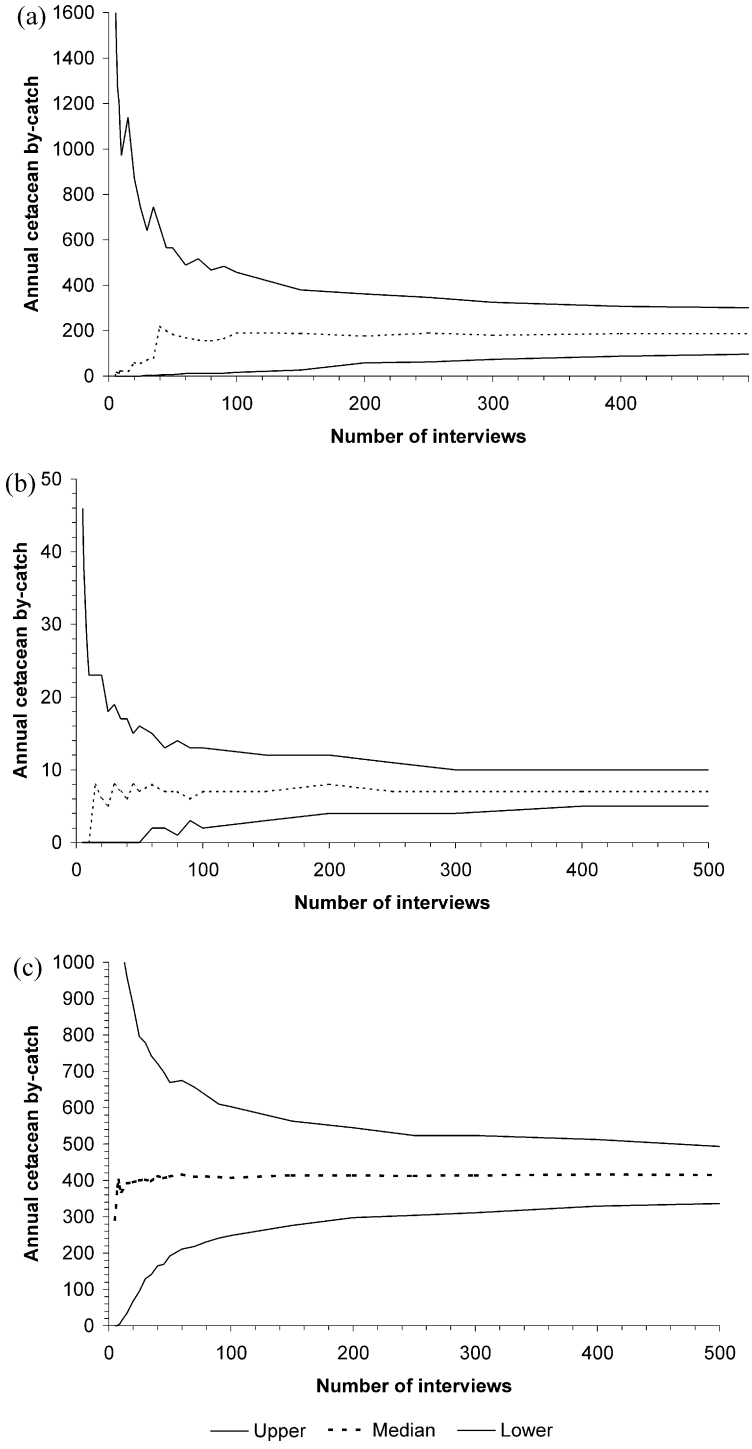

Fig. 5. Accuracy and precision of marine mammal by-catch estimates from interviews in relation to number of simulated interviews. Median estimated cetacean by-catch and 95% confidence limits for three of the studied strata, for different numbers of interviews. (a) inshore gillnets, (b), inshore traps, (c) offshore trawls.

Mammal Protection Act (MMPA) in the United States provides a possible model for a framework in which managers and fishermen could co-operate to monitor and mitigate cetacean mortality in fishing gear, in a system that protects both fishing interests and cetaceans. By-catch reduction measures can even have market benefits, e.g. allowing fishermen to promote their catch as dolphin friendly. Nevertheless, it is important to recognise that the current system of fishery management in Europe does not encourage such co-operation.

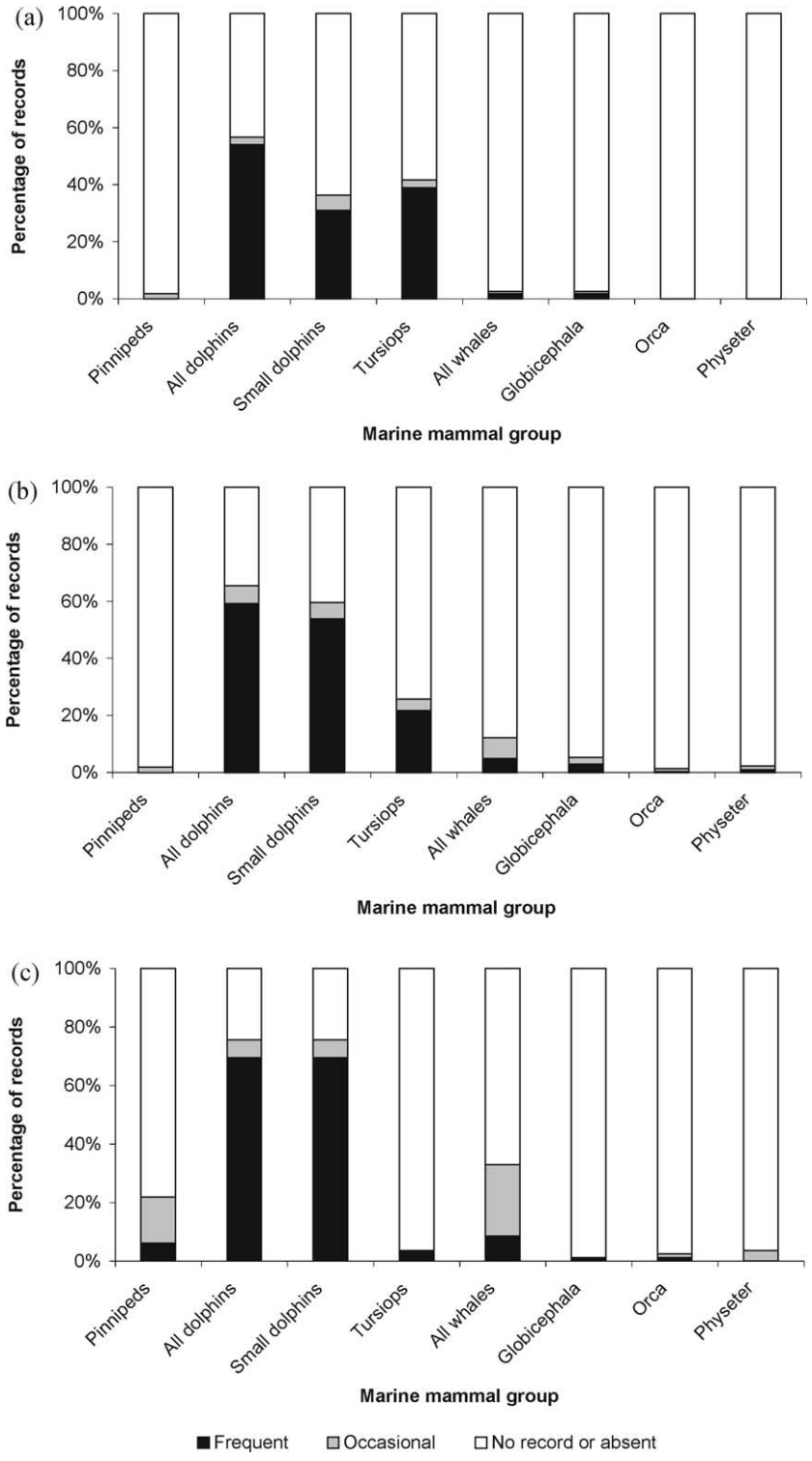

Fig. 6. Summary of marine mammal sightings reported by fishermen in (a) inshore and (b) offshore Galician waters, and (c) at Grand Sole. The proportions of interview records reporting frequent, occasional, and no marine mammal sightings.

Most studies on by-catches of cetaceans in European fisheries involved observers on board the fishing vessels (e.g. Couperus, 1997; Tregenza and Collet, 1998). The on-board observations in the present study led to an estimate of zero by-catches. However, although observers were able to travel on boats deploying lines, seines, traps and trawls it was not possible to obtain the agreement of skippers of boats deploying gillnets. Both the by-catch literature and the interview data from the present study suggest that gillnets are a major cause of by-catch mortality in cetaceans. If we allow that the data were representative of other sectors of the fishery, the low power of the study in relation to the scale of fishing activity in Galicia means that we can be 95% confident only that by-catch events occur during fewer than one in 20 fishing trips. Given that Galician fishing vessels undertake more than a million fishing trips annually, the number of marine mammal by-catches could still be very high. Based on simulation results (calibrated using interview data) we estimate that least 500 observer trips would be needed annually, and possibly as many as 2000 trips, to provide an adequate level of by-catch monitoring.

The voluntary reporting scheme yielded 17 cetacean carcases over 2 years, including all the most common species. Under-reporting is suspected, as in comparable schemes. Thus, official data from Portuguese trawl fisheries, based on reports by skippers, recorded 12 cetacean by-catches in 1980. However, in 1981 it became illegal to catch and sell marine mammals in Portugal and only six by-catches were reported between 1981 and 1994 (Sequeira and Ferreira, 1994).

The interview data on cetacean by-catches are obviously subject to a range of errors and biases and may be regarded as providing, at best, a rough guide to the scale of the problem. Clearly, if there is a perception among fishermen that admission of marine mammal by-catches will damage the image of the industry, the veracity of interview data is doubtful. On the other hand, the readiness with which many Galician fishermen

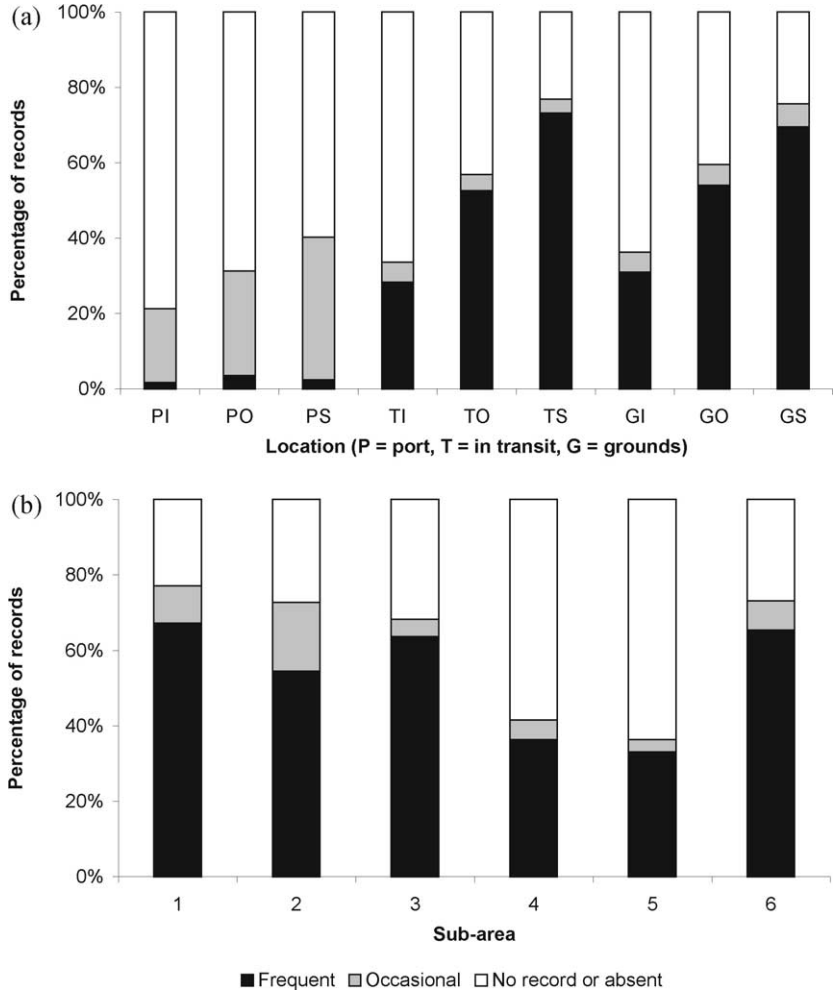

Fig. 7. Small dolphin sightings by fishermen. The proportions of interview records reporting frequent, occasional, and no small dolphin sightings: (a) sightings in ports, in transit and on fishing grounds from boats working in the three main fishing zones (inshore, offshore, Grand Sole); (b) sightings on fishing grounds in Galician waters—results separated according to the sub-area in which the home port occurs (see Fig. 1).

spoke about catching (and even eating) cetaceans suggested that this was not a problem. In contrast, in trials of a similar questionnaire in the UK, fishermen invariably declined to answer questions about marine mammals (pers. obs.). Face-to-face interviews are probably more reliable than telephone interviews and it helps if the interviewer and fishermen already know each other (Lien et al., 1994). In the present study, the interviewer had extensive previous contacts with people working in the industry and it is thought that this will have maximised the reliability of the data. Another point made by Lien et al. (1994) is that fishermen tend to count '1–2–3–4–5–dozens–hundreds–thousands': clearly such data are unsuitable for parametric statistics but the analysis in the present study should be robust to this. Finally, it should be borne in mind that interviews are used routinely in studies in the economic and social sciences and, at worst, may represent valuable ancillary data in situations where data are hard to obtain by any other means.

Interview results indicated that most categories of fishing lead to some cetacean by-catch, including gillnets, long-lines, seines, traps and trawls. It is likely that the majority of by-catches are common dolphins, although bottlenose dolphins are also by-caught frequently. The difference in distribution of common and bottlenose dolphins, with the latter more common in inshore waters, is reflected in the results on by-catches and incidental sightings. As noted previously, Galician fishermen do not routinely distinguish between common dolphins and harbour porpoises. The carcase recovery data confirmed that both species are caught. However, common dolphins make up 47% of strandings while porpoises account for only 7% (López et al., 2002). Thus, the majority of "small dolphin" by-catch records probably refer to common dolphins. In the only previous study of fishery by-catches of cetaceans in Galician waters, Aguilar (1997) presented results from observer trips on fishing boats and from interviews with fishermen in Galicia and Asturias. He reported that

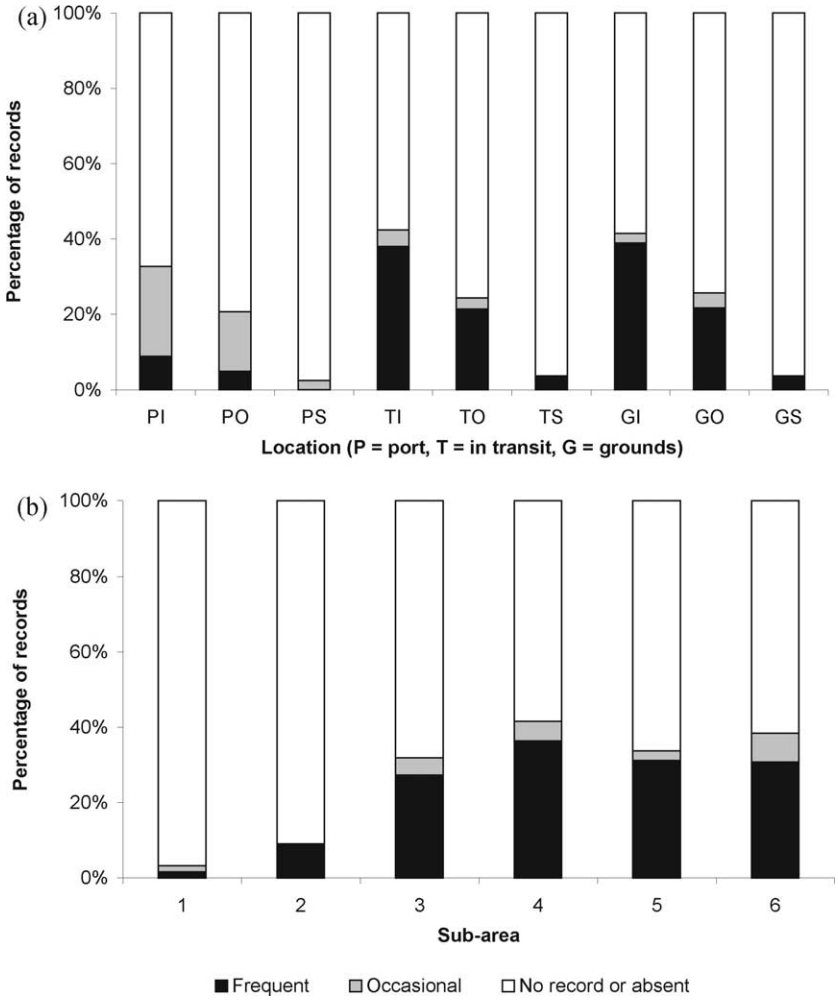

Fig. 8. Bottlenose dolphin sightings by fishermen. The proportions of interview records reporting frequent, occasional, and no bottlenose dolphin sightings: (a) sightings in ports, in transit and on fishing grounds from boats working in the three main fishing zones (inshore, offshore, Grand Sole); (b) sightings on fishing grounds in Galician waters—results separated according to the sub-area in which the home port occurs.

around 80% of by-catches are probably dolphins, mainly common dolphins and, secondly, bottlenose dolphins.

Offshore trawling was identified in this study as a major contributor to common dolphin by-catch mortality. Aguilar (1997) identified pair trawls as being the main cause of common dolphin mortality. He reported that, according to the fishermen interviewed, during nocturnal fishing it was rare not to catch dolphins, usually between one and ten and sometimes 30 or more. During 1996 and 1997, observers were present on four trips using pair trawls at night and in all cases common

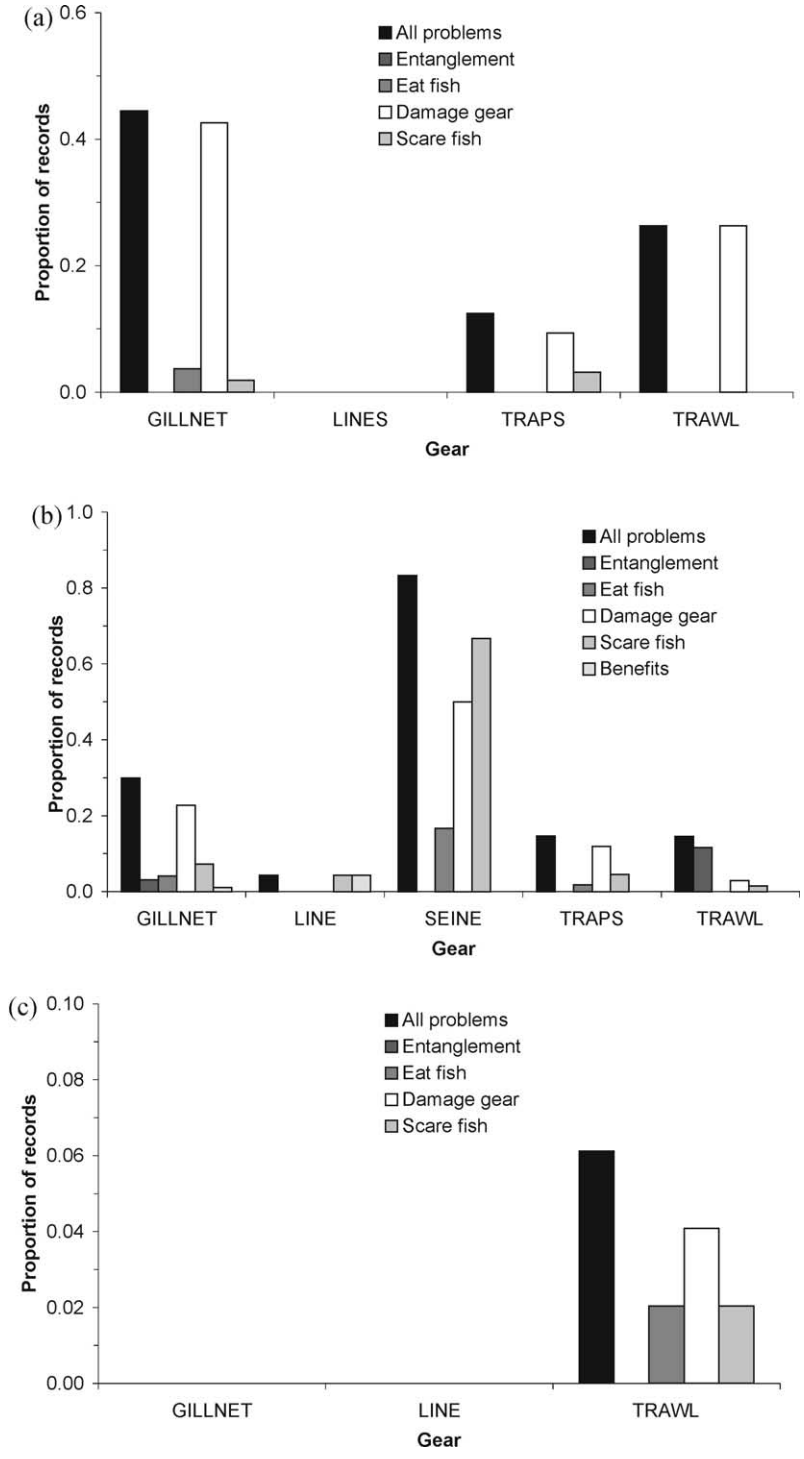

Fig. 9. Fishermen's reports of ''problems'' caused by marine mammals during fishing activities. The proportions of interview records reporting any problem, entanglement, consumption of fish, damage to gear and scaring of fish in (a) inshore waters, (b) offshore waters* and (c) Grand Sole. [*The offshore waters interview records also include reports of improved fishing in the vicinity of marine mammals, categorised as ''benefits''].

dolphins were caught, totalling eight individuals (Aguilar, 1997). In studies elsewhere in Europe, driftnets and trawls are generally recorded as taking mainly common dolphins, also striped and white-sided dolphins (Goujon et al., 1993a; Couperus, 1997; Tregenza and Collet, 1998; Morizur et al., 1999; Silvani et al., 1999).

Common dolphins are apparently frequently caught in gillnets in Galicia, certainly in inshore waters and possibly also in offshore waters. Data from Portugal also suggest that most cetacean mortality in gillnets is of common dolphins (Sequeira and Ferreira, 1994). Studies elsewhere in Europe highlight the importance of gillnets as a cause of by-catch mortality in harbour porpoises (Tregenza et al., 1997a, b; Berrow and Rogan, 1998; Carlström and Berggren, 1999; Northridge and Hammond, 1999). However, Berrow and Rogan (1998) found that, while porpoise was the most commonly recorded species in gillnets, around 25% of records were of common dolphins.

Regarding quantitative results from the interview survey, both estimated totals and confidence limits were strongly influenced by two unusually high figures, one for (offshore) Galician waters and one for Grand Sole. The unusual figure (150 dolphins/year) obtained from a gillnet fisherman in the northern part of Galicia is surprising in that the area in question is one in which few cetaceans are seen and few strandings recorded (López et al., 2002). Excluding these extreme values results in a 50% drop in the estimated by-catch of dolphins in Galician waters while the estimate for Grand Sole drops by almost two thirds. The adjusted estimated total annual by-catches in Galician waters are 764 common dolphins and 53 bottlenose dolphins.

The IWC stated that the anthropogenic removal rate of any cetacean population should not exceed half the maximum net growth rate of the population (IWC, 1995). For harbour porpoises, it was concluded that a removal rate of 1% in any population was unsustainable and thus cause for concern. In the USA, the MMPA requires Potential Biological Removal (PBR) to be estimated for all cetacean populations affected by fishery by-catch in US waters. In practice, PBR is estimated as the product of half the potential growth rate of a population, the population size and a 'recovery factor'. The recovery factor is a somewhat arbitrary value between 0.1 and 1.0, which reflects the uncertainty of the population estimate used in the equation. The more uncertain the population estimate, the lower the recovery factor and the lower the PBR. Under the MMPA, the critical by-catch mortality rate in porpoise populations is set at one quarter of the net growth rate, or around 1% (Caswell et al., 1996). At the second meeting of ASCOBANS, in 1997, it was agreed that, in general, an anthropogenic removal of more than 2% of the best available population estimate was an "unacceptable interaction".

The only population estimates available for small cetaceans in Galician waters were based on opportunistic sightings by observers on fishing boats (López et al., in preparation; see Aguilar, 1997 for previous work). The minimum estimates for population sizes of common dolphins and bottlenose dolphins in Galician waters are 8140 and 660 respectively, although in both cases with wide confidence limits. Nevertheless, applying a precautionary approach it would be reasonable to specify maximum by-catch removal rates of 2% of these figures, i.e. 160 and 13 animals respectively.

The interview data in the present study suggest that by-catch mortality substantially exceeds these figures. We believe that it is essential that, minimally, an extensive and long-term by-catch monitoring programme, using on-board observers, is put in place. Subject to improved quantification of by-catch mortality, some kind of by-catch reduction measures may be required. Given the high social and economic importance of fishing in Galicia, measures that significantly restrict fishing are unlikely to be successfully implemented. However, possible measures include reductions in nocturnal trawling, delaying shooting trawl gear and/or hauling the gear more slowly if dolphins are present in the area, and reducing soaktime of gillnets.

Acknowledgements

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