J. Northw. Atl. Fish. Sci., Vol. 22: 209–218

Interactions Between Dutch Midwater Trawl and Atlantic White-sided Dolphins (*Lagenorhynchus acutus*) Southwest of Ireland

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Abstract

Incidental catches of cetaceans in the Dutch pelagic trawl fishery are largely restricted to late-winter early-spring in an area along the continental slope southwest of Ireland. Available evidence indicates that annual variations in such incidents are large. Using combined mid-water trawl by-catch and dolphin stomach content data, the hypothesis is put forward that Atlantic white-sided dolphin (*Lagenorhynchus acutus*), normally a more oceanic species, may actively search for mackerel (*Scomber scombrus*) closer to shore in early-spring, at least in some years. Supporting data were from an observer program during 1992–94, which covered seven trips representing 5% of the annual effort in the fishery. Also over the period 1989–94, a total of 71 records of by-catch incidents were collected (involving a minimum of 312 individuals), of which 41 occured in 1994 (172 individuals). Approximately 90% of the incidents occurred late-winter early-spring, when both the mackerel and horse mackerel (*Trachurus trachurus*) pelagic fisheries were operating in the same area, southwest of Ireland. Incidence frequency peaked by late February and March, when mackerel is known to move into the area during its southward migration. The Atlantic white-sided dolphin was the main cetacean species in the by-catch (83% of all identified individuals). Other species recorded included long-finned pilot whale (*Globicephala melas*), short-beaked common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*) and the white-beaked dolphin (*Lagenorhynchus albirostris*). The stomachs of 47 Atlantic white-sided dolphins, 11 common dolphins, two bottlenose dolphins and one white-beaked dolphin were examined. Fresh mackerel remains were found in nearly all white-sided dolphin stomachs, whereas fresh horse mackerel remains occured only in stomachs of bottlenose and common dolphins. Deep-water fish otolith incidents suggested that white-sided, common and bottlenose dolphin had completely different diets before moving to the southwest of Ireland.

Keywords: *Delphinus delphis*, diet, *Globicephala melas*, incidental by-catch, *Lagenorhynchus acutus*, midwater trawling, Northeast Atlantic, *Tursiops truncatus*

Introduction

Worldwide attention has been given to interactions of cetaceans with gillnet and driftnet fisheries (e.g. Northridge, 1991; Jefferson and Curry, 1994; Perrin *et al.*, 1994), while information on interactions with trawl fisheries has been very limited (Waring *et al.*, 1990; Fertl and Leatherwood, 1997).

A pilot study on discarding and incidental catches of marine mammals in the Dutch midwater trawl fisheries was started in October 1992. The economically most important fishery is a beam trawl fishery for flatfish (plaice, *Pleuronectus platessa* and Sole, *Solea solea*), with approximately 500 vessels. Due to the physical constraints of the fishing gear (with vertical opening of less than 1 m), by-catches of marine mammals in this fishery have been very limited. The second most important fishery in economic terms is the midwater trawl fishery for pelagic species, including horse mackerel (*Trachurus trachurus*), mackerel (*Scomber scombrus*) and herring (*Clupea harengus*). The use of gillnets has been very limited in the Netherlands (approximately 4 vessels). This paper describes the patterns of incidental by-catches of small cetaceans in relation to the seasonal distribution of the Dutch midwater trawl fishery and the feeding ecology of different species of bycaught cetaceans based on their stomach contents.

The Dutch Pelagic Fishery

The Dutch pelagic fleet consisted of 12 freezer trawlers, while an additional nine non-Dtuch trawlers were operating for the same company with foreign flags. The average annual catch of the Dutch fleet has been in the order of 300 000 metric tons (Grainger, 1992).

The vertical opening of the pelagic trawls used varied between 30 and 60 m, while the horizontal spread of the wings ranged from 80 to 120 m. Mesh size in the front part of the net were up to 30 m, rapidly diminishing towards the cod end. In the cod end, the stretched mesh size was 4 cm. The duration of fishing trips varied between 2.5 and 5 weeks, depending on catch rates. Fishing areas were in the North Sea and around the British Isles along the continental shelf (Fig. 1).

In January, part of the fleet fished for horse mackerel southwest of Ireland. At the same time other trawlers were fishing north of Scotland for wintering mackerel. As mackerel migrates over a period of a few months to the spawning area south of Ireland (Anon., MS 1990), their schools are followed by the trawlers. As a consequence, the two fisheries merge by late February and March, resulting in a mixed fishery for both horse mackerel and mackerel southwest of Ireland.

Methods

By-catch records

In 1989, two freezer trawlers cooperating in the market sampling program were asked also to report by-catch, but the response met with limited success. Therefore, during 1992–94 an observer program was started and seven trips were studied by observers on board of five different freezer trawlers (Table 1), covering an equivalent of approximately 5% of the total annual effort. The observer estimated discards of fish, encouraged crews to report incidental catches of cetaceans and instructed the crew on species identification. Informal conversations with skippers and crew also allowed documentation of time and area of former incidental catches. As a direct consequence of this program three skippers agreed in 1993 to report all by-catches, and in 1994, all skippers of the Dutch vessels (12) and two vessels under English flag were willing to cooperate. To improve the data, each vessel received a poster with colour illustrations of small cetaceans (from a Dutch identification guide: Peet *et al*., 1992) and information about the project. In December 1994, nine skippers had reported by-catches on a special form. In this program a total 71 by-catch records of cetaceans were collected over a period of six years (Table 2). In general the data were considered representative, however, the species identified as 'common dolphin' was assumed to be the short beaked common dolphin (*Delphinus delphis*: see Heyning and Perrin, 1994).

Analysis of stomach contents

In response to a special request, eight skippers whenever possible kept the by-catch dolphins deep-frozen on board. A total of 47 Atlantic white-sided dolphins, 11 short-beaked common dolphins, two bottlenose dolphins and one white-beaked dolphin were landed in 1993 and 1994. As a part of this project, stomachs were retrieved and stored deep-frozen (-30°C) for subsequent further analysis. For analysis the stomachs were thawed and contents weighed to the nearest gram. Intact and partial digested fish and squid were separated from the skeletal remains. Whenever possible, body length of fish or mantle length of squid was measured, or size class estimated according to the methods used and developed in the ICES stomach sampling program (Anon., MS 1991). The remaining contents were rinsed through three nested sieves (0.425, 0.800 and 3.350 mm) to obtain intact pieces of tissue and bones. Otoliths and squid beaks were removed and stored in 80% ethanol. Readily identifiable fish and partially digested squid were stored in 4% formaldehyde solution. Fish remains pending identification were stored in ethanol. The number of bony fish represented by skeletal remains was estimated by halving the number of sagittal otoliths.

Whenever possible prey items were identified to the lowest taxon using a local reference collection as well as published identification keys and pictorial guides (Härkönen, 1986; Kotthaus, 1972). The number of cephalopods was estimated from the maximum number of lower or upper beaks retrieved for each species. Only the fish component of the stomach contents will be considered in this study, since cephalopod beaks have not yet been analysed. Only otoliths retrieved from the 0.800 and 3.350 mm sieve were used as the contents in the 0.425 mm sieve only contained heavily worn or eroded (fractions of) otoliths.

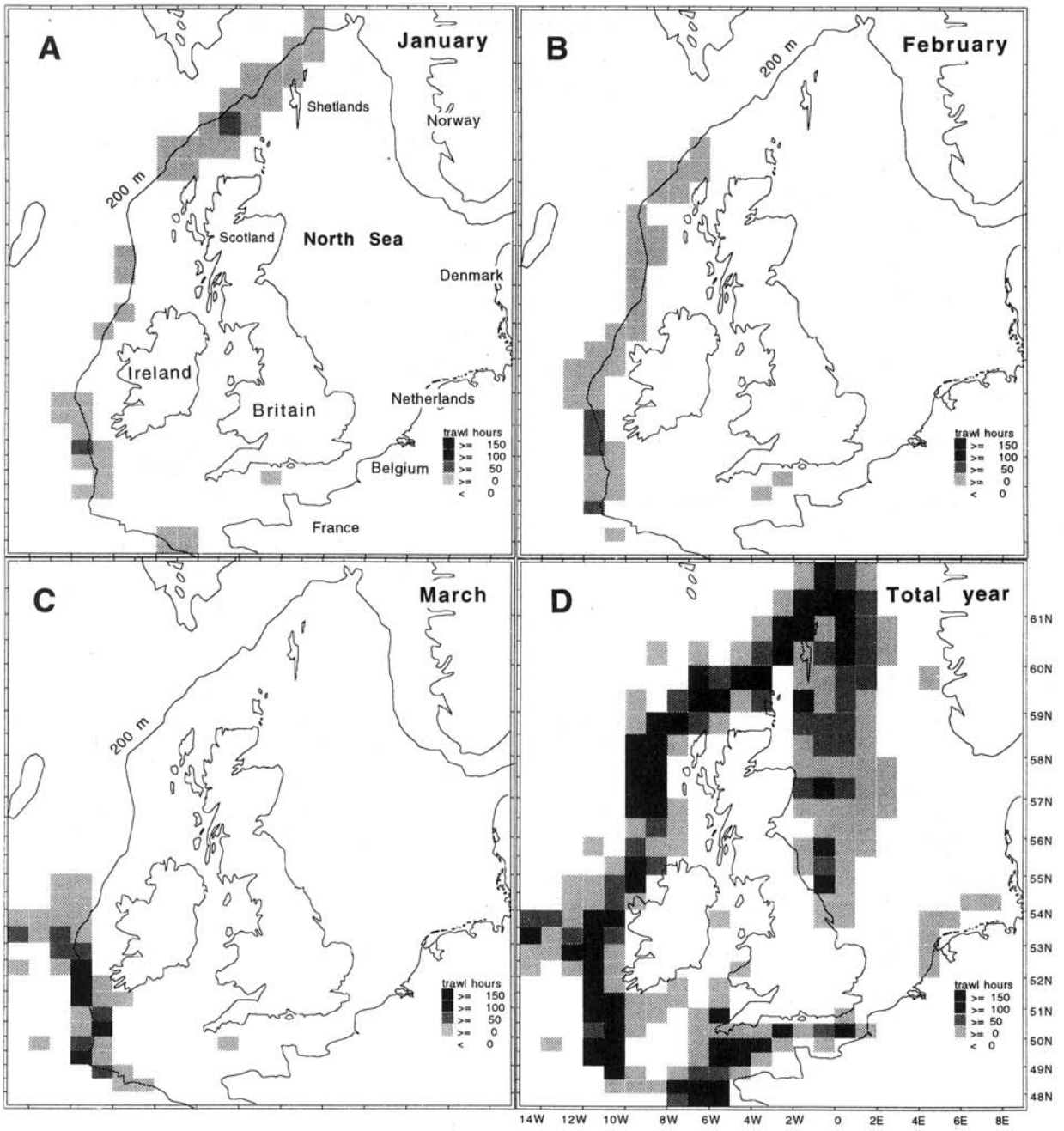

Fig. 1. Estimated average fishing effort in1989–94 of the Dutch freezer trawler fleet in hours trawling per ICES rectangle. (**A**) January; (**B**) February; (**C**) March; (**D**) Total year.

Results

Figure 1 (a–c) shows the estimated average fishing effort (1989–94) by month January–March. Effort was calculated by extrapolation from the effort of 2–3 vessels which submitted detailed information on their fishing operations, to the total Dutch fleet, within the framework of a market sampling program. Figure 2 shows the estimated catches of the Dutch fleet in the area between 48°30' and 54°30'N, and 8° and 14°W by week. The catches consisted only of horse mackerel until week 7, whereas mackerel became an important component from week 8 onwards.

TABLE 1. Periods of fishing trips with an observer on board.* Number and letter codes refer to ICES areas covered.

Period	Target species	By-catch/ secondary target	Area*
19 Oct –7 Nov 92	mackerel	herring	IVaW, E (N of Shetland)
16 Feb –6 Mar 93	horse mackerel	mackerel	VII,c,j (SW of Ireland)
19 Mar–6 Apr 93	blue whiting	greater argentine/ horse mackerel mackerel	VIIb,c,j,(k) (W of Ireland)
27 Jul–16 Aug 93	herring	horse mackerel/ mackerel	IVb, IVaW, VIaN, VIaZ (St. Kilda, North Sea)
29 Jan–26 Feb 94	horse mackerel	mackerel	VIIb,j,(c) (SW of Ireland)
4 Mar–28 Mar 94	horse mackerel	mackerel	VIIh,j (SW of Ireland)
24 Aug–26 Sep 94	horse mackerel	mackerel/ pilchard	VIIh,e,l (S off Cornwall)

TABLE 2. Number of by-catch incidents per year.

Year	1989	1990	1991	1992	1993	1994
Size of Dutch fleet (No. of vessels)	11	12	13	13	13	12
No. of Dutch vessels reporting	2	2	3	3	3	12
No. of records	2	7	10	3	6	38
No. of dolphins	20	26	61	11	15	117
No. of English vessels reporting	0	0	0	0	2	2
No. of records	–	–	–	–	2	3
No. of dolphins	–	–	–	–	7	55

By-catches

Of the 71 by-catch incidents recorded, 62 (277 individuals: 89%) occurred southwest of Ireland. Of the total number of 312 individuals, 197 (67%) were identified to species (Table 3). Figure 3 shows that the catch positions were scattered between 48°30' and 54°30'N, along the 200 m isobath. Very few records originated from the North Sea and the entrance of the Channel and none from west of Scotland waters. All reports from the period February through April refer to the area southwest of Ireland, whereas the few reports from other areas refer to other periods of the year (Fig. 4).

The species most frequently caught was the Atlantic white-sided dolphin (78% of all identified cetaceans; southwest of Ireland 83%). A few incidences of this species were reported in early January and one in September, all for the area southwest of Ireland. Other species involved were the long-finned pilot whale (*Globicephala melas*;

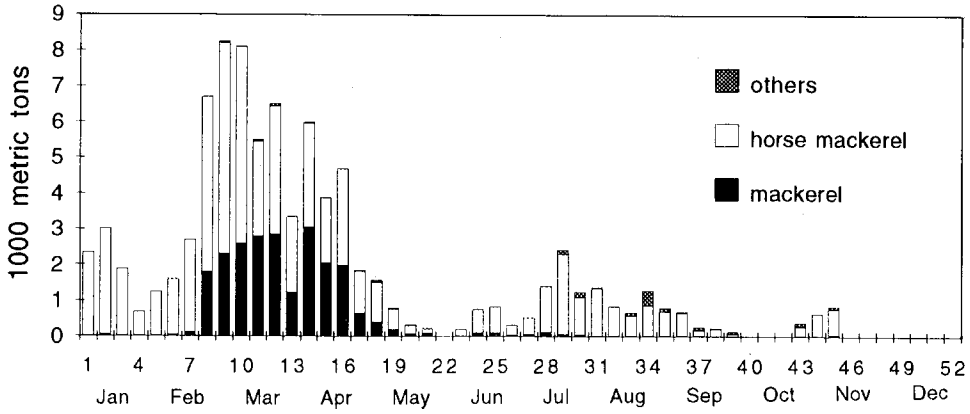

Fig. 2. Estimated average weekly catches in 1989–94 southwest of Ireland (48°30'–54°30' north; 8°–14° west).

TABLE 3. Records of by-catch incidents and corresponding number of individuals caught (in parentheses) during 1989–94. *Unidentified dolphins are here considered to belong to one of the three by-caught dolphin species: white-sided dolphin, common dolphin or bottlenose dolphin.

Species	SW of Ireland	Other areas	Total
White-sided dolphin	32 (153)	0 (0)	32 (153)
White-beaked dolphin	0 (0)	1 (3)	1 (3)
Common dolphin	4 (9)	2 (5)	6 (14)
Bottlenose dolphin	2 (3)	0 (0)	2 (3)
Unidentified dolphin*	16 (93)	5 (22)	21 (115)
Long-finned pilot whale	8 (19)	1 (5)	9 (24)
Total	62 (277)	9 (35)	71 (312)

12%), common dolphin (7%), bottlenose dolphin (1.5%) and the white-beaked dolphin (1.5%). A relatively large proportion of the dolphins (40%) could not be identified to species, though the majority of these may have been white-sided dolphins, at least those from the area southwest of Ireland.

Stomach contents

Nearly all white-sided dolphins (44 out of 46) had intact or partly digested fish in their stomachs, most of which (88% in numbers of all stomachs) consisted of mackerel (Fig. 5). Remains of horse mackerel were found in stomachs of common dolphin (6%) and bottlenose dolphin (50%), but were completely absent from white-sided dolphin stomachs. The food composition according to the otoliths retrieved differed substantially from that indicated by relatively fresh material. Otoliths of mesopelagic species like silvery pout (*Gadiculus argenteus*), lanternfishes (Myctophidae) and pearlsides (*Maurolicus muelleri*) were the most frequently found. Silvery pout were found most frequently in white-sided dolphins, pearlsides in common dolphins and greater argentine (*Argentina silus*) and hake (*Merluccius merluccius*) in bottlenose dolphins.

Discussion

Incidental catches of cetaceans in the Dutch pelagic trawl fishery are largely restricted to late-winter early-spring, in an area along the continental slope southwest of Ireland. These incidents show a distinct peak during the period when mackerel move into the area and are caught by the fishery. The main species of cetacean incidentally caught southwest of Ireland (83% of identified cases) was the Atlantic

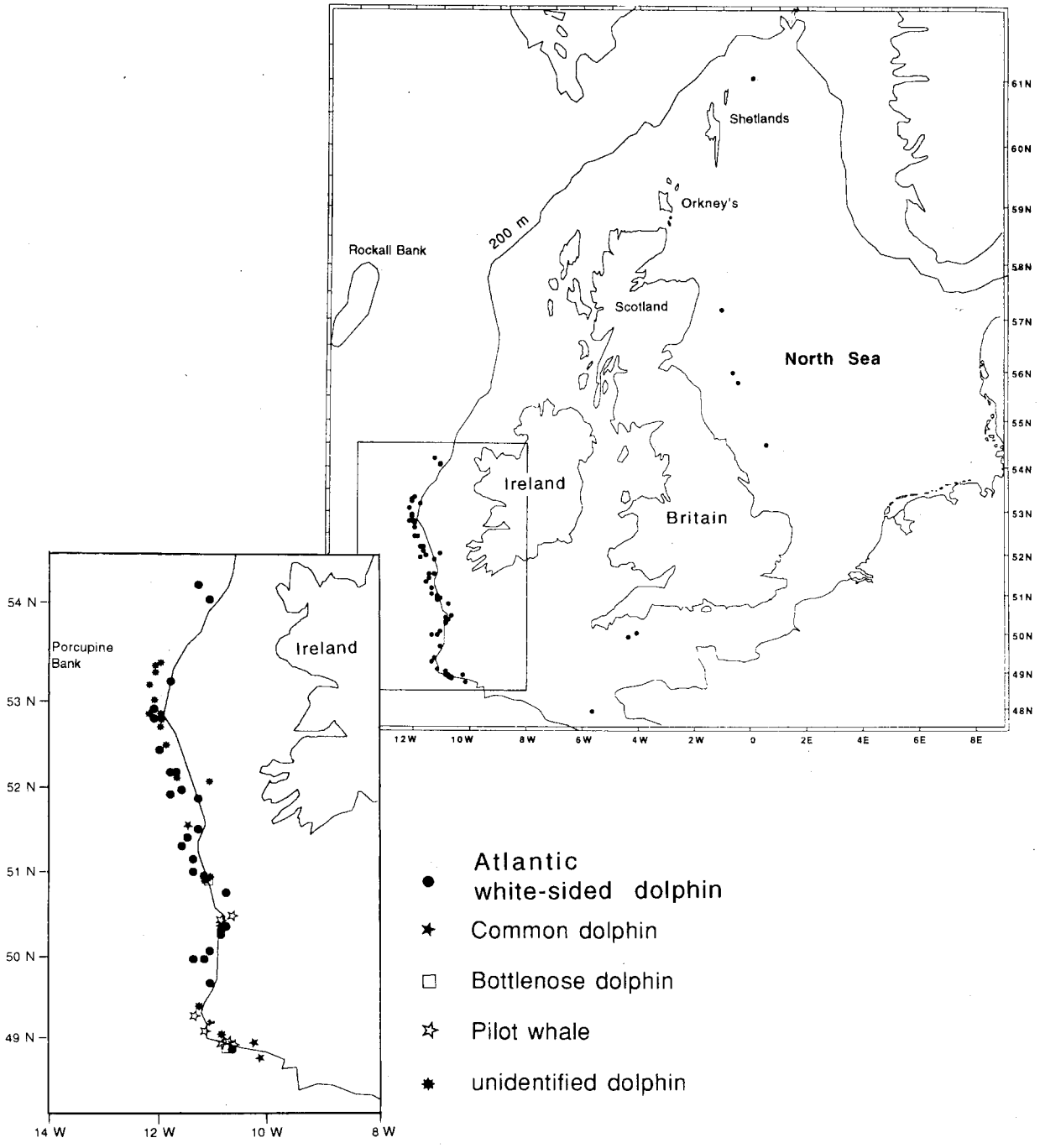

Fig. 3. Positions of all recorded by-catch incidents in 1989–94. Box: by-catch positions southwest of Ireland.

white-sided dolphin. Although the number of cooperating vessels was lower in 1993, information provided by the skippers indicated that the number of incidental catches was much higher in 1994 than in 1993. Preliminary results also indicated that incidents were much lower in 1995 than in 1994. Therefore, the information available suggest that the number of cetaceans killed in the Dutch pelagic fishery varies considerably form year to year. It is not possible on the basis of the limited data available to estimate the extent of the by-catch problem.

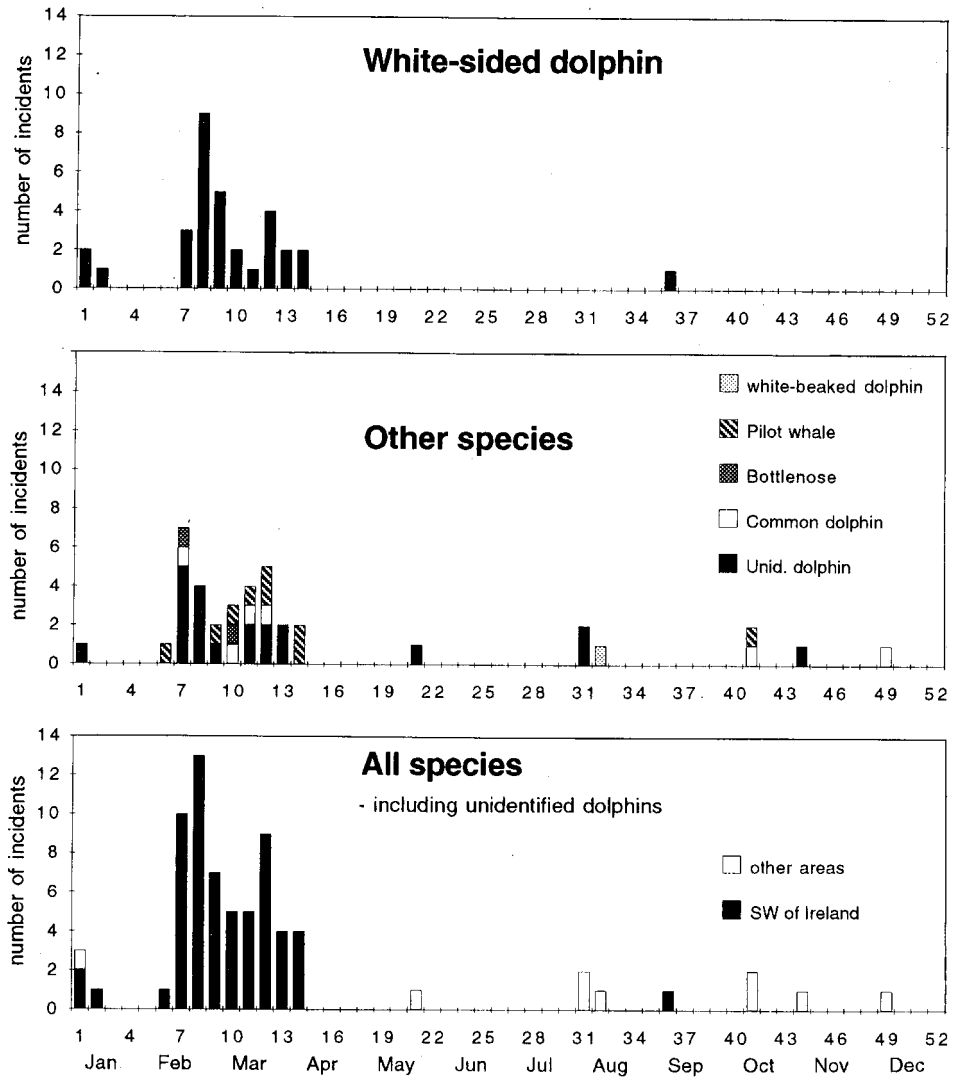

Fig. 4. By-catch records per week in 1989–94 of Atlantic white-sided dolphins, other species and all species by area.

The analysis of the stomach contents indicated that white-sided dolphins had been feeding heavily on mackerel shortly before they were caught. Since many fish were completely intact, dolphins were probably feeding when they became trapped, possibly during hauling. However, horse mackerel were notably absent in their stomachs even though they were present in the catches. Apparently, white-sided dolphins have a clear preference for mackerel above the more bonier horse mackerel. This finding is in sharp contrast with the presence of horse mackerel in the stomachs of common and bottlenose dolphins in the same area during the same period.

According to the analysis of otoliths found in stomachs, the diet of white-sided dolphins was completely different, being dominated by silvery pout, lanternfishes and pearlsides. These mesopelagic species are known to migrate to the surface layers during night (Whitehead *et al.*, 1984), but do not occur in the catches of freezer trawlers. Therefore, it is likely that the animals had been feeding in deeper water before they started to prey on mackerel in the neighbourhood of the trawlers.

The most frequently found species (by percentage occurence) in the stomachs of four

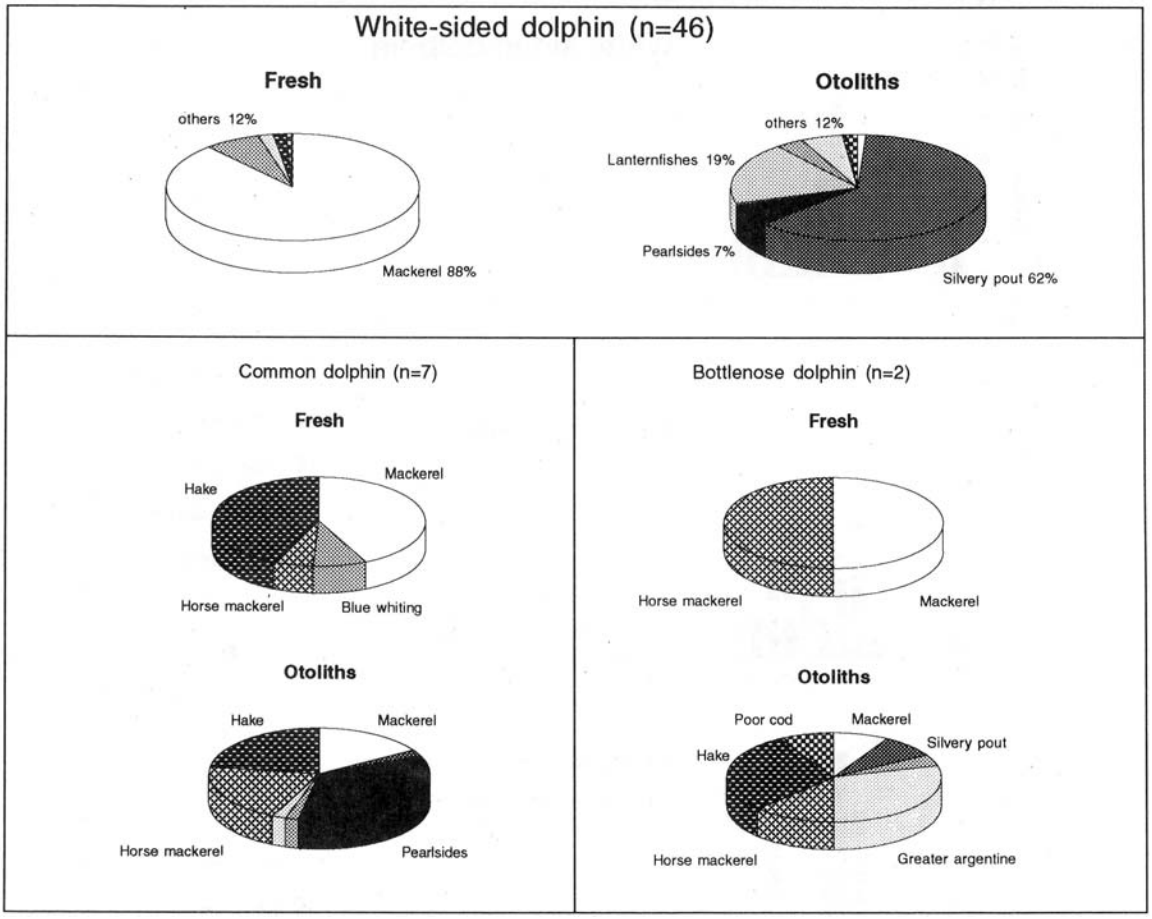

Fig. 5. Remains of fresh fish and otoliths in stomachs (n = 46) of Atlantic white-sided dolphin, common dolphin (n = 7) and bottlenose dolphin (n = 2), caught southwest of Ireland in January–April.

stranded Atlantic white-sided dolphins from the Irish west coast, were silvery pout (41%) and mackerel (10%; Berrow and Rogan, MS 1995). Desportes (MS 1985) found that in the stomach of a white-sided dolphin from the Gulf of Biscay, the prey items were exclusively of blue whiting (*Micromesistius poutasson*). In that area the common dolphin is known to feed mainly on gadoids, horse mackerel, clupeids, mackerel and cephalopods (Collet, MS 1981; Desportes, MS 1985; Berrow and Rogan, MS 1995).

Worldwide, cetaceans are sometimes seen near trawlers during hauling scavenging on fish which slip through the meshes (Fertl and Leatherwood, 1997). The crews of Dutch pelagic trawlers frequently observe killer whales (*Orcinus orca*) and, off the northeast coast of the United States, long-finned pilot whales have been observed coming up to the rear of the trawlers when the net is being hauled up (Couperus, 1994; Waring *et al*., 1990). In the area southwest of Ireland, long-finned pilot whales show the same behaviour (Fertl and Leatherwood, 1997). Also, in this area Atlantic white-sided dolphins have been seen scavenging in the wake of a trawler (Leopold and Couperus, 1995). This behaviour of oppurtunistic feeding makes cetaceans probably more vulnerable for becoming trapped in trawl nets. On the other hand, it seems that opportunistic feeding does not neccessarily result in more incidental catches. For example, in this project not a single catch of a killer whale was reported, while according to the crews this cetacean species is the most frequently observed scavenger (Couperus, 1994).

Some of the smaller otoliths (e.g. *Maurolicus muelleri* and Myctophidae) found in the dolphin

stomachs may have been from the stomachs of prey eaten by the dolphin. To test this, stomachs of 33 intact mackerel were collected and stored in 80% ethanol. Subsequent examination showed that 29 out of 33 stomachs were empty. The four stomachs with some food, contained respectively euphausiids, fish vertebrae, fish scales and unidentified soft tissue. No fresh remains of bony fish, nor any otoliths were found. Therefore, no serious bias is to be expected from the number of otoliths from "secondary preys".

Experiments on the digestion rates of captive marine mammals (mainly seals) indicate that otoliths pass through the digestive track within 3–30 hr (Prime, MS 1979; Da Silva and Neilson, 1985; Murie and Lavigne, 1986), while no hard remains of bony fish were found in pigs after 12–15 hr (Finley and Gibb, 1982). However, this information could not be used to estimate the period, since the meal from which the otoliths found in the stomach originated was not known. MacMahon and Tash (1979) found that otoliths of green sunfish (*Lepomis cyanellus*) were still identifiable after 12 hr, in 0.01 N hydrochloric acid solution (simulated gastric acid condition), but were completely dissolved after 24 hr. Within the predators, the dissolution may take longer due to the buffering of gastric juices by ingested food and because it takes some time before the acid solution to reach the sagittal otoliths in the fish head. Smaller otoliths erode rather quickly (Jobling and Breiby,1986) and it seems likely that the retrieved otoliths represented food consumed within the last 24 hr. Due to differences in erosion rates, the contribution of species with large otoliths (silvery pout, lanternfishes, blue whiting and hake) is probably overestimated compared to species with more fragile otoliths (mackerel, pearlsides). However, retrieval of the tiny otoliths of pearlsides indicates that the contribution of mackerel in the otolith fraction is not underestimated.

Little is known about distribution and migration patterns of Atlantic white-sided dolphins in the Northeast Atlantic. A peak in sightings and strandings at the east coast of Scotland in summer (Evans, MS 1992), suggests that white-sided dolphins are attracted by concentrations of herring at that time of the year (e.g. Cushing and Bridger, 1966). In the area southwest of Ireland the species seems to be more common than previously thought, but may have a distribution well offshore (Evans, MS 1992; Leopold and Couperus, 1995).

In conclusion, the following picture is proposed. The Atlantic white-sided dolphins migrate from deeper oceanic water into the shelf edge area (approximately 200 m), when the mackerel schools arrive on their southward migration. Slopes off the southwest of Ireland are steep and a dolphin could probably swim from deep water onto the shelf edge area in a relatively short period of a few hours. A possible explanation for the sudden appearance of the dolphins in trawl nets, is that they usually feed in deeper water and become attracted to schools of mackerel. The midwater trawlers generally operate as a fleet, often within a few miles from each other, which generates variation in the frequency of incidental catches, depending on the patchiness in the dolphin distribution in relation to the distribution of the fleet. Differences in susceptibility of different species are propably related to differences in behaviour as exemplified by the considerable differences in diet.

Acknowledgements

For this study, I relied heavily on information and support from the crews of Dutch freezer trawlers; I am grateful for their cooperation. I thank Niels Daan and Henk Heessen for commenting on earlier versions of the manuscript.

References

ANON. MS 1990. Second report of the EEC – Norwegian Joint Scientific Group on migration and area distribution of Mackerel (western stock). Brussels, 12–13 December 1989. *ICES C.M. Doc.*, No. H:5, 43 p.

MS 1991. Manual for the ICES North Sea Stomach Sampling Project in 1991. *ICES C.M. Doc.*, No. G:3, 12 p.

BERROW, S. D., and E. ROGAN. MS 1995. Stomach contents of harbour porpoise and dolphins in Irish waters. European Research on Cetaceans 9 – Proc. of the 9th Annual European Cetacean Conference, Lugano, Switzerland.

COUPERUS, A.S. 1994. Killer whales (*Orcinus orca*) scavenging on discards of freezer trawlers north east of the Shetland islands. *Aquatic Mammals*, **20**: 47–51.

CUSHING, D. H., and J. P. BRIDGER. 1966. The stock of herring in the North Sea and changes due to fishing. *Fish. Invest.*, **25**: 1–62.

COLLET, A.S. MS 1981. Biologie du dauphin commun *Delphinus delphis* L. en Atlantique Nord-Est. Doctoral thesis, University of Poitiers, 156 p.

DA SILVA, J., and J. D. NEILSON. 1985. Limitations of using otoliths in scats to estimate prey consumption in seals. *Can. J. Aquat. Sci.*, **42**: 1439–1442.

DESPORTES, G. MS 1985. La nutrition des odontocetes en atlantique nord-est (côtes Françaises – iles Feroë). Doctoral thesis, University of Poitiers, 190 p.

EVANS, P. G. H. MS 1992. Status review of cetaceans in British and Irish waters. *Mammal Society Cetacean Group*, Oxford, 99 p.

FERTL, D., and S. LEATHERWOOD. 1997. A review of cetacean interactions with trawls. *J. Northw. Atl. Fish. Sci.* 22: 219–248 (this volume).

FINLEY, K. J., and E. J. GIBB. 1982. Summer diet of the narwal (*Monodon monoceros*) in Pond Inlet, Northern Baffin Island. *Can. J. Zool.*, **60**: 3353–3363.

GRAINGER, R. J. R. (Ed.). 1992. *ICES Fisheries Statistics* – 1988, **73**: 116 p.

HÄRKONEN, T. 1986. Guide to the otoliths of the bony fishes of the Northeast Atlantic. Danbui Aps, Hellerup, Denmark, 256 p.

HEYNING, J. E. and W. F. PERRIN. 1994. Evidence for two species of common dolphins (Genus *Delphinus*) from the eastern North Pacific. Nat. Mist. Mus. LA County, Contrib. in Sci., No. 447, 35 p.

JEFFERSON, T. A., and B. E. CURRY. 1994. A global review of porpoise (*Cetacea*: *Phocoenidae*) mortality in gillnets. *Biological Conservation*, **67**: 167–183.

JOBLING, M., and A. BREIBY. 1986. The use and abuse of fish otoliths in Studies of feeding Habits of Marine Piscivores. *Sarsia*, **71**: 265–274.

KOTTHAUS, A. 1972. Die meso- und bathypelagischen Fische der "Meteor"-Rossbreiten-Expedition 1970 (2. und 3. Fahrtabschnitt). "Meteor" Forsch.-Ergebnisse, Reihe D no. 11, Berlin/Stuttgart: 28 p.

LEOPOLD, M.F., and A.S. COUPERUS. 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.

MACMAHON, T. E., and J.C. TASH. 1979. Effects of formalin (buffered and unbuffered) and hydrochloric acid on fish otoliths. *Copeia*, **1**: 155–156.

MURIE, D. M., and D. M. LAVIGNE. 1986. Interpretation of otoliths in stomach content analyses of phocid seals: quantifying fish consumption. *Can. J. Zool.*, **64**: 1152–1157.

NORTHRIDGE, S. P. 1991. Driftnet fisheries and their impact on non-target species: a worldwide review. *FAO Fish. Tech. Pap.*, **320**: 115 p.

PEET, G., H. NIJKAMP, P.-H. NELISSEN, and F.-J. MAAS. 1992. Porpoises, dolphins and whales of the North sea (in Dutch). M & P Publishers, Weert/ Netherlands: 80 p.

PERRIN, W. F., G. P. DONOVAN, and J. BARLOW. (eds.) 1994. Gillnets and cetaceans. *Rep. int. Whal. Comm.*, Special issue 15: 629 p.

PRIME, J. H. MS 1979. Observations on the digestion of some gadoid fish otoliths by a young common seal. *ICES C.M. Doc.*, No. N:14, 3 p.

WARING, G. T., P. GERRIOR, P. M. PAYNE, B. L. PERRY, and J. R. NICOLAS. 1990. Incidental take of marine mammals in foreign fishery activities off the Northeast United States, 1977–88. *Fish. Bull. U.S.*, **88**: 347–360.

WHITEHEAD, P. J. P., M.-L. BAUCHOT, J.-C. HUREAU, J. NIELSEN, and E. TORTONESE. 1984. Fishes of the North-eastern Atlantic and the Mediterranean – Vol. I–III. UNESCO, United Kingdom, 1473 p.