DISCARDING PRACTICES AND MARINE MAMMAL BY-CATCH IN THE CELTIC SEA HERRING FISHERY

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ABSTRACT

Pelagic fisheries account for 83% of the total number of fish landed into Irish ports, with mackerel *Scomber scrombrus*, horse-mackerel *Trachurus trachurus* and herring *Clupea harengus* constituting 97% of this. Despite the importance of pelagic fish species, there is little published information on discarding practices for most Irish trawl fisheries and no study of marine mammal by-catch. Fisheries scientists accompanied commercial trawlers fishing herring in the Celtic Sea during the 1994/5 season. During the study, 85 days were spent at sea, with 78 tows monitored, amounting to 101h of fishing effort, which was 7% of the total effort in the fishery. Most fishing was carried out in International Council for the Exploration of the Sea (ICES) divisions VIIg01, VIIg02 and VIIa20, and most fish were caught in VIIg01 and VIIa20. The fishery was very selective, with 99.5% of the total weight of the catch being the target species. Mean size ($\pm$SE) of herring caught was extremely consistent, ranging from 24.8 ± 2.7cm in October to 26.0 ± 2.0cm in January. Overall, 1270 tonnes of fish were observed being caught, of which 1214 tonnes were landed and 57 tonnes discarded (4.7%). Whiting *Merlangius merlangus* was the most frequently recorded non-target fish species; mackerel and horse-mackerel were also frequently caught. Four grey seals *Halichoerus grypus* were caught during the study at a rate of one per 317.5 tonnes of fish or 0.05 seals per tow. This catch rate extrapolates to around 60 seals caught in the fishery, which is not thought to have a significant impact on the Irish seal population.

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INTRODUCTION

A thorough understanding of the composition of commercial fishing catches is essential in the management of fishery resources and the assessment of the impact of this industry on non-target species. Despite the importance of such fundamental information, there have been remarkably few published studies on discarding practices in the north-east Atlantic, although national fisheries research institutes often have relevant unpublished data. Most published studies involve demersal or benthic fisheries, especially those for shrimp (for review see Andrew and Pepperell 1992), where the by-catch may be five–ten times greater by weight than the landed catch. There are no published studies of by-catch or discarding in commercial pelagic trawl fisheries in the north-east Atlantic, although Connolly and Kelly (1996) recently presented the results from an experimental trawl and long-line fishery at the Rockall Trough off the north-west coast of Ireland. They found that there was greater species diversity and higher discard rates from catches in bottom trawls compared to long-lining. An estimated 7530 tonnes of fish were discarded from the international fleets fishing in the Rockall area in 1995 (*ibid.*).

Recent studies in the north Atlantic (e.g. Read *et al.* 1993; Lowry and Teilman 1994; Trippel *et al.* 1996; Tregenza *et al.* 1997) have shown that entanglement in gill nets may be significantly reducing populations of small cetaceans, but there have been comparatively few studies of incidental capture by trawl fisheries (Hofman 1990; Waring *et al.* 1990). In a recent review of incidental capture of cetaceans in Irish waters, Berrow and Rogan (in prep.) found that most records of entanglement involved gill nets. There was only one record of a cetacean being caught in a trawl net (Cotton 1984), although there is indirect evidence from stranded animals that they do get caught in trawl fisheries. Kuiken *et al.* (1994) showed that the mortality of common dolphins *Delphinus delphis* washed up on the coast of Cornwall in south-west England during 1992 had been due to fishing; and Berrow and Rogan (1997) suggested that similar strandings of common dolphins along the south coast of Ireland were also likely to be fishery related. The cause of death of white-sided dolphins *Lagenorhynchus acutus* on the western seaboard of Ireland in the spring of 1989 and 1990 might possibly be related to offshore mackerel fishing (Berrow and Smiddy 1989; Berrow and Stark 1990); and Smiddy (1984; 1985) suggested that harbour porpoises *Phocoena phocoena* stranded on the County

Cork coast may have been caught by the local herring fishery. Despite this circumstantial evidence, there has been only one study attempting to quantify marine mammal by-catch in Irish waters. Tregenza *et al.* (1997) showed that up to 2237 (95% CI 900–3500) harbour porpoises were caught annually in bottom-set gill nets in the Celtic Sea. There have been no studies of entanglement in trawl fisheries in Ireland.

The Celtic Sea herring fishery is perhaps the most important single fishery in the Irish industry and was worth an estimated IR£3.5 million in 1992 (Molloy 1994). There was a rapid increase in international catches of herring from the Celtic Sea to 30,000–40,000 tonnes per annum during the 1950s and 1960s. This followed an increase in fishing effort from the Dutch fleet and increased efficiency in the Irish fleet, following the introduction of paired mid-water trawling (*ibid.*). The catch peaked in 1970 at around 44,000 tonnes but declined through the 1970s, because the stock collapsed owing to high fishing mortality coupled with low recruitment, and the fishery was closed in 1977. It re-opened in 1982 and management policies have attempted to allow a Total Allowable Catch (TAC) of around 20,000 tonnes per annum (*ibid.*).

The herring stock subjected to this fishery migrates inshore to traditional spawning beds between Carnsore Point, Co. Wexford, and Loop Head, Co. Clare (Fig. 1). Spawning takes place during November and January and the stock is assessed and managed as one unit with two components, the autumn and winter spawning components or stocklets (*ibid.*). There were 184 Irish-registered vessels licensed to fish herring in the Celtic Sea during the 1994/5 season but only 49 vessels actually fished. Licensed boats ranged from 7.6m to 25.7m long and from 20 to 233 Gross Registered Tonnes (GRT), but only the larger vessels actually entered the fishery (Department of the Marine, pers. comm.) During the 1994/5 season the fishery opened on 9 October 1994 and closed on 17 February 1995. Most herring were landed during December and January into Cobh, Co. Cork, and Dunmore East, Co. Waterford, and the TAC was 18,000 tonnes.

As part of a collaborative study of a number of European trawl fisheries (Morizur *et al.* 1995), fish discarding practices and marine mammal by-catch in the Celtic Sea herring fishery were studied during the 1994/5 fishing season.

METHODOLOGY

Fishery scientists accompanied commercial fishing vessels for the duration of a fishing trip. Herring were all caught by pair trawling, where two vessels tow a single net between them. Each vessel alternately led the tow and communicated, via VHF radio, with the pair trawler on depth of tow, turning and cessation of towing. Vessels tended to return to port immediately after a successful tow, as the market required fish landed fresh to maintain quality. All monitored vessels were 21–25m long and 78–200 GRT. Maximum net openings were around 15–20m high and 20–30m wide and nets were towed at around four knots. Only one scientist was deployed on each pair of vessels.

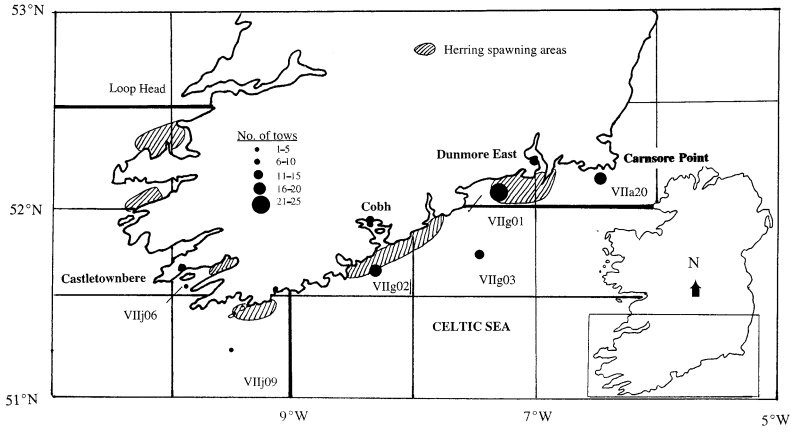

Fig. 1—ICES divisions and distribution of fishing effort along the south coast of Ireland in the Celtic Sea herring fishery during 1994/5.

On each trip a record was kept of the location of the vessel when towing, the time, duration and depth of each tow, and the depth of water. At the end of each tow the cod-end was brought to the side of the lead vessel and the catch was lifted by a winch into the hold. Some vessels in the fishery with refrigerated seawater tanks (RSW vessels) use pumps to transfer the fish into the hold, but all the monitored vessels lifted their catch. Only the catch by the vessel with the scientist onboard was monitored, as it was not possible to accurately observe the partner vessel's lifts. The tonnage of fish caught was estimated using three methods: (1) by recording the number of lifts from the cod-end into the vessel, (2) by recording the number of bins filled when unloading the catch ashore and (3) from consultation with the fishermen, who can often assess very accurately the amount of fish caught. Whenever possible, method 1 was used, but the sum of multiple catches could be confirmed using method 2. Large catches were occasionally split between partner vessels, and fish could either be discarded directly from the cod-end or from the vessel after being taken on board. This could influence the catch and discard estimate per tow if the catch was split or if discarding from the vessel included fish from more than one tow. Only four (5%) of the tows were split between vessels, and most of the fish that were caught were landed, thus any error due to these factors would be small.

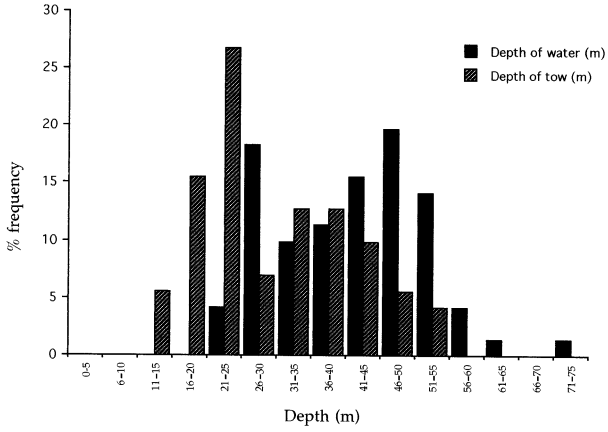

Fig. 2—Frequency distribution of depth of water fished and depth of tow while fishing for herring ($n = 78$).

The catch from each tow was sampled by collecting a box of fish (45–50kg) from the middle of the tow as it came on board. All species in the sample box were identified and measured (total length: TL). In addition species observed in the catch but not recorded in the sample box were recorded as present but were not quantified or measured in the catch. For larger species such as marine mammals the unit of sampling was the whole tow, as the entire catch brought into the vessel could be easily inspected for large animals. Species not recorded in the sample box were recorded as present or absent in the tow and expressed as a proportion of the total number of tows. For species recorded in the sample box their proportion of the total weight of the sample was also calculated. The weight of the mean length of fish in each sample box was used in these calculations.

The size of landed and discarded herring for each month was investigated using a one-way ANOVA to compare the mean length of herring caught in each tow. A G-test, using the Williams' correction, was used to test for differences in length frequency distributions between landed and discarded fish. The G-test has theoretical advantages over the traditional chi-squared test as a goodness of fit test (Sokal and Rolff 1981). All means are given $\pm$ their standard error.

RESULTS

FISHING EFFORT

A total of 85 days was spent at sea between 23 October 1994 and 27 January 1995, during which time 78 tows and 101h of towing time were monitored (Table 1). Effort peaked during December (43%), with only 5% of the total in October. Fishing started during the autumn off south-west Ireland in ICES division VIIj06, but most effort during the season occurred close inshore in VIIg01, VIIg02 and VIIa20 and slightly less in VIIg03 (Fig. 1).

Shoals of herring were located by echo-sounders. Skippers were able to identify herring by the characteristics of the mark on the sounder. The duration of each tow varied from 15min to 170min with a mean of 78.7 ± 6.4min ($n = 78$) and a mode of 65min. The depth of water fished is shown in Fig. 2 and ranged from 24m to 75m (mean: 43.8 ± 3.2m). Nets were towed at depths of 14–55m (mean: 32.4 ± 3.3m) (Fig. 2).

LANDED AND DISCARDED CATCH

The tonnage of fish landed and discarded from each ICES statistical rectangle is shown in Table 2. Of the 1270 tonnes of fish caught during this study, 1214 tonnes were landed and 57 tonnes were discarded at sea (Table 2), which is a rate of 4.7%, i.e. for every tonne of fish landed 0.047 tonnes were discarded. Rates varied each month, from 2.3% to 3.9% from October to December, and peaked at 7.9% in January. All discarded catch in VIIj06 occurred during a single tow in October, and 2 tonnes were discarded in VIIg02 in November. Discards in VIIg03 occurred during single tows in November (4.9 tonnes), December (12.6

Table 1—Number of days at sea and fishing effort sampled.

Month	*Observer days at sea*	*Number of tows*	*Duration of tows (min)*	*Proportion of total sampled tows (%)*
October	3	4	330	5
November	27	18	1740	29
December	23	30	2580	43
January	32	26	1415	23
Total	85	78[a]	6065	100

[a] One tow was not sampled.

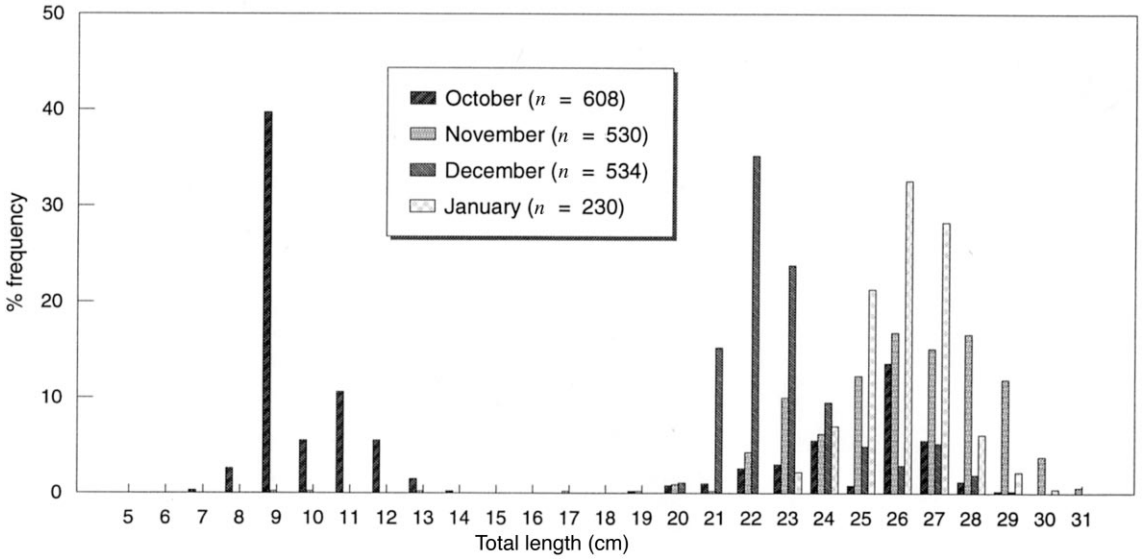

Fig. 3—Length frequency distributions of herring discarded by month in the Celtic Sea herring fishery (sample size in legend).

tonnes) and January (36 tonnes). Nearly half of the fish (44.3%) were caught in VIIg01 off Dunmore East, Co.Waterford, and most of the discards (94.7%) were in VIIg03. Most fish were caught in December (559.8 tonnes) and January (490.2 tonnes), with only 184.6 tonnes caught in November and 35.4 tonnes in October. In October, 3 tonnes were caught in VIIj06 and 31.4 tonnes in VIIj09. If we compare the discard rate to the total amount of fish caught in each area, 50% of those caught in VIIg03 were discarded but less than 2% in VIIg02 and VIIj06.

There was no significant difference in the duration ($t = 0.36$, $P > 0.05$) or depth of tow ($t = 0.65$, $P > 0.05$) between landed ($n = 75$) and discarded ($n = 3$) catches, nor was there a correlation between the amount of fish caught and the duration ($r = 0.43$, $P > 0.05$) or depth of tow ($r = 0.05$, $P > 0.05$).

Table 2—Total fish landed and discarded (tonnes) in each ICES statistical rectangle.

ICES division	*Landed*	*Discarded*	*Total*
VIIj06	53	1	54
VIIj09	31.4	—	31.4
VIIg01	563	—	563
VIIg02	177.3	2	179.3
VIIg03	110.4	53.5	163.9
VIIa20	278.4	—	278.4
Total	1213.5	56.5	1270

SIZE CHARACTERISTICS OF HERRING

The vessels monitored during the study were very highly selective, with herring, the target species, constituting the bulk of the catch in terms of both the total number and the total weight of fish caught. The proportion of herring in the sample from each tow ranged from 75.6% to 100% but averaged 98.6 ± 1.8% and accounted for over 98% of the sample on 60 (78%) tows. Herring accounted for 99.5% by weight of the total fish landed.

There was a significant difference in the mean length of herring discarded in each month ($F_{31, 898} = 569.9$, $P < 0.001$), with the smallest herring discarded in October (14.9 ± 2.7cm, $n = 605$) and the largest in January (26.1 ± 1.1cm, $n = 230$) (Fig. 3). The mean length of landed herring was significantly smaller (*t*-test, $P < 0.05$) for five tows—three in November (mean ± SE: 24.0 ± 1.8cm, 23.6 ± 1.5cm and 22.2 ± 1.1cm) and two in December (22.4 ± 1.4cm and 21.9 ± 2.4cm)—but if these tows are removed from the data there is no significant difference in the mean size of herring landed in the remaining tows in each month—October ($F_{2, 702} = 4.2$, $P < 0.05$), November ($F_{12, 3637} = 0.86$, $P < 0.05$), December ($F_{26, 8000} = 0.15$, $P < 0.05$) and January ($F_{23, 6085} = 0.41$, $P < 0.05$). The length of landed herring was very consistent, with a mode of 26–27cm recorded from all tows in October ($n = 3$), from 75% of those in November ($n = 16$), from 73% in December ($n = 29$) and from 83% in January ($n = 24$). If the length frequency distributions between landed and discarded herring (for herring >19cm TL) are compared (Fig. 4), larger fish were landed

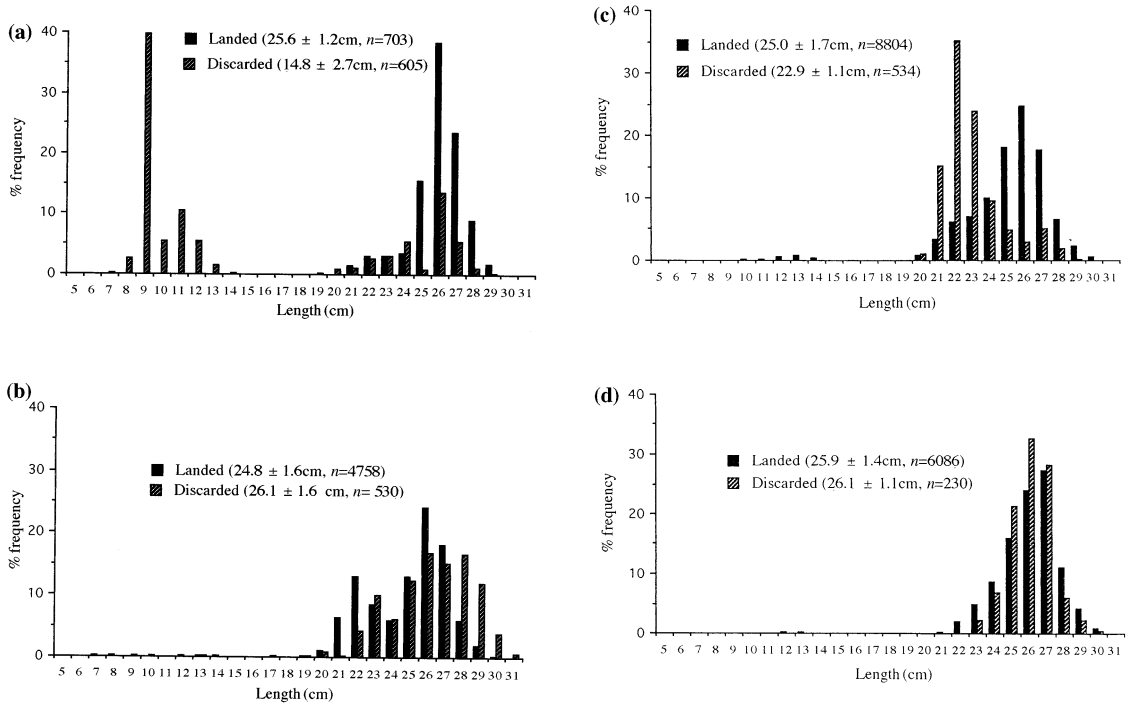

Fig. 4—Length frequency distribution of landed and discarded herring by month in the Celtic Sea herring fishery: (a) October, (b) November, (c) December, (d) January.

than were discarded in October ($G = 380.4$, df = 10, $P < 0.01$) and December ($G = 974.4$, df = 11, $P < 0.01$) but smaller fish were landed than discarded in November ($G = 349.1$, df = 12, $P < 0.01$) and January ($G = 46.3$, df = 8, $P < 0.01$). In October 71% of the fish discarded were less than 19cm TL (Fig. 4) and were all from a single tow. The data suggest that two groups of fish may have been caught in November and December, one with a mode of 22cm and another with one of 26cm TL (Fig. 4). Fish belonging to the smaller group (22cm TL) were discarded in December but landed in November.

NON-TARGET SPECIES

The presence or absence of non-target species in the catch was recorded for 46 tows. Of the twenty species identified, whiting *Merlangius merlangus* was by far the most frequent, occurring in 37 (84%) of tows. Mackerel *Scomber scrombrus* (32%) and cod *Gadus morhua* (30%) were also regularly recorded, but most non-target species occurred in less than 10% of tows, namely, horse-mackerel *Trachurus trachurus*, megrim *Lepidorhombus whiffiagonis*, hake *Merluccius merluccius*, red gurnard *Aspitrigla cuculus*, grey gurnard *Eutrigla gurnardus*, dragonet *Callionynus lyra*, conger *Conger conger*, dab *Limanda limanda*, monkfish *Lophias piscatorius*, lesser-spotted dogfish *Scyliorhinus canicula*, spurdog *Squalus acanthias*, squid *Todoropsis* and octopus *Eledone cirrhosa*. The only marine mammals caught were single grey seals *Halichoerus grypus*, which were recorded in four tows, all in VIIa20 near to the Saltee Islands. All seals were adults measuring 1.7–1.9m, two were sexed ($n = 2$) and both were male. There was no significant difference (t-test, $P > 0.05$) in the mean size of herring caught in tows with grey seal by-catch compared to tows without. On-site post-mortem examination ($n = 2$) showed that both seals had been feeding on herring at the time of death.

The size of landed and discarded fish species when recorded in the sample box from each tow is shown in Table 3. There was no significant difference between the size of landed or discaded whiting ($t = 0.34$, $P > 0.05$) or horse-mackerel ($t = 0.58$, $P > 0.05$). There were too few data to analyse the other species caught.

DISCUSSION

The present study is the first attempt to quantify marine mammal by-catch in a trawl fishery in Ireland and the most extensive study of discarding in the herring fishery. The nature of the fishery made monitoring catches problematical. Up to 49 vessels operated during the study period, making short trips, usually less than 1 day long, from a number of ports and often landing into a different port from that from which they departed. During

the study period 1270 tonnes of fish were caught, and, assuming a TAC for the fishery of 18,000 tonnes (J. Molloy, pers. comm.), 7% of the TAC was monitored. During the 1994/5 season the autumn herring stock was considered poor, with low abundance and poor quality resulting in only a small amount of fishing during October and November off south-west Ireland. The lower fishing effort than usual in ICES Division VIIj earlier in the season may have affected the overall results for the fishery. The size frequency distribution of herring caught in this fishery was remarkably consistent throughout all areas fished, which suggests that there would not have been major differences in the size of herring caught off the south-west coast had fishing effort been higher.

Molloy (1994) suggested that to maintain the TAC for this fishery it was essential to eliminate discards. Reasons for discarding at sea varied, but most fish (64%) were discarded owing to market requirements for a high roe content, with fishermen only landing high-quality fish to maximise their profits from quota restrictions. One catch was discarded owing to a high proportion of small herring in the catch and one owing to a high proportion of mackerel (6% of all fish in sample), which may have resulted in the whole catch being rejected on landing. Both of these catches were very small (1 and 2 tonnes) and not worth the expense or time of landing, so they were discarded. The small herring discarded in October were most likely from a different cohort, but the data also suggest that two groups of herring may be caught by the fishery, one with a mode of 22cm and one with one of 26cm TL. Whether these fish are from two different cohorts or from separate populations is not known. The distribution of trawl depth is similar to water depth, which is consistent with fishermen trying to catch herring close to spawning on the seabed. There was no relationship between fishing effort (duration, water depth, fishing area) and discarding, which may have identified factors to help minimise this practice.

Inter-annual variation in the size of fish caught and the discard rate is not known, but discarding during the 1994/5 season was generally considered by skippers to be low, owing to the low abundance of herring in traditional spawning areas. As fish were harder to catch than usual, most fish were landed, and only towards the end of the fishing season did discarding increase, as fisheries officers from the Department of the Marine and Natural Resources (the regulatory authority) restricted the amount of fish each vessel was allowed to land to ensure that the TAC for the season was not exceeded. The discard rate during 1994/5 was 4.7%, which would increase the actual catch from the TAC of 18,000 tonnes to 18,900 tonnes. This rate compares favourably with other trawl fisheries in the north-east Atlantic, where a 94% and 283% discarding rate has been recorded for demersal and benthic fisheries (Burke *et al.* 1993; Evans *et al.* 1994). The ICES Herring Working Group (1996) assumes a discard rate of 10% for the Celtic Sea fishery. This level was not based on any data but on reports from fishermen. The rate estimated from the present study therefore confirms as realistic the estimate used by the Working Group.

The only marine mammals caught in this study were grey seals, at a rate of 0.05 seals per tow (25.3h towing time) or one seal per 317.5 tonnes of fish caught. If we assume a TAC for the fishery of 18,000 tonnes and a discard rate at sea of 5%, the total amount of fish caught in the fishery will be around 18,900 tonnes. The total extrapolated catch of grey seals will therefore be approximately 60 individuals. Grey seals were regularly seen feeding on fish during hauling and were often seen diving between the pair trawlers during towing, which suggests that they can usually avoid the net and only occasionally become entangled. Grey seals are common in Irish waters, but there are no recent population estimates. Summers (1983) estimated a breeding population of around 2000 individuals in small colonies of less than 60 animals along the

Table 3—Size distribution of landed and discarded catch.

Species	*Landed*			*Discarded*		
	Mean ± SE	*Range*	*n*	*Mean ± SE*	*Range*	*n*
Whiting	26.8 ± 2.5	7–43	244	24.9 ± 2.2	17–31	7
Mackerel	24.9 ± 2.3	19–34	49	18.0	—	1
Scad	21.8 ± 1.9	20–27	4	20.6 ± 1.4	18–23	5
Hake	33.5 ± 0.8	33–34	2	—	—	—
Dab	24.5 ± 2.5	20–29	2	—	—	—
Plaice	17.0	—	1	—	—	—
Dragonet	21.0	—	1	—	—	—
Grey seal	—	—	—	—	1.7–1.9	4

south coast (Lockley 1966), but a large non-breeding population probably occurs in Irish waters. All seals were caught near the Saltee Islands in County Wexford, a known breeding site where up to 60 pups have been born in recent years (O. Kiely, pers. comm.). Grey seals in south Wales, the closest colonies for which breeding biology is known, pup and breed from September to October, during which time they fast (King 1983). After breeding, there is a period of feeding at sea from November to January, when there is likely to be considerable geographial movement. Immigration into the Celtic Sea from colonies in west Wales (*c.* 5000 seals) and the much larger Scottish population is suspected, but the extent of this immigration is unknown. The herring fishery operates during this post-breeding dispersal and, although local populations may be affected, this fishing mortality is unlikely to cause any decline in the Irish grey seal population. More information on population structure, feeding range and immigration is required before a proper assessment of this mortality can be made.

Only one sighting of cetaceans was reported, a group of four harbour porpoises outside Cork Harbour (51°45′N, 8°13′W) on 11 January 1995, and none was caught in fishing gear. All the fishing during the study was close inshore (<15km), and, although porpoises are thought to be mainly a coastal species (Evans 1980), results suggest that there was little contact between the fishing fleet and cetaceans. Harbour porpoises can be difficult to observe from commercial fishing vessels (Tregenza *et al.* 1997) but are known to eat herring in Irish waters (Rogan and Berrow 1996). Although the occasional entanglement may occur, any incidental capture of cetaceans in this fishery would appear to be minimal. The ability of a trawler to catch cetaceans is strongly influenced by the size of the net opening and the towing speed. The largest trawlers in Ireland fish mackerel and horse-mackerel along the west coast and mainly operate out of Killybegs, Co. Donegal. The results of a complementary study of Dutch freeze trawlers fishing off the west coast of Ireland has shown that they catch dolphins at a rate of 0.04 dolphins per tow, or one dolphin per 93 towing hours (Couperus *et al.* 1995). It is highly probable that the large Irish trawlers also catch dolphins and it is important to quantify this by-catch.

The results of this study suggest that the Celtic Sea herring fishery is very selective and that discarding is within the figures estimated for fishery models. There was no significant by-catch of non-target species and interactions with marine mammals were minimal.

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REFERENCES

Andrew, N.L. and Pepperell, J.G. 1992 The by-catch of shrimp trawl fisheries. *Annual Review of Oceanography and Marine Biology* **30**, 527–65.

ICES Herring Assessment Working Group 1996 Report of the Herring Assessment Working Group for the area south of 62°N. ICES Doc CM.1995, 221–7.

Berrow, S.D. and Rogan, E. 1997 Review of cetaceans stranded on the Irish coast 1901–95. *Mammal Review* **27** (1), 51–76.

Berrow, S.D. and Rogan, E. (in prep.) Incidental capture of cetaceans in Irish waters.

Berrow, S.D. and Smiddy, P. 1989 White-sided dolphins *Lagenorhynchus acutus* Gray. *Irish Naturalists' Journal* **23** (4), 158–9.

Berrow, S.D. and Stark, D. 1990 White-sided dolphins *Lagenorhynchus acutus* Gray. *Irish Naturalists' Journal* **23** (8), 334.

Burke, W.T., Feeberg, M. and Miles, E.L. (eds) 1993 *The United Nations resolutions on driftnet fisheries*. School of Marine Sciences, University of Washington.

Connolly, P.L. and Kelly, C.J. 1996 Catch and discards from experimental trawl and longline fishing in the deep water of the Rockall Trough. *Journal of Fish Biology* **49**, 132–44.

Cotton, D.C.F. 1984 Minke whale *Balaenoptera acutorostrata* Lacépède. *Irish Naturalists' Journal* **21**, 538.

Couperus, A.J. 1995 By-catch and discarding in the Dutch pelagic trawl fishery. In Y. Morizur, N.J.C. Tregenza, H. Heessen, S.D. Berrow and S. Pouvreau (eds), *By-catch and discarding in pelagic trawl fisheries*. Report to EU DG XIV-C-1, study contract BIOECO/93/017.

Evans, P.G.H. 1980 Cetaceans in British waters. *Mammal Review* **10** (1), 1–52.

Evans, S.M., Hunter, J.E., Elizal and Wahju, R.I. 1994 Composition and fate of the catch and bycatch in the Farne Deep (North Sea) Nephrops fishery. *ICES Journal of Marine Science* **51**, 155–68.

Hofman, R.J. 1990 Cetacean entanglement in fishing gear. *Mammal Review* **20** (1), 53–64.

King, J.E. 1983 *Seals of the world*. Oxford University Press.

Kuiken, T., Simpson, V.R., Allchin, C.R. *et al.* 1994 Mass mortality of common dolphins (*Delphinus delphis*) in south-west England due to accidental capture in fishing gear. *The Veterinary Record* **134**, 81–9.

Lowry, N. and Teilman, J. 1994 Bycatch and bycatch reduction of the harbour porpoise (*Phocoena phocoena*) in Danish waters. *Report of the International Whaling Commission* (Special Issue 15), 203–9.

Lockley, R.M. 1966 The distribution of grey and common seals on the coasts of Ireland. *Irish Naturalists' Journal* **15**, 136–43.

Molloy, J. 1994 The assessment and management of the Celtic Sea herring stock, 1958–1993. *Maximum sustainable yields from fish stocks*. Conference held at the Imperial Hotel, Cork (14–15 May 1993), 37–45.

Morizur, Y., Tregenza, N.J.C., Heessen, H., Berrow, S.D. and Pouvreau, S. 1995 *By-catch and discarding in pelagic trawl fisheries*. Report to EU DG XIV-C-1, study contract BIOECO/93/017.

Read, A.J., Kraus, S.D., Bisack, K.D. and Palka, D. 1993 Harbour porpoises and gill nets in the Gulf of Maine. *Conservation Biology* **7** (1), 189–93.

Rogan, E. and Berrow, S.D. 1996 A review of harbour porpoises *Phocoena phocoena* in Irish waters. *Report of the International Whaling Commission* **46**, 595–605.

Smiddy, P.S. 1984 Common porpoises *Phocoena phocoena* L. *Irish Naturalists' Journal* **21** (8), 360–1.

Smiddy, P.S. 1985 Common porpoises *Phocoena phocoena* L. *Irish Naturalists' Journal* **21** (12), 541.

Sokal, R.R. and Rolff, F.J. 1981 *Biometry* (2nd edn). New York. Freeman and Company.

Summers, C.F. 1983 The grey seal in Ireland. An unpublished report to the Minister for Fisheries, Forestry and Wildlife.

Tregenza, N.J.C., Berrow, S.D., Hammond, P.S. and Leaper, R. 1997 Harbour porpoise, *Phocoena phocoena* L.—bycatch in set gill nets in the Celtic Sea. *ICES Journal of Marine Science*.

Trippel, E.A., Wang, J.Y., Strong, M.B., Carter, L.S. and Conway, J.D. 1996 Incidental mortality of harbour porpoise (*Phocoena phocoena*) by the gill-net fishery in the lower Bay of Fundy. *Canadian Journal of Fisheries and Aquatic Sciences* **53**, 1294–300.

Waring, G.T., Gerrior, P., Payne, P.M., Barry, B.L. and Nichols, J.R. 1990 Incidental take of marine mammals in foreign fishery activities off the north-east United States, 1977–88. *Fishery Bulletin* **88** (2), 347–60.

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