ELSEVIER

Fisheries Research 41 (1999) 297–307

FISHERIES RESEARCH

Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic

Y. Morizur[a], S.D. Berrow[b,1,*], N.J.C. Tregenza[c], A.S. Couperus[d], S. Pouvreau[a]

[a]*IFREMER, Centre de Brest, BP 70, 29280, Plouzané, France*
[b]*Aquaculture Development Centre, Department of Zoology, University College, Cork, Ireland*
[c]*Cornwall Trust for Nature Conservation, Five Acres, Allet, Truro, TR49DJ, Cornwall, UK*
[d]*RIVO-dlo, Haringkade 1, PO Box 68, 1970 AB IJmuiden, Netherlands*

Received 31 December 1998; accepted 7 January 1999

Abstract

Marine mammal by-catch in 11 pelagic trawl fisheries operated by four different countries in the northeast Atlantic was studied. Observers accompanied commercial fishing vessels and monitored 374 tows totalling 1771 h of towing during 377 days fishing. Three species of marine mammal were identified in by-catches (white-sided dolphin, *Lagenorhynchus acutus*, common dolphin, *Delphinus delphis* and grey seal *Halichoerus grypus*) and a fourth, bottlenose dolphin *Tursiops truncatus*, was probably present. Dolphins were caught in four of the 11 fisheries and seal in one. In those fisheries with cetacean by-catch, rates varied from 0.0606 to 0.1000 per tow and 0.0107 to 0.0137 per hour of towing and were highest in the French sea bass fishery and lowest in the French tuna fishery. Grey seals were caught in the Irish Celtic Sea herring fishery at a rate of 0.0513 per tow or 0.0396 per hour of towing. The mean ±SD dolphin catch rate for all fisheries combined was 0.048±0.013 per tow (one dolphin per 20.7 tows), or 0.0185±0.0019 per hour of towing (one dolphin per 98 h of towing) and, for all marine mammals, 0.059±0.019 (1 per 17.0 tows) or 0.0124±0.0121 (1 per 80.6 h of towing). 95% confidence intervals, calculated on untransformed data, for all fisheries combined were 0.4–1.6 dolphins per 100 h of towing.

No operational factors were correlated with by-catch rates but the haul-back procedure was identified as a potentially important factor. All dolphin by-catches occurred during the night which may be a due to an association between cetaceans and trawlers at night. White-sided dolphins and grey seals were observed feeding around the net during towing and this behaviour may make them more vulnerable to capture. Operational difficulties in observing by-catch and potentially significant annual fluctuation in catch rates warrant further observer studies of these and other trawl fisheries.

Keywords: Marine mammal by-catch; Trawl fisheries; Northeast Atlantic

1. Introduction

The incidental capture of marine mammals by commercial fisheries is often a controversial and emotive, but poorly understood issue. Northridge (1984), in a review of fisheries interactions throughout

*Corresponding author. Tel.: +44-1223-221-611; fax: +44-1223-221-259; e-mail: sdbe@pcmail.nerc-bas.ac.uk

[1]Present address: Marine Life Science Division, British Antarctic Survey, High Cross, Madingley Road, CD3 OET, Cambridge, UK.

0165-7836/99/$ – see front matter
PII: S0165-7836(99)00013-2

the world, concluded that no species of marine mammal can be excluded from the possibility of some conflict with fishermen but the lack of adequate data prohibits an assessment of the full extent and potential impacts of many of these interactions.

The northeast Atlantic Ocean, especially in areas over the continental shelf, provide some of the most productive and intensively fished waters in the world (ICES, 1997). Most records of incidental capture of marine mammals in this area come from gill-net fisheries (see Global Review in Perrin et al. (1994)) and are thought to be unsustainable in some locations (Tregenza et al., 1997a). Although cetaceans have been known to be caught in trawl fisheries in the northwest Atlantic for many years (Waring et al., 1990; Fertl and Leatherwood, 1997) and a number of mammal species have been reported in trawl fisheries from the northeast Atlantic (Northridge, 1984, 1991; Fertl and Leatherwood, 1997), most records are anecdotal and no attempt has been made to quantify marine mammal by-catch in any trawl fishery in these areas.

Two species of dolphin, bottlenose *Tursiops truncatus* and common dolphin *Delphinus delphis* were reported by Duguy and Hussenot (1982) as taken in mid or deep-water trawls on the French Atlantic coast between 1971 and 1981 and three long-finned pilot whales *Globicephala melas* in bottom or mid-water trawls. A long-finned pilot whale was also reported in a demersal trawl off Cornwall, southwest England by Northridge (1991) and a single minke whale *Balaenoptera acutorostrata* off northwest Ireland (Berrow and Rogan, in press). Further reports of cetaceans in trawl nets in the northeast Atlantic involve white-beaked dolphin *Lagenorhynchus albirostris* in the North Sea (Leatherwood and Reeves, 1983), common dolphins in mid-water trawls in the English Channel (Northridge, 1991) and the occasional harbour porpoise *Phocoena phocoena* in Swedish, Danish and German waters (Berggren, 1994; Kinze, 1994; Kock and Benke, 1996).

Large numbers of strandings of cetaceans have also been reported as being possibly caused by interactions with pelagic trawling in several areas of the northeast Atlantic. Kuiken et al. (1994) identified a mackerel *Scomber scombrus* fishery as the most likely cause of a mass mortality of common dolphins in southwest England in 1992/1993. The same fishery was thought to be responsible for similar strandings of common and white-sided dolphin *Lagenorhynchus acutus* off the south and west coasts of Ireland and a herring *Clupea harengus* fishery for harbour porpoise strandings off the southern Irish coast (Berrow and Rogan, 1997), Collet and Mison (1995) reported 600 dolphins stranded in two days in February 1989 between Landes and Vendee on the French Atlantic coast and, more recently, 629 dolphins were stranded between 13 February and 4 March 1997 on southern Brittany and Biscay coasts (Collet, A. personal communication). Both events were thought to be a result of fishing mortality by trawlers as many cadavers showed signs of incidental capture. Fishery interactions were identified as the main cause of death of stranded harbour porpoises in the UK by Baker and Martin (1992).

As part of a study of by-catch and discarding practices in pelagic trawl fisheries in the northeast Atlantic (Morizur et al., Contract EC DG XIV-C-1, BIOECO/93/017, 1996) a wide range of trawl fisheries was monitored for both marine mammal by-catch and fish discarding. This is the first specific study aimed at quantifying marine mammal by-catch in pelagic trawl fisheries by European fishing fleets. Results from some of the individual fleets have been reported elsewhere (Couperus, 1997; Berrow et al., 1998) but in this paper we present all the data on the incidental capture of marine mammals in all the fisheries studied and discuss some possible underlying factors leading to this interaction.

2. Methodology

2.1. Fisheries sampled

Eleven trawl fisheries operated by four different countries were studied: namely French anchovy *Engraulis encrasicolus*, hake *Merluccius merluccius*, tuna *Thunnus alalunga*, black bream *Spondyliosoma cantharus* and sea bass *Dicentrarchus labrax* fisheries, UK and French pilchard *Sardina pilchardus* fisheries, UK mackerel, Irish herring and French and Dutch horse-mackerel *Trachurus sp*. fisheries. Although a wide variety of fisheries were studied all operate seasonally in the area from the Bay of Biscay (43°36′N, 1°44′W), north to southwest Ireland and

in the western approaches to the English Channel (47°20′N, 10°12′W).

Scientific observers accompanied commercial fishing vessels to observe fishing effort and record the incidental capture of marine mammals. Fishery scientists were employed specifically for this study and had no other responsibilities beyond this remit. Dutch, UK and Irish partners restricted monitoring to single, large fisheries and attempted to sample a large proportion of the fishery while the French partners, due to the large number of artisanal fisheries, attempted to sample a wide range of fisheries but with restricted coverage and concentrating on the Bay of Biscay and in the western approaches to the English Channel. Monitoring of the Dutch horse-mackerel fishery was carried out at a time at the time of year when cetacean bycatch was thought to be highest.

2.2. Fishing effort

Observers studied as many tows as possible during each fishing trip. The duration, depth and location of each tow were recorded, as well as the tonnage of fish caught and the intended target species. Different fish species may be targeted during the same fishing trip, especially by French trawlers and each tow was allocated to a specific fishery after checking the observer's information with the species composition of landings. Total catch from each tow was estimated by the number of lifts per tow (in the case of vessels which did not use a fish pump) or from the landings data obtained from the fishermen's logbook. Data from non-pelagic tows in the French fishery, which occurred occasionally in the pelagic fisheries, are not presented.

2.3. Incidental capture of marine mammals

The unit of sampling for marine mammals was the tow as it was hoped that all mammals caught could be recorded, identified, measured, and if possible, landed. The body temperature of by-caught mammals was measured by Dutch observers shortly after coming onboard, by inserting a flexible probe 45 cm into the body via the anus or with a pin thermometer stabbed in the belly of the animal. Temperatures collected in this way must be considered to be minimum estimates, because the pin does not reach the middle of the body. Post-mortem examination of landed mammals was carried out whenever possible and these results have been presented elsewhere (Hartmann et al., 1994; Addink et al., 1997; Couperus, 1997). Stomach contents of two white-sided dolphins and four common dolphins by-caught in the Dutch horse-mackerel fishery were analysed as part of another study (Couperus, 1997).

2.4. Marine-mammal sightings

Sightings of marine mammals at sea during the course of fishing was recorded for UK, Irish and Dutch fisheries. Continuous daily records were kept on UK vessels of boat activity, speed, sea-state, daylight, and periods of observation. Sightings from Irish and Dutch vessels were opportunistic though dedicated observation periods were carried out during some Irish trips.

3. Results

3.1. Sampling effort

The number of vessels in each fishery studied and the estimated landings for the entire fishery are shown in Table 1. The principal fishing seasons and location of the majority of effort in each fishery by ICES Division are also presented but it should be remembered that fishing is very dynamic and there can be major changes in effort both seasonally and between years within the same fishery. The exact location of some fisheries (UK mackerel and pilchard) was not recorded following requests by the vessels skipper. Estimated proportion of annual effort sampled in this study ranged between fisheries from 28% for the UK pilchard fishery to 0.03% for the French anchovy fishery, the latter due to lack of collaboration in some French harbours (Table 2).

Fishing effort and the season when sampling was carried out is shown in Table 2 and fishing areas are presented in Fig. 1. During 377 fishing days at sea, 374 tows were sampled. Fishing effort was fairly evenly distributed between the fleets with 130 (35%) tows by French vessels, 119 (32%) by Dutch vessels and 77 (21%) and 48 (13%) by Irish and UK vessels (Table 2). Total fishing effort amounted to

Table 1
Typography of sampled fisheries and estimated landings (tonnes) from data supplied by National Departments of Marine (year in which statistics relate to in parantheses)

Fishery	No. of active vessels[a] (year)	Estimated landings (tonnes)	Main ICES Divisions fished	Fishing season
Dutch horse-mackerel	12 (1995)	110 000 (1994)	VIId-e, VIIh, VIIj	January–June
French hake	120 (1992)	3310 (1994)	VIIIa–b	All year[b]
French tuna	50 (1992)	1907 (1994)	VIIIa–d	August–December
French sea bass	70 (1992)	217 (1994)	VIIe, VIIIb	January–March
French horse-mackerel	130 (1992)	3235 (1994)	VIIIa	January–August
French anchovy	130 (1992)	14 500 (1994)	VIIIa–b	June–March
French black bream	15 (1992)	691 (1994)	VIIe	April–June October–December
French pilchard	90 (1992)	3700 (1994)	VIIIa	April–October
Irish herring	49 (1994)	20 000 (1994)	VIIg	October–February
UK mackerel	12 (1990)	4800 (1990)	VIIe	October–March
UK Pilchard	12 (1990)	1330 (1990)	VIIe	October–March

[a] The same vessels participate in a number of fisheries, therefore the total fleet is not the sum of the individual fleets.
[b] Location of fishery changes through the year.

1771 h of towing with Dutch trawlers accounting for nearly one half (47%).

3.2. Marine mammal by-catch

Three species of marine mammals were definitely by-caught during this study namely: 12 common dolphins, five white-sided dolphins, and four grey seals (Table 3). A large dolphin, thought to be a bottlenose dolphin was also reported as by-caught in the French tuna fishery. Dolphins were caught in four fisheries, one-half (nine dolphins) in the Dutch horse-mackerel fishery, four each in the French hake and tuna fishery and one in the French sea bass fishery. Of the 18 dolphins caught six were caught as single individuals. The other incidents involved two, three (twice) and four dolphins together. All grey seals were caught as single individuals in the Irish herring fishery and no marine mammals were observed by-caught in the UK mackerel or pilchard fisheries or French anchovy, black bream or pilchard fisheries.

All by-caught mammals were adults and both sexes (four females and nine males) were caught (Table 3).

Table 2
Fishing effort and fishing season sampled and estimated fraction of total annual effort sampled

Fishery	Fishing season sampled	Days at sea	No. of tows	No. of sampled tows	Hours of towing	Annual effort sampled (%)
Dutch horse-mackerel	January–March, 1994/1995	102	216	119	841	3.0
French hake	September–November, 1994 and February, April–June, 1995	30	73	52	338	0.3
French tuna	August–October, 1994	50	66	43	265	1.6
French sea bass	January, February, April, 1995	9	21	10	73	1.6
French horse-mackerel	January–March, 1995	9	14	7	19	0.4
French anchovy	March and June, 1995	9	21	11	15	<0.1
French black bream	May–June, 1995	5	5	3	9	0.1
French pilchard	May 1995	2	4	4	3	0.1
Irish herring	October–January, 1994/1995	85	78	77	101	7.0
UK mackerel	November–March, 1993/1994	59	36	34	72	4.0
UK pilchard	October–December, 1993	17	15	14	35	28.0
TOTAL		377	528	374	1771	

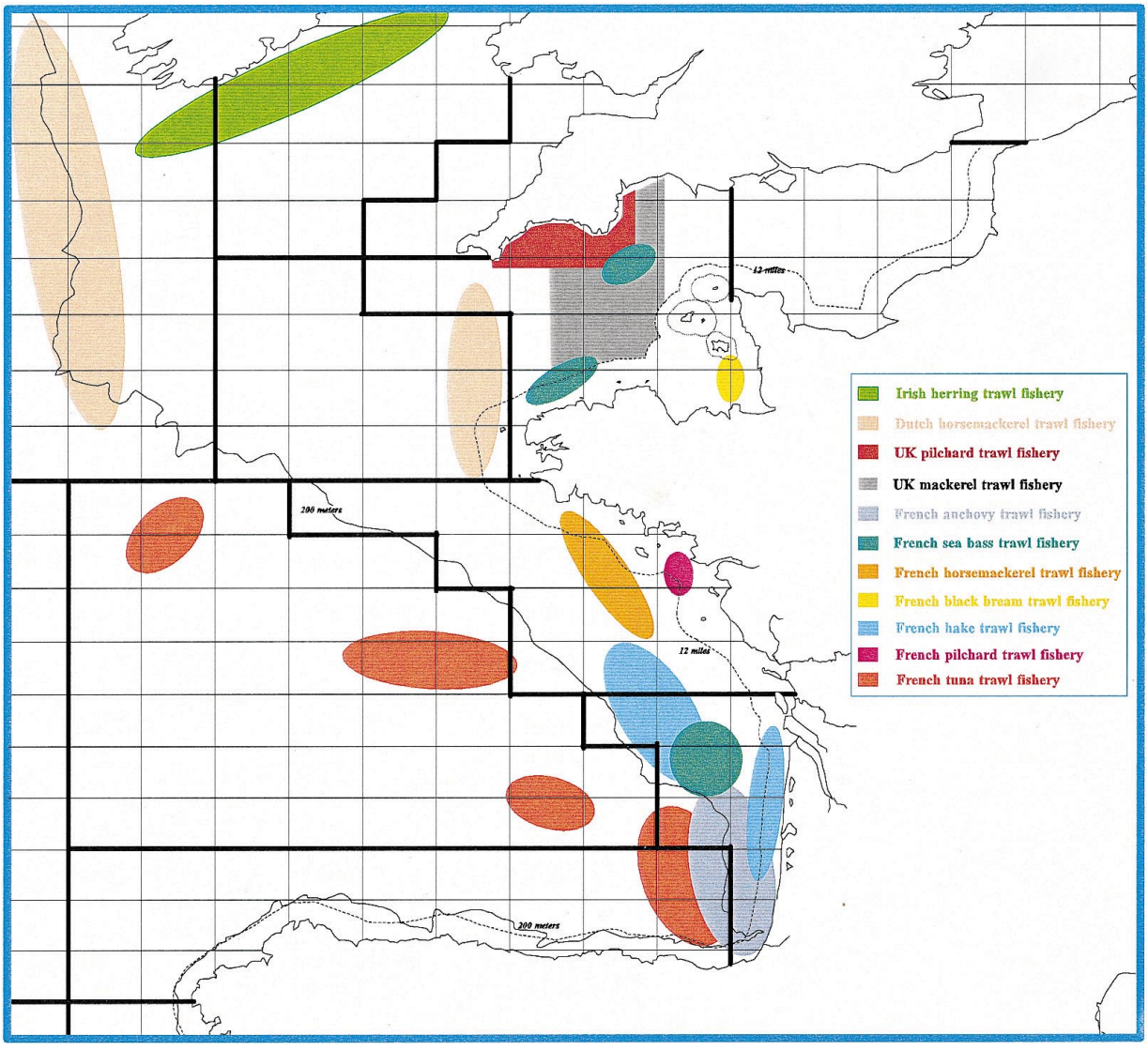

Fig. 1. Map of the main areas fished during the study and location of dedicated cetacean sighting surveys, MICA and SCANS (see text).

When blubber thickness (12–22 mm) was recorded, all were apparently healthy. One dolphin was entangled in the forward lines of the net, while all other animals caught were free within the lighting bag. Body temperature of the nine cetaceans for which it was measured ranged from 26.6°C to 38.0°C but exceeded 34.0°C for seven (78%) of the individuals. All Dutch dolphin by-catches were in nets hauled at night and all French by-catches were between 02.00 and 08.00 h.

3.3. Marine mammal catch rate

Mammal by-catch rates have been calculated for each fishery and are expressed as the number of individuals per hour of towing and per tow. Catch rates of dolphins, in fisheries with dolphin by-catch, ranged from 0.0606 to 0.1000 per tow and from 0.0107 to 0.0137 per hour of towing (Table 4). The catch rate of seals in the Irish herring fishery was 0.0513 seals per tow or 0.0396 per hour of tow. Catch rates, for

Table 3
Species and number of by-caught marine mammals and fishing procedure at time of capture

Fishery	Species	Number in tow	Sex	Length (m)
Dutch horse-mackerel	Common dolphin	4	1♀, 3♂	1.92, 2.03, 2.00, 2.12
	White-sided dolphin	5	1♀, 4♂	2.00, 2.30, 2.32, 2.63, 2.47
French hake	Common dolphin	4	2♀, 1♂	2.03, 1.97, 1.80
French tuna	Common dolphin	3	?	?
	Bottlenose dolphin[a]	1	?	?
French sea bass	Common dolphin	1	1♂	1.80
Irish herring	Grey seal	4×1	2♂, 2?	1.70–1.90
Total	Dolphins	18		
	Seals	4		

[a]Probably this species.

fisheries where a by-catch was recorded, were highest for the French sea bass fishery and lowest for the French tuna fishery. The mean ±SD dolphin catch rate for all fisheries combined was 0.048±0.013 per tow (1 dolphin per 20.7 tows), or 0.0185±0.0019 per hour of towing (1 dolphin per 98 h of towing) and, for all marine mammals, 0.059±0.019 (1 per 17.0 tows) or 0.0124± 0.0121 (1 per 80.6 h of towing). 95% confidence intervals, based on untransformed data, were 0.4–1.6 dolphins per 100 h of towing and a mean of 1.0.

3.4. Marine-mammal prevalence in fishing area

Two sightings were made during 1214 h of observation (511 h in daylight, 703 h of darkness) in the UK study but sea-state was less than 2 (above which the ability to detect dolphins declines markedly) for only 48 h. Both sightings were of four common dolphins, at 4°N 34′W and 4°N 44′W, respectively, that briefly approached the vessel while it was searching for fish at 5.2–5.5 knots. The only sighting of harbour porpoises was a single group of four seen during the Irish study at 51°45′N, 8°13′W, but grey seals were seen on six occasions feeding near to the trawl in the same fishery. In the Dutch study 31 sightings were recorded by the observer, all to the southwest of Ireland (Fig. 1). The most frequently observed species (39%) was the pilot whale (12 sightings; c183 individuals), followed by common (9 sightings, c307 individuals), bottlenose (6 sightings, c158 individuals) and white-sided dolphins

Table 4
Summary of practices in studied fisheries and marine mammal catch rates ($\times 10^{-2}$)

Fishery	Towing speed (nmls h^{-1})	Mesh size at cod-end (mm)	Width of headline (m)	Vertical aperture (m)	Depth of tows/water depth (m)	Rate per tow ($\times 10^2$)	Rate per hour of towing ($\times 10^{-2}$)
Dutch horse-mackerel		40	80–120	30–60	100/400	7.56	1.07
French hake	3.0–3.5	65–70	100–200	25–60	45/130	7.69	1.18
French tuna	3.5–4.5	80–110	140–160	38–40	50/1000–4000	6.06	1.51
French sea bass[a]	3.0–3.5	65–85	133–195	40–60	10/50	10.00	1.37
French horsemackerel[a]	3.0	65	133–195	40–45	60/100	0.00	0.00
French anchovy[a]	3.5–4.0	20	102	25–30	80/200	0.00	0.00
French black bream	3.5–4.0	90–100	119–134	15–18	20/30	0.00	0.00
French pilchard	3.0–3.5		114	20–27	20/40	0.00	0.00
Irish herring[a]	4.0		20–30	15–20	30/50	5.13	3.96
UK mackerel	3.2	40	64	11–24	36	0.00	0.00
UK pilchard	4.0	40	64	11–24	55	0.00	0.00
Total					Dolphins	4.81	1.02
					Overall	5.88	1.24

[a] Mainly pair trawlers, zero by-catch means none observed during sampled trips and does not imply there is no by-catch in fishery.

(3 sightings, c452 individuals). White-sided dolphins were seen twice following the vessel. One pod of seven pilot whales were observed for 30 min at the cod-end when the catch was being pumped on board. A mixed group of 12 bottlenose dolphins and 25 pilot whales were observed for a few minutes about 400 m behind the vessel during shooting of the net. On two other occasions pilot whales were seen swimming towards the stern of the vessel during shooting and hauling.

4. Discussion

This is the first attempt to quantify marine mammal by-catch by pelagic trawl fisheries in the northeast Atlantic. The study was compromised in France and Ireland by some fishing fleets and ports not wishing to co-operate. There is no legislation to enforce co-operation with observer studies in any of the countries involved and some of the original fisheries and seasons intended for monitoring had to be omitted.

The incidental capture of a marine mammal in a trawl fishery is a rare event. Only 18 individuals were caught in 11 of the 374 trawls sampled, totalling 1771 h of towing. However, given the size of the European fleet and the amount of fishing effort the total numbers of marine mammals may be biologically significant. It is not possible to control the wide variety of factors that may influence incidental capture and so researchers must attempt to record a wide range of parameters including fishing gear, the method of fishing and the prevailing conditions at the time of capture in an attempt to identify correlations in the data and understand how and why these animals are caught. The number of marine mammal by-catches reported here is too low to identify the factors which may lead to entrapment of mammals in northeast Atlantic trawl fisheries but the data presented do make an important contribution to present knowledge of these interactions in European waters.

Fish pumps were used extensively in some fisheries which compromised the ability of the observer to record all marine mammal by-catches. Dutch fisheries usually (98%) emptied the cod-end inboard after pumping the majority of the catch into holds but the UK mackerel and pilchard trawl fisheries studied emptied the cod-end out-board and thus any by-caught marine mammal may have gone unobserved. No vessels which used fish pumps in the Irish herring fishery were monitored. If buoyant a cadaver may be observed on the water surface near to the vessel but not when discarded at night or if it surfaces some distance away. Most cetaceans are neutrally buoyant when caught in gill-nets (Tregenza et al., 1997a) and probably go unnoticed. Where by-catch was not recorded in a fishery this does not imply that it never occurs, only that it did not occur or was not seen during monitored trips and it is thought that some marine mammal by-catch occurs in all the fisheries studied. Thus by-catch estimates reported here must be treated as minimum.

4.1. Biological factors influencing by-catch

In the Dutch horse-mackerel and Irish herring fishery the species by-caught (grey seals and white-sided dolphins) were also observed feeding on the target fish species around the nets. Of those by-caught animals landed for post-mortem examination, fresh or partially digested mackerel were found in 44 out of 46 white-sided dolphins (Couperus, 1997) and fresh herring in both grey seals examined (Berrow et al., 1998). Couperus (1997) also reported the remains of horse-mackerel, the target species of the fishery, in the stomachs of by-caught common and bottlenose dolphins but these were absent from stomachs of white-sided dolphins. Clearly the relationship between the fish shoals targeted by pelagic trawlers and incidental capture varies with both cetaceans and fish species present but by-catches of white-sided and common dolphins started to occur in the Dutch horse-mackerel fishery only when mackerel began to appear in the catches (Couperus, 1997). By-caught individuals may not be feeding on the same target species of the fishery but an associated non-target species or may be attracted to discards made available by fishing activity.

In the Dutch fishery white-sided dolphins were observed for more than 30 min swimming in the vessels wake probably scavenging for fish (Leopold and Couperus, 1995) making them vulnerable to entanglement during hauling. The feeding association between cetaceans and trawl nets was reviewed by Fertl and Leatherwood (1997). At least 15–16 species in all areas of the world feed in association with trawlers. Trawlers may be considered a concentrated

source of food in an otherwise patchy environment or a source of food, e.g., deep water fish or cephalopod species otherwise unavailable to small cetaceans (Fertl and Leatherwood, 1997). There is often considerable overlap between prey species recovered from by-caught cetaceans and the target species of the fishery. Couperus (1997) showed white-sided dolphins were feeding on different prey species before associating with the horse-mackerel fishery. Most of the dolphin by-catches in the present study occurred during the night or close to dawn. Waring et al. (1990) suggested that diurnal movements of prey species, especially squid, may explain some of the complex pattern of variation they reported between diurnal and nocturnal catch rates of common dolphins and pilot whales. By scavenging at night, white-sided dolphins may avoid competition with gannets *Sula bassana* which scavenge in large numbers around pelagic trawlers. There was no indication that common dolphins were attracted to discards although they frequently bow-rode vessels during towing. Stomach contents of by-caught individuals from this fishery showed they were feeding on horse-mackerel, hake and blue whiting *Micromesistius poutassou* as well as mackerel prior to capture (Couperus, 1997). Pilot whales also seem to be attracted to the net or, more likely, to fish and squid caught in the net meshes as they may also feed on discarded fish (Couperus, 1993). It is not known if they were feeding in and around the net during hauling similar to that reported by Waring et al. (1990). Although no pilot whales were caught during the present study Couperus (1997) reported that 12% of by-catches in the Dutch pelagic fishery between 1989 and 1994, mainly off southwest Ireland, involved this species. Albacore tuna caught in the French tuna fishery are two large (53–90 cm, TL) to be the prey of dolphins caught in that fishery and it is more likely that dolphins were feeding on a similar prey species to the tuna as cephalopods accounted for 52% of prey items in the stomachs of common dolphins caught in this fishery (Morizur, Unpublished data.)

The prevalence of mammals in the area of the fishery clearly must, at some level, be a determinant of by-catch rates. The Irish study was the only one to record the presence and capture of seals in the area of the fishery. Dolphin sightings were made on three of the four trips accompanied during the Dutch study. The only trip which predominantly caught horse-mackerel had no dolphin sightings and no dolphin by-catch. Interestingly although common dolphins were the most frequently observed dolphin species, white-sided, which were only the third most frequently sighted, predominated in the by-catches. This also suggests that the association of white-sided dolphins with this fishery is different from that of other dolphin species, with white-sided much more likely to obtain food from the trawlers than other species which will increase the likelihood of their being caught. Dolphin sightings in an area around 100 km to the west of the study area during the winters, 1992 and 1993 were much higher (Tregenza et al., 1997b) and certainly strandings data (Kuiken et al., 1994) indicate that in some years dolphins do enter the area where the UK mackerel and pilchard fisheries off southwest England operate, however this may be sporadic and thus marine mammal by-catch may also show large inter-annual fluctuations. A large increase in the number of dolphins caught in the Dutch pelagic trawl fisheries was reported in 1994, a result of increased reporting but it was also thought to be a high year for by-catches (Couperus, 1997).

4.2. Operational factors influencing by-catch

Although the number of individuals caught is small the pattern of by-catch can usefully be compared to published data from the northwest Atlantic (Waring et al., 1990). Between 1977 and 1988 the US government recorded 538 marine mammal by-catches by foreign vessels fishing off the northwest US coast. Waring et al. (1990) identified a number of factors which may be important in marine mammal capture, including biological factors such as the target species of the fishery, prevalence of marine mammals in the fishing area and time of day to operational considerations including, tow duration, level of tow in water column, size of net opening, haul-back speed and gear design.

No relationship was found between tow duration and marine mammal by-catch. The Dutch body temperatures recorded in by-caught dolphins were close to that for a living animal (37°C) suggesting that they had only recently died and had been captured during or close to hauling. However dolphins, due to their thick, insulating, blubber layer, may maintain a high body temperature many hours after death (Couperus, Unpublished data). Despite these precautions some

aspect of the haul-back process, perhaps entrapment by net closure, may cause by-catch. This is an area worthy of further investigation as it is part of the fishing procedure that can potentially be modified. A companion study (De Haan et al., 1997) is attempting to record the behaviour of dolphins around fishing nets during trawling using acoustic and other methods.

In fisheries on the continental shelf the vertical trawl opening may occupy more than half of the water column (e.g. French hake, sea bass, horse-mackerel, and black bream, Irish herring and UK mackerel and pilchard fisheries, see Table 4). There are no indications from the present study that level of tow was a significant factor in marine mammal by-catch but it would be difficult to distinguish between the depth where by-catch occurred from the depth of the target shoal without doing experimental fishing at a depth inconsistent with catching fish. However, it might prove possible to identify large differences in by-catch rates if they were related to the close vicinity of the sea surface or sea bed. Similarly, though the number of by-caught individuals were too few to assess the influence of the size of the net opening, individuals were caught in net openings ranging from 15 by 20 m (grey seals in the Irish herring fishery) to 150 by 50 m (common dolphin in the French sea bass fishery).

At present no feasible action has been identified which would enable pelagic trawl fisheries to avoid cetacean by-catches. All dolphin by-catch occurred at night but confining trawling to daylight hours is impossible to enforce and not yet of established benefit. Other possibilities include transmission of sounds to frighten dolphins away; large mesh nets across the net mouth to discourage cetacean entry; and cod-end escape devices, but all these are often of limited success (Fertl and Leatherwood, 1997) and no trials have been carried out on their effectiveness in the northeast Atlantic. All of these might affect fish catches and would not be readily accepted by the fishing industry.

4.3. *Biological significance of marine mammal by-catches*

No by-catch was reported in the UK mackerel and pilchard fisheries but under-recording is strongly suspected due to the nature of fishing practice. Berrow et al. (1998) considered it unlikely that by-catch of grey seals in the Celtic Sea herring fishery would cause any decline in the Irish grey seal population. By-catch rates have not been stratified for season or location due to the low number of incidents and for five fisheries the estimated proportion of the fishery sampled was less than 1%. Although catch rates per hour of towing were similar across the fisheries studied the confidence intervals for individual fisheries are wide. For fisheries where no by-catch was recorded in this study even though it probably exists catch rates would have to be applied from a different fishery. Any extrapolation to all pelagic fisheries would involve unacceptable assumptions and application of these minimum catch rates to such large fisheries and could produce inaccurate and very misleading results.

The marine mammal populations subject to mortality by these fisheries are also subject to by-catch in other fisheries and other fleets in the same fisheries other than those studied. Common and bottlenose dolphins are caught in the tuna drift net fishery (Goujon, 1993; Antoine et al., 1997) and in smaller numbers in set gill nets in the Celtic Sea (Tregenza et al., 1997a, b). White-sided dolphins are believed to be caught by Irish trawlers fishing for mackerel off the west coast of Ireland (Berrow and Rogan, 1997) and this by-catch may be quite high as there have been unconfirmed reports of up to 50 dolphins in a single tow. Clearly the extent of marine mammal mortality on the populations reported here is only a fraction of that attributable to fishing. Stock assessment of these species is still very limited and stock boundaries are not known for any cetacean species affected. Abundance estimates have been made for some areas, namely the MICA survey which covered an area of the tuna drift net fishery in 1993 (Goujon, 1993) and the Celtic Shelf in 1994 (Hammond et al., 1995) (Fig. 1). Common dolphin abundance was estimated at 61 888 (95%CI, 35 461–108 010) by Goujon (1993) and 75 449 (95% CI, 22 900–248 900) on the Celtic Shelf by Hammond et al. (1995). They also estimated an abundance of 833 *Lagenorhynchus* dolphins (white-sided and white-beaked dolphins) in the Celtic Sea during the survey. Both these surveys were conducted during the summer and may not necessarily reflect cetacean abundance during the winter.

The International Whaling Commission (IWC) (Anon, 1996) have recently agreed that, following the precautionary principal, by-catch should in no

case exceed one half of the maximum growth rate of a population. Woodley and Read (1991) estimated that the maximum rate of increase of otherwise unstressed populations of small cetaceans was around 4% but the IWC have adopted a figure of 1% of estimated abundance above which has expressed concern over the sustainability of anthropogenic removals (Anon, 1996). Obviously the reported by-catch in this study does not come near to this level of removal but further observer studies will have to be carried out before catch rates can be confidently extrapolated to whole fleets and fisheries and before the potential impact of incidental capture in pelagic and other trawl fisheries fully assessed. Considering the highly variable catch rate between fisheries, this will take many years, and monitoring should be incorporated into fisheries management programmes so that this information is collected in a systematic and consistent manner.

Acknowledgements

We would like to thank the fishermen and the fishing organisations (Comité National des Pêches Maritimes, Cornish Fish Producers Organisation, Dutch Freezer-trawler Association, Irish South and West Fishermen's Organisation) for their help and co-operation and the observers who carried out field work. This study was funded by the European Commission Contract EC DG XIV-C-1, Study BIOECO/93/017.

References

Addink, M., García Hartmann, M., Couperus, B., 1997. A note on life-history parameters of the Atlantic White-sided dolphin (*Lagenorhynchus acutus*) from animals bycaught in the north-eastern Atlantic. Rep. Int. Whal. Commn. 47, 637–639.

Anon, 1996. Report of the Sub-Committee on Small Cetaceans. Rep. Int. Whal. Commn., 46, 160–179.

Antoine, L., Goujon, M., Massart, G., 1997. Captures accidentelles de dauphins dans les filets derivants á thons en Atlantique Nord Est. ICES, CM 1997/Q:10.

Baker, J.R., Martin, A.R., 1992. Causes of mortality and parasites and internal lesions in harbour porpoises (*Phocoena phocoena*) from British waters. Veterinary Record 130, 554–558.

Berggren, P., 1994. Bycatches of the harbour porpoises (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Sea; 1973–1993. Rep. Int. Whal. Commn. (Special Issue) 15, 211–215.

Berrow, S.D., O'Neill, M., Brogan, D., 1998. Discarding practices and marine mammal by-catch in the Celtic Sea herring fishery. Biol. Environ., Proc. Roy. Irish Acad. 98B(1), 1–8.

Berrow, S.D., Rogan, E., 1997. Review of cetaceans stranded on the Irish coast, 1901–1995. Mammal Rev. 27(1), 51–76.

Berrow, S.D., Rogan, E., in press. Incidental capture of cetaceans in Irish waters. Ir. Nat. J.

Collet, A. and Mison, V., 1995. Analyse des échouages de cétacés sur le littoral français. Rapport contrat IFREMER-DRV-RH no. 94.2.511036, p. 32.

Couperus, A.S., 1993. Killer whales and pilot whales near trawlers east of Shetland. Sula 7(2), 41–52.

Couperus, A.S., 1997. Interactions between Dutch midwater trawl and Atlantic White-sided dolphins (*Lagenorhynchus acutus*) southwest of Ireland. J. Northw. Atl. Fish. Sci. 22, 209–218.

De Haan, D., Dremiere, P.Y., Woodward, B., Kastelein, R.A., Amundin, M., Hansen, K., 1997. Prevention of by-catch of small cetaceans in pelagic trawl by technical means. ICES, CM 1997/Q: 20.

Duguy, R., Hussenot, E., 1982. Occasional captures of delphinids in the northeast Atlantic. Rep. Int. Whal. Comm. 32, 461–462.

Fertl, D., Leatherwood, S., 1997. A review of cetacean interactions with trawls. J. Northw. Atl. Fish. Sci. 22, 219–248.

Goujon, M., 1993. Rapport interne de la Direction des Ressources Vivantes de I'IFREMER, RIDRV 93.034.

Hammond, P.S., Benke, M., Berggren, P., Borehers, D.L., Buckland, S.J., Collet, A., Meide-Jørgensen, M.P., Heimlich-Boran, S., Iby, A.R., Leopold, M.F., Øien, N., 1995. Distribution and abundance of the Harbour Porpoise and other small cetaceans in the North Sea and adjacent waters. Final Report to EU DGXI, LIFE 92-2/UK/027.

Hartmann, M.G., Couperus, A.S., Addink, M.J., 1994. The diagnosis of by-catch: preliminary results of research in The Netherlands. In: Kuiken, T. (Ed), Proceedings of the Second ECS Workshop on Cetacean Patholog: Diagnosis of By-catch in Cetaceans, pp. 16–23.

ICES 1997. Report of the ICES Advisory Committee on Fishery Management, 1996, Parts 1 and 2. ICES Coop Res. Rep. 221, 318 and 324.

Kinze, C.C., 1994. Incidental catches of Harbour porpoises (*Phocoena phocoena*) in Danish waters, 1986–1989. Rep. Int. Whal. Commn. (Special Issue) 15, 183–187.

Kock, K.-H., Benke, H., 1996. On the by-catch of harbour porpoises (*Phocoena phocoena*) in German fisheries in the Baltic and North Sea. Arch. Fish. Mar. Res. 44, 95–114.

Kuiken, T., Simpson, V.R., Allchin, C.R., Bennett, P.M., Codd, G.A., Harris, E.A., Howes, G.J., Kennedy, S., Kirkwood, J.K., Law, R.J., Merrett, N.R., Phillips, S., 1994. Mass mortality of common dolphins (*Delphinus delphis*) in south west England due to incidental capture in fishing gear. Veterinary Record 134, 81–89.

Leatherwood, S., Reeves, R.R., 1983. Bottlenose dolphin *Tursiops truncatus* and other toothed cetaceans. In: Chapman, J.A., Feldhamer, G.A. (Eds.), Wild Mammals of North America: Biology, Management and Economics, John Hopkins University Press, Baltimore, pp. 369–414.

Leopold, M.F., Couperus, A.S., 1995. Sightings of Atlantic White-sided dolphins *Lagenorhynchus acutus* near the south-eastern limit of the known range in the north-east Atlantic. Lutra 38, 77–80.

Northridge, S.P., 1984. World review of interactions between marine mammals and fisheries. FAO Fisheries Technical Paper, 251.

Northridge, S.P., 1991. An updated world review of interactions between marine mammals and fisheries. FAO Fisheries Technical Paper 251, Suppl. 1.

Perrin, W.F., Donovan, G.P., Barlow, J., 1994. Gillnets and Cetaceans. International Whaling Commission, Special issue 15, Cambridge, UK, pp. 1–53.

Tregenza, N.J.C., Berrow, S.D., Leaper, R., Hammond, P.S., 1997a. Harbour porpoise, *Phocoena phocoena* L., by-catch in set gill nets in the Celtic Sea. ICES J. Mar. Sci. 54, 896–904.

Tregenza, N.J.C., Berrow, S.D., Leaper, R., Hammond, P.S., 1997b. Common dolphin, *Delphinus delphis* L., bycatch in bottom set gillnets in the Celtic Sea. Rep. Int. Whal. Commn. 47, 835–839.

Waring, G.T, Gerior, P., Payne, M.P., Parry, B.L., Nicolas, J.R., 1990. Incidental take of marine mammals in foreign fishery activities off the northeast United States, 1977–1988. Fish. Bull. 88, 347–360.

Woodley, T.H., Read, A.J., 1991. Potential rates of increase of a harbour porpoise (*Phocoena phocoena*) population subjected to incidental mortality in commercial fisheries. Can. J. Fish. Aquat. Sci. 48, 2429–2435.