

Results of a short study on by-catches and discards in pelagic fisheries in Scotland (UK)

Graham J. Pierce *, Jamie Dyson, Eoghan Kelly, Jacqueline D. Eggleton, Paul Whomersley, Iain A. G. Young, M. Begoña Santos, Jianjun Wang, Nicola J. Spencer

Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, UK

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Abstract

Observers were placed on pelagic vessels in the Scottish fisheries for mackerel (*Scomber scombrus*), herring (*Clupea harengus*), “maatje” herring (herring caught just before their first spawning) and argentines (*Argentina silus*) to monitor by-catch composition and discarding practices. A total of 67 days was spent at sea, 11 on the argentine fleet, 28 on the herring fleet, 12 on the “maatje” herring fleet and 16 on the mackerel fleet. The level of by-catch generally ranged from <1% to around 2.5% of the total catch. The argentine fishery took a significant proportion of blue whiting (*Micromesistius poutassou*) (approx. 10% of the overall catch) but this was landed and sold in the market. The greatest range of by-catch species was found in the argentine fishery, including 11 species of fish and one species of squid. Discarding rates in the fisheries varied, with herring and argentine fisheries showing no discards, the mackerel fishery a discard rate of around 4% and the “maatje” herring fishery a discard rate of around 11%. By-catches included small numbers of gannets (*Morus bassanus*) but no marine mammals. If the sampled trips were representative, results indicate that marine mammal by-catch events typically occur during less than one in 20 hauls in the fisheries studied. A larger scale study is needed to confirm this. Cetaceans were sighted in the vicinity of the fishing boats during 4% of observed fishing activities. © 2002 Ifremer/CNRS/Inra/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS. All rights reserved.

Résumé

Résultats d'une courte étude sur les captures accessoires et les rejets de pêcheries pélagiques en Ecosse (G.-B.). Des observateurs embarqués sur des bateaux de pêche pélagique sur les zones de pêche écossaises de maquereau (*Scomber scombrus*), hareng (*Clupea harengus*), de jeunes harengs dits « maatje » (harengs capturés juste avant la première ponte) et d'argentine (*Argentina silus*) ont permis d'estimer la composition des captures accessoires et les pratiques de rejets. Un total de 67 jours a été passé en mer, 11 sur la flottille de pêche aux argentines, 28 sur celle du hareng, 12 sur celle de jeunes harengs « maatje » et 16 sur celle du maquereau. Le niveau des captures accessoires s'étend généralement entre des valeurs < 1% et environ 2.5 % des captures totales. La pêche des argentines prend une proportion significative de merlan bleu (*Micromesistius poutassou*) (approx. 10 % de l'ensemble des captures) mais cela est débarqué et commercialisé. Le plus grand nombre d'espèces accessoires a été trouvé lors des pêches d'argentines, comprenant 11 espèces de poisson et une espèce d'encornet. Les taux de rejet varient selon les pêcheries, aucun rejet dans les pêcheries de hareng et d'argentine, autour de 4 % de rejet dans celle du maquereau, et enfin 11% environ dans celle des jeunes harengs « maatje ». Les captures accessoires incluent un petit nombre de jeunes fous de Bassan (*Morus bassanus*) mais pas de mammifère marin. Si les campagnes de pêche échantillonnées sont représentatives, les résultats indiquent que les prises accidentelles de mammifères marins arrivent moins d'une fois sur 20 traits de chalut dans les pêcheries étudiées. Une étude à plus grande échelle est nécessaire pour confirmer cela. Les cétacés sont observés à proximité des bateaux de pêche durant environ 4 % des activités de pêche. © 2002 Ifremer/CNRS/Inra/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS. Tous droits réservés.

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* Corresponding author.

E-mail address: g.j.pierce@abdn.ac.uk (G.J. Pierce).

1. Introduction

Most of the published research on by-catch and discarding focuses on demersal fisheries (e.g. Conan and Cheynier, 1980; Blasdale and Newton, 1998; Stratoudakis et al., 1999, 2001; Tamsett and Janacek, 1999; Anon., 2001). By-catch and discarding occur on a large scale in demersal fisheries, especially in shrimp or *Nephrops* fisheries where the by-catch can be 10 times greater in weight than the landed catch (Andrew and Pepperell, 1992; Alverson et al., 1994; Evans et al., 1994).

Discarding rates in pelagic trawling and seining are generally considered to be low (see Alverson et al., 1994). However, few studies have provided quantitative published data on discard rates for pelagic/mid-water fisheries in northern European waters. A study of fisheries for herring and mackerel (Anon., 1999) recorded discard rates in ICES fishery sub-areas IVa and VIa to be 2.8% for herring and 1.8% for mackerel. No by-catch data were collected. Landings of the target species in 11 pelagic fisheries in the North-eastern Atlantic ranged from 31% to 95% of the total catch by weight with discard rates ranging from 2% to 56% (Morizur et al., 1995).

Dutch boats were recorded taking a few tonnes of greater argentines (*Argentinus silus*) as by-catch in a fishery for blue whiting (*Micromesistius poutassou*) near the Porcupine bank, later catching more argentines over a wider area west of Scotland (Heesson and Kuiter, 1991).

In the EU, the Habitats Directive (92/43/EEC), Article 12, requires Member States to establish a system to monitor the incidental capture and killing of animals such as cetaceans during fishing activities. Although several European states operate monitoring programmes for cetacean strandings, from which some information on by-catch mortality can be obtained, most on-board observations have been carried out within the scope of short-term projects (Spencer et al., 2000). Several previous studies have recorded cetacean by-catches by pelagic/mid-water trawlers (Aguilar, 1997; Couperus, 1997; Fertl and Leatherwood, 1997; Lens, 1997; Berrow et al., 1998; Tregenza and Collet, 1998; Morizur et al., 1999).

The current study took place during January to August 2001, under the auspices of the Study Project programme run by the Directorate General for Fisheries (DGF) of the Commission of the European Communities (CEC). It aimed to collect information on by-catch and discarding in the Scottish pelagic and mid-water fisheries, specifically those for herring, mackerel and argentines. All these fisheries are highly seasonal. The mackerel fishery typically takes place between January and March, while the herring fishery runs from late May to August. In between these two periods, some boats fish for blue whiting while others are engaged in an experimental fishery for argentines. Although argentines taken in deep water are likely to be *Argentina silus* (as described by Heesson and Kuiter, 1991), catches in the area

fished by the Scottish fleet may also include *A. sphyraena*, which occurs on the continental shelf (Wheeler, 1969).

Although all the boats in the fisheries studied are registered and based in Scotland, the majority (84%) of fishing effort (hours fished) monitored in the mackerel fishery took place to the west of Ireland. We sub-divided the herring fishery for the purposes of this study into the standard herring fishery and that for “maatje” herring. Maatje herring are herring caught just before their first spawning. So-called after the cured product for which they are used, they are characterised by a distinct level of sub-cutaneous fat. They fetch a much higher price than ordinary herring and, because of this, higher levels of discarding may be expected in this fishery. Maatje herring are available only for a short season in the summer (late May to late June in 2001) prior to the onset of breeding. The argentine fishery is an experimental mid-water fishery, targeting spawning aggregations and, at present, involving very few boats. This species is vulnerable to overfishing due to their slow growth, low fecundity and high age at first maturity (Gordon, 2001). The boats monitored were fishing to the north and northwest of mainland Scotland and the Outer Hebrides.

A specific remit for the study, and a key objective for the final round of Study Projects, was to record cetacean by-catches. One important question concerning cetacean by-catches in fisheries is the relationship between the frequency with which they are present in the vicinity of fishing activities and the frequency with which they are by-caught. This has implications for the type of mitigation methods that might be used. Accordingly, during the present study, on-board observers recorded cetacean sightings in the vicinity of the boats during fishing activities.

2. Methods

Most observer studies on by-catch and discards in European pelagic fisheries have, to date, been funded by the CEC, notably through the “Study Project” programme run by the DGF. In terms of designing a sampling programme, this has two potential disadvantages: the constraints placed on the time-scale and need to rely on voluntary co-operation by fishermen. The present study was part of the last round of Study Projects and was limited to a maximum duration of 9 months. While the Scottish Pelagic Fishermen’s Association gave the project partners permission to approach individual skippers, participation was entirely voluntary. A further consideration is that marine mammal by-catch is a more sensitive issue than fish by-catch, since fishermen (with some justification) fear the adverse publicity that may be generated. Consequently, voluntary participation is less common.

Observers accompanied commercial pelagic trawlers for a series of trips from January to August 2001. The vessels in the herring fisheries can use both purse seines and pelagic

trawls depending on factors such as the target species, conditions and time of day. However, in this study purse seines were observed in use only in the maatje herring fishery. The boats in the mackerel fishery used pair trawls on two of the trips and a single trawl on the other. The boats in the argentine fishery used only single pelagic trawls. All the vessels pumped the fish from the net directly into seawater-filled holding tanks.

While on board the vessels the observer recorded the time, duration, position and tonnage of each haul. The position and activity (steaming, searching, hauling, etc.) of the vessel were also recorded periodically. The weight of fish in each haul was estimated by the skipper (to the nearest 0.5 tonnes). A first estimate was obtained immediately after the haul, based on how full the cod-end appeared. If this estimate was later shown to be inaccurate, based on figures obtained when the fish were landed, then the estimate would be revised. The first estimates were usually consistent with amounts landed. Estimates of discards were based on the haul weight estimates, as discards were invariably either the entire contents of a cod-end or the entire contents of the fish hold (the sum total of the weight of the hauls up to that point). The proportion of discards reported for each fleet was calculated in two ways: (a) the total weight of discarded fish summed across all observed trips divided by the total weight of catches summed across all trips and (b) the average of the proportions for individual observed hauls. The latter approach allows an estimate of standard deviation to be made.

By-catch was measured by taking one to two baskets (32–64 kg) of the catch as it was pumped from the net. Length frequency data were collected for the target species (approx. 100–200 fish measured per sampled haul, depending on fish size). The presence of any non-target species was recorded and total length of each non-target fish was measured. The lengths of target and non-target species in the sample baskets were converted into weight estimates using length–weight relationship data. For most fish species, these data were obtained from published sources (Coull et al., 1989; Froese and Pauly, 2001). In rare cases where no length–weight conversion factors were available, e.g. for hatchet fish (*Argyropelecus* sp.), estimates were made based on known length and weight of other fish of the same species. On occasion, some of the by-catch could not be measured. In these cases the average length from the previous haul(s) was used and weight estimated from this as above. Once the total weight of each species in the sample was estimated then this could be scaled up to give an estimate of the weight of each species in the haul. Derivation of estimates of the overall and average proportion of by-catch for each fleet was as described above for discards.

The presence of non-target species on deck, in the net or anywhere apart from the sample baskets was noted but not included in the quantitative by-catch estimates. Greenland sharks (*Somniosus microcephalus*) caught on one vessel were however large enough for their presence and contri-

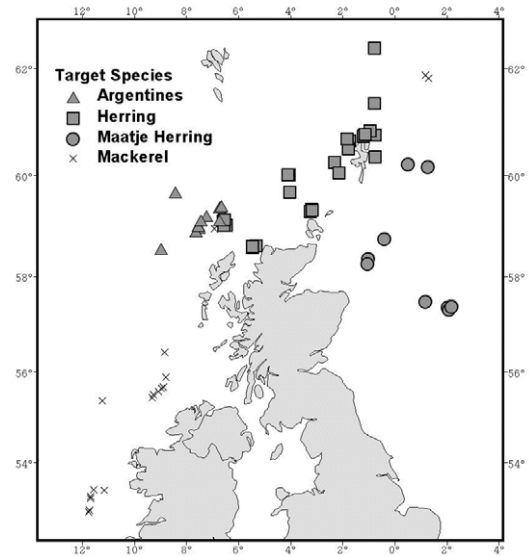


Fig. 1. Map showing locations of sampled hauls.

bution to weight of the haul to be easily determined and they were included in the by-catch estimates.

To estimate the proportion of total effort in the fisheries that was observed, we obtained data on days absent from ports for all the boats participating in each fishery the previous year (Scottish Fisheries Statistics, 2000).

Observers were present on deck during daytime fishing operations and continuously scanned the surrounding waters for presence of cetaceans. Any cetaceans seen were identified to species if possible, using identification keys provided by the Sea Watch Foundation.

3. Results

3.1. Fishing effort

In total 67 days were spent on boats by observers. The distribution of observer effort is summarised in Table 1 and locations of sampled hauls are indicated in Fig. 1. In terms of the proportion of annual fishing effort sampled, based on effort data for 2000, approx. 12% of activity in the small argentine fishery was sampled, as compared to 5% in the herring fishery and 1% in the mackerel fishery (Table 2).

3.2. Catch composition and by-catch

3.2.1. Maatje herring

The target species, maatje herring, accounted for over 99% of the overall catch by weight. The by-catch was 0.6% of the overall catch (by-haul mean 2%, Table 3). The only by-catch species observed was haddock (*Melanogrammus aeglefinus*, Table 4).

Table 1
Distribution of observer effort

Fishery	Observer days at sea	Tows observed	Sample size for discards	Sample size for by-catch
Mackerel	16	17 (3465 t, 39.4 h)	15 (3465 t, 37.5 h)	7 ^a (1950 t, 14.2 h)
Argentines	11	12 (375 t, 94.8 h)	12 (375 t, 94.8 h)	11 (370 t, 85.5 h)
Maatje herring	12	11 ^b (415 t, 13.3 h)	11 (415 t, 13.3 h)	6 (315 t, 7.4 h)
Herring	28	29 ^c (1998 t, 49.2 h)	27 (1998 t, 48.7 h)	20 (1577 t, 36.7 h)

Sample size data tabulated are the numbers of tows observed and the numbers yielding data on discards and by-catch, with estimated total catch (tonnes) and total duration (hours) of these tows in parentheses. Discard data could not always be obtained—and no by-catch data could be obtained—when the trawl was taken by the sister ship during pair trawling. Also, by-catch data could not be collected when 100% of the haul was slipped.

^a Two further hauls provided qualitative data on by-catches.

^b One haul was slipped so did not contribute to the total recorded catch.

^c Two tows had zero catches.

3.2.2. Herring

The target species, herring, accounted for around 98% by weight of the overall catch (by-catch 2.3%). The mean per-haul percentage by-catch was 3.3% (Table 3). The by-catch included four species of fish and one species of sea bird. Mackerel was the main by-catch species, comprising 69% of the by-catch by-weight and 1.6% of the total catch. Haddock, horse mackerel (*Trachurus trachurus*) and whiting (*Merlangius merlangus*) were all present in the samples. Gannets (*Morus bassanus*) were observed entangled in the net but were not present in the samples (Table 4).

3.2.3. Mackerel

The target species, mackerel, accounted for 99% of the catch by weight. The overall percentage by-catch was 0.9% (per-haul mean 0.8%, Table 3). It should be noted that one observed haul was slipped, apparently due to containing a high proportion of other species. It is obviously impossible to reliably quantify this but, if the slipped haul had

comprised 50% of by-catch species, the overall by-catch rate would rise to around 4% (Table 3). Horse mackerel comprised almost two-thirds of the by-catch, while boarfish (*Capros aper*) and ling (*Molva molva*) were also present in the samples. By-catches of blue whiting, saithe (*Pollachius virens*), herring, haddock and pout (*Trisopterus esmarkii*) were observed elsewhere in the hauls (Table 4).

Argentines: The target species, argentines, accounted for approximately 89% of the catch by weight. The majority of fish sampled by the observers were in the range 30–50 cm total length, indicating that the catch was primarily *Argentina silus*. The conspecific *A. sphyraena* reaches only 27 cm in length (Wheeler, 1969). Overall by-catch was 11% (mean by-haul 9.3%, Table 3). However, of the “by-catch” species, blue whiting, which made up 9.5% of the overall catch, was considered marketable. Excluding blue whiting, by-catch represented only 1.5% of the overall catch (mean by-haul 1.6%). Of the other by-caught species, spurdog (*Squalus acanthius*), orange roughy (*Hoplostethus atlanticus*), black

Table 2
Observer effort in 2001 as a proportion of total effort * in the fishery

Fishery	Observer effort (days at sea)	Fishery effort (days at sea)	Percentage of effort observed
All herring	40	751	5.3
Mackerel	16	1438	1.1
Argentines	11	93	11.8

* Based on the 2000-fishing season.

Table 3
Summary of proportions of discards and by-catches

Fishery	Overall discards	Mean discards	Overall by-catch	Mean by-catch
Mackerel	0.043	0.133 (0.352, 15)	0.007	0.008 (0.012, 8)
Mackerel (adjusted)	0.107 ^a		0.042 ^b	0.041 (0.127, 15) ^b
Argentines	0	0 (0, 12)	0.109	0.093 (0.098, 11)
Argentines (adjusted)			0.015 ^c	0.016 (0.035, 11) ^c
Maatje herring	0.108	0.364 (0.505, 11)	0.006	0.020 (0.046, 6)
Maatje herring (adjusted)	0.189 ^a			
Herring	0	0 (0, 27)	0.023	0.033 (0.050, 20)

The overall proportions are the total estimated discard (or by-catch) weight during observed hauls divided by total catch weight during observed hauls. Mean proportions (with standard deviations and sample sizes in parentheses) are averages of proportions observed for individual hauls.

^a For one haul that was slipped, total catch and discards were assumed to equal the average catch for the other observed hauls in this fishery.

^b By-catch data were unavailable for the slipped haul and an arbitrary value of 50% of the catch was used. For other hauls with missing by-catch data, the average proportion of by-catch in the seven observed hauls was used.

^c By-catches were recalculated excluding blue whiting which, although not a primary target species, was landed and marketed.

Table 4
By-catch composition in the studied fisheries

	Fishery	Argentines	Maatje herring	Herring
	Mackerel			
All species % by-catch	0.66 0.79 (1.23, 8)	11.03 9.33 (9.81, 11)	0.63 2.04 (4.61, 6)	2.30 3.32 (4.98, 20)
Blue whiting <i>Micromesistius poutassou</i>	+	9.51 7.71 (7.69)		
Haddock <i>Melanogrammus aeglefinus</i>	+		0.63 2.04 (4.61)	0.59 0.33 (0.90)
Ling <i>Molva molva</i>	0.24 0.42 (1.19)			
Pout <i>Trisopterus esmarkii</i>	+			
Saithe <i>Pollachius virens</i>	+			
Whiting <i>Merlangius merlangus</i>				0.01 0.03 (0.12)
Herring <i>Clupea harengus</i>	+			
Mackerel <i>Scomber scombrus</i>		0.42 0.44 (1.11)		1.59 2.70 (4.98)
Horse mackerel <i>Trachurus trachurus</i>	0.41 0.35 (0.65)			0.11 0.27 (0.69)
Angler <i>Lophius piscatorius</i>		+		
Black scabbard <i>Aphanopus carbo</i>		0.14 0.15 (0.35)		
Bluefish <i>Pomatomus saltatrix</i>		+		
Boar fish <i>Capros aper</i>	0.01 0.01 (0.02)			
Hatchet fish <i>Argyrolepecus</i> sp.		+		
Orange roughy <i>Hoplostethus atlanticus</i>		0.61 0.68 (2.25)		
Redfish <i>Sebastes marinus</i>		0.05 0.05 (0.12)		
Friilled shark <i>Chlamydoselachus anguineus</i>		+		
Greenland shark <i>Somniosus microcephalus</i>		0.23 (0.22, 0.50)		
Spurdog <i>Squalus acanthius</i>		0.08 0.08 (0.28)		
Velvet belly shark <i>Etmopterus spinax</i>		+		
Flying squid <i>Todarodes sagittatus</i>		+		
Gannet <i>Morus bassanus</i>		+		+

Overall percentage by-catch (by weight) and per-haul mean percentage by-catch (with standard deviation and sample size). Sample sizes are given only for the all species values since they are the same for individual species.

scabbard (*Aphanopus carbo*), mackerel, hatchet fish, redfish (*Sebastes marinus*) and velvet belly shark (*Etmopterus spinax*) were all present in the samples (Table 4). Greenland shark, angler (*Lophius piscatorius*), friilled shark (*Chlamydoselachus anguineus*), flying squid (*Todarodes sagittatus*) and gannets were observed elsewhere in the hauls. Bluefish (*Pomatomus saltatrix*), a species rarely recorded in NE Atlantic waters, was also tentatively identified from a haul taken at 59° 25' N 9° 11' W.

Gannets were observed on four occasions caught in nets as they were being hauled, 21 being caught in two hauls in the herring fishery near Shetland and around 20 in two hauls in the argentine fishery. Assuming that gannet by-catches

would have been noted by observers during all hauls (not just those during which fish by-catch was sampled), the predicted catch rates work out at 33 gannets per 100 h fished in herring fisheries (including maatje herring) and 19 per 100 h fished in the argentine fishery. Scaling up to the fisheries as a whole, using effort figures for 2000 (Table 3), this gives estimated total catches of around 620 and 160 gannets respectively in the herring and argentine fisheries. However, of the 21 gannets seen to be caught in the herring fishery, at least two were released alive so the mortality figures may not be as high as our crude calculations suggest. Assuming 10% survival, the combined annual mortality in the two fisheries would be around 700 birds.

In a total of 105 h fishing in the argentine fishery, two Greenland sharks and one of each of the other three species of sharks recorded were by-caught, *i.e.* approximately to five sharks caught per 100 h fishing.

No by-catches of marine mammals were observed during the 69 studied hauls. Assuming that hauls were sampled at random, and based on simple probability theory, we can be 95% confident that the underlying catch rate for marine mammals in the pelagic fisheries studied is no more than 0.05 (*i.e.* five events per 100 hauls). Obviously, we can be less certain about underlying catch rates in individual fisheries, given the lower number of hauls sampled.

3.3. Discards

In the maatje herring fishery, around 11% of the total catch was discarded (Table 3). The discards comprised three complete hauls, which weighed 25, 15 and 5 tonnes, respectively. All three discarded hauls were caught on the same trip and were discarded because the fish were too small; the first two were thrown back and the third was slipped. In the mackerel fishery, approximately 4% of the total catch was discarded. This comprised one complete haul, slipped because the fish were too small. No discards were observed in the herring or argentine fisheries (Table 3).

3.4. Cetacean sightings

Marine mammals were sighted in the vicinity of pelagic trawlers on four separate occasions, three during fishing operations, *i.e.* marine mammals were observed to be present during just over 4% of observed fishing operations.

Three sightings were from a boat fishing for argentinians on the edge of the continental shelf (ICES area VI) during May. On 23rd May a whale (probably a small killer whale *Orcinus orca*) was seen as fish were being pumped aboard. On 24th May, a pod of between six and eight Atlantic white-sided dolphins (*Lagenorhynchus acutus*) circled the boat at a distance of about 500 m as the net was being hauled. On the same day a minke whale (*Balaenoptera acutorostrata*) was seen while the boat was steaming towards its home port.

The fourth sighting, made near North Rona (ICES area VI) during the herring fishery in August was of a minke whale, observed 25–30 m away from the vessel as the net was being hauled.

4. Discussion

This was a short study (the duration having been set by the funding body) and it was not possible to sample a high proportion of the fishing effort. For example, the 16 days of mackerel fishing sampled in the present study represents only around 1% of the total fishing effort in that fishery in 2000. Furthermore, reliance on voluntary participation

meant that random selection of trips was impossible: instead, the study made opportunistic use of all available trips. Media coverage of cetacean by-catch is often emotive in content and hostile to the fishing industry (Ross et al., 2001). On the other hand, reflecting in part the rather non-specific requirements of the EU Habitats Directive, European fishermen and fishery regulatory authorities are not presently obliged to monitor marine mammal by-catches. This is in contrast to the USA, where the Marine Mammal Protection Act places a statutory duty on fishery managers and fishermen to participate in monitoring and by-catch mitigation programmes.

In view of the above points, the present estimates of fish by-catch and discards must be viewed as provisional. The relatively large between-haul variation in by-catch rates also points to the need for further sampling effort. Nevertheless, the study indicates that all the fisheries studied had relatively low levels of by-catch and discarding during the study period. However, discarding in pelagic fisheries may be high at times, depending on the season and target species (Megapescas, 1999).

The maatje herring fishery had the lowest level (<1%) and variety of by-catch and the highest level of discarding (10%) amongst the fisheries studied. These results are not surprising in that maatje herring fetch a high price compared to ordinary herring and buyers demand a high quality from the fish. Skippers are reluctant to retain “low quality” catches such as small fish or those mixed with other species as these hauls would fetch a lower price. Freshness is also important and once a catch of maatje herring has been made a boat will normally return to port as soon as possible. The three hauls observed to be discarded all contained fish that were too small. The only by-catch species observed in this fishery was haddock. No mixed shoals (hauls with a large proportion of another pelagic fish, such as mackerel with herring) were caught. This may be because the sonar signature of maatje herring is very faint and quite distinctive and the boats were targeting these signatures exclusively.

The rest of the herring fishery had a low by-catch rate (2%) and no discards were observed. The main by-catch species was mackerel, which appears to have been due to the occurrence of mixed shoals.

In the Celtic Sea herring fishery, by-catch was found to be 0.5% of the total catch and 4.7% of the catch was discarded (Morizur et al., 1995). These levels are more similar to the results for the Scottish maatje herring fishery than the main Scottish herring fishery. This is most likely due to the fact that the boats sampled in the 1995 study were targeting herring mainly for the Japanese roe market which, like the maatje herring market, pays a high price for good quality fish and targets fish in a specific maturity condition, thereby encouraging the discarding of other fish (Morizur et al., 1995). The chief difference between the herring fisheries in the Celtic Sea and Scottish herring fishery is the large variety of by-catch in the Celtic Sea herring fishery. Thirteen fish species and two cetacean species were present

as by-catch in the Celtic Sea fishery, contrasting with four fish and one bird species in the Scottish herring fishery (and only one by-catch species in the maatje herring fishery).

The mackerel fishery had a low rate of by-catch: the best estimate was <1%, although the figure could be as high as 4%. The discard rate was estimated to be between 4% and 11%. The “discarding” observed consisted of the slippage of two complete hauls, one comprising of small fish and one containing (according to the skipper) a high proportion of by-catch species. The absence of catch data for the latter haul explains the uncertainty about discard and by-catch rates.

A study of the mackerel fishery off the Scottish coast in ICES sub-areas IVa and VIa indicated a discarding rate of 1.8% (Anon., 1999), whereas the English mackerel fishery had a discarding rate of 11% (Morizur et al., 1995). The majority of the mackerel fishing sampled in the present study took place off the west coast of Ireland, in the same general area as the mackerel fishery in the 1995 study.

While the argentine fishery had the highest proportion of “by-catch” and greatest variety of by-catch species of all the fisheries studied (including four species of shark), the bulk of the by-catch was blue whiting, which is marketable and was landed. The remaining by-catch represented only 1.5% of the total catch. In Scotland, the argentine fishery appears to have started around 6 years ago and has subsequently increased in importance, with the season lasting 8 weeks in 2001.

Virtually all the by-catch observed in the fisheries studied was fish with only two exceptions. Flying squid (*Todarodes sagittatus*) were observed in the wings of the net after several of the hauls in the argentine fishery. The presence of *Todarodes* is unsurprising, since it feeds mainly on small pelagic fish such as argentines, blue whiting and pearlsheds (*Maurollicus muelleri*) (Lordan et al., 2001).

By-catches of gannets were observed in the herring and argentine fisheries. Extrapolating from observed mortalities, this corresponds to around 140 gannet deaths per year in the argentine fishery and 560 per year in the herring fishery. It should be borne in mind that gannets were caught in relatively few observed catches and a more comprehensive survey of seabird by-catches is required. The gannets were diving at and around the nets while the nets were being hauled. In the herring fishery at least two of the gannets were released alive. Relatively few studies have quantified seabird by-catch mortality. Common guillemots (*Uria aalge*) were the most frequently by-caught bird in nets off Newfoundland (Piatt and Nettleship, 1987) while great shearwaters (*Puffinus gravis*) were the species most frequently caught in long-lines off South Africa (Barnes et al., 1997).

No marine mammals were present in the by-catch which, given the number of hauls observed and assuming that these were representative, allows us to say that we are 95% confident that marine mammal by-catch events typically occur during less than one in 20 hauls in the fisheries

studied. The by-catch rate for marine mammals may of course be much lower than this figure, but more trips would be needed to confirm this. The value obtained cannot be extrapolated to seasons, years, locations, fishing methods or target species other than those studied because, although the distribution of by-catch might be randomly distributed in relation to observation effort it certainly will not be random with respect to season, location, etc.

While it is recognised that observers who are also tasked with measuring fish in the catch may be more likely to miss the occurrence of marine mammals, in view of the expense of observer studies, this represents a sensible approach (Northridge, 1996). In the present study, use of “multi-task” observers was judged to be successful.

Many cetacean species have been recorded feeding in the vicinity of trawls (Fertl and Leatherwood, 1997). However, the low frequency of cetacean sightings suggests that cetaceans were not normally present in the vicinity of fishing activities during this study. Most fishing observed took place during daylight hours—fishing for herring and maatje herring was always during the day, while the diurnal pattern of fishing varied between boats in the other fisheries. It would be interesting however to augment surface visual observation with acoustic recording to detect cetacean presence (Connelly et al., 1997), which would allow night-time data collection. Cetacean entanglement in trawls apparently occurs more frequently at night than it does in the daytime (Aguilar, 1997; Crespo et al., 1997).

Future study of catches, by-catches and discards in mid-water pelagic fisheries is very desirable in the light of the growing interest in these resources and the fact that they have not been studied to the same degree as many other commercial fisheries. While the zero marine mammal by-catch is an encouraging and important result, support from more extensive studies is essential.

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