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Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea

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ABSTRACT: Most types of fishery produce discards and offal in considerable quantities which are fed upon by seabirds. This paper demonstrates the importance to seabirds of fishery waste in the North Sea. The total amount of fishery waste in the North Sea region is estimated at 62800 t of offal, 262200 t of roundfish, 299300 t of flatfish, 15000 t of elasmobranchs and 149700 t of benthic invertebrates per year, representing 4% of the total biomass of fish and 22% of the total landings. This equals an energy value of about 3.4×10^{12} kJ. Beam trawl fisheries discharge discards at the highest rates of all fishing fleets. Their discard fraction is dominated by flatfish which are less favoured by seabirds because of their shape. In contrast, the amounts of discards from pelagic and gadid fisheries are less, but fish species and lengths are more appropriate as food for seabirds. The number of seabirds potentially supported by fishery waste in the North Sea is estimated to be roughly 5.9 million individuals in an average scavenger community (composition in proportion to the seasonal abundance of scavenging species). During experimental discard studies, the proportions of fishery waste consumed by seabirds was calculated. We estimated that the mass of discards and offal consumed by birds during our study amounted to 55000 t of offal, 206000 t of roundfish, 38000 t of flatfish, 2000 t of elasmobranchs and 9000 t of benthic invertebrates.

KEY WORDS: Fisheries · Discards · Offal · Seabirds · Food · Energy requirements · North Sea

INTRODUCTION

Discarding unwanted parts of the catch has been common practice since the beginning of fisheries. However, by the end of the 19th century, people were becoming concerned about the waste of this valuable resource. For example, Weigelt (1891) investigated the nature, amount, use and exploitation of fishery waste produced by German fisheries. During the second half of the 20th century, with a rapid increase in fishing effort, these concerns increased because large proportions of young fish of commercial species were killed (e.g. Sahrhage 1958, 1959). Additionally, the influence of fisheries is of interest to other biological and environmental sciences that focus on the effects of human activities on other aspects of the environment.

The availability of large amounts of discards and offal is one of the factors which may have contributed to the rapid growth of some seabird populations (e.g. Dunnet et al. 1990, Lloyd et al. 1991). Large-scale studies in the North Sea have demonstrated that scavenging seabirds make extensive use of fishery waste, above all of offal and roundfish, but also to some extent of flatfish, cephalopods and benthic invertebrates (Camphuysen et al. 1993, 1995). The proportions of discards and offal seasonally consumed by seabirds are relatively well known for the North Sea as a whole. In order to calculate the total number of seabirds which could be sustained by this food supply, data on the amount of discards and on the energetics of seabirds

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are needed. Information on discards is available for some fisheries (e.g. beam trawl, gadid and pelagic fisheries) while for others the information is lacking (set net and industrial fisheries). The shrimp fishery and other near-coastal fisheries are omitted from these analyses because those areas are occupied by seabird communities that differ from the pelagic community addressed here and because the composition of the discards deviates considerably from that of offshore fisheries. Seabird energetics have been studied sufficiently to enable approximations of seabird energy demands in the North Sea (e.g. Birt-Friesen et al. 1989, Anonymous 1994d, Bryant & Furness 1995).

Here, we estimate the amount of discards and offal discharged by commercial fisheries, the proportion consumed by seabirds and the number of seabirds potentially sustained by this type of food. This information is valuable since it is expected that future developments of North Sea fisheries will lead to a reduction of fishing effort and/or fish biomass caught, followed consequently by a reduction or change in the amounts and type of fish discarded (e.g. Furness 1992, Hubold 1994). We thus also consider possible effects of a shortened food supply on the scavenging species breeding along the North Sea coast.

METHODS

This paper is based upon data obtained during a study of scavenging seabirds in the North Sea (Camphuysen et al. 1995) and a comprehensive review of information in the fisheries literature on the quantities of fish, benthos and offal discarded in the North Sea. Field studies of scavenging seabirds were carried out from February 1994 to March 1995. The distributions, abundances and feeding behaviour of scavenging seabirds were investigated from fishery research vessels engaged in the 'International Bottom Trawl Survey' (IBTS; Anonymous 1990) during all 4 seasons (winter: January/February 1993, spring: April/May 1994, summer: August/September 1994, autumn: October/November 1994).

We define as 'discards' fish and invertebrates which are caught at sea and which are subsequently discharged again because they (1) are too small to be commercially exploited, (2) are below the official minimum landing size, (3) belong to a species for which there is no demand or (4) are caught in excess of the fishing quota. 'Offal' is defined as the livers and intestines of marketable fish that have been removed during fish sorting and cleaning (Hudson & Furness 1988).

The amounts of discards and offal and their calorific values were estimated from published data. If not given in the literature, we estimated discard totals. In the last few years some data about discards have been published both by fishery and seabird biologists, but few specific studies have been conducted (reviewed e.g. in Anonymous 1994e, Weber 1995). Hence it was impossible to obtain data of sufficient quality for all fishery types in the North Sea. In this paper, we also omit the coastal zone. Hence, the shrimp fishery restricted to the Wadden Sea area is not included although extensive data on discards have been compiled there (Tiews 1983, Berghahn 1990, Tiews & Wienbeck 1990, Walter & Becker 1994). The most recent statistics on landings originate from 1988 (Anonymous 1992). Therefore, landings data were estimated for 1992 on the basis of ICES working groups reports (see Table 1 for sources).

For quantifying the amount of offal discarded in all fisheries we assumed that it represents a constant proportion of the landed mass of each species, following Anonymous (1994e). Our estimate for 1992 is based on statistics of all demersal fish landed from the North Sea (see Table 1 for sources). Offal originating from dab, flounder, plaice, sole, turbot *Psetta maxima* and witch *Glyptocephalus cynoglossus* were assigned to beam trawl fisheries, offal originating from other species were assigned to non-beam trawl fisheries (see Table 1 for scientific names of fish species).

For discards in pelagic fisheries, no absolute figures are given. Because of incomplete coverage, Corten (1991) did not give any estimates of the total amount of discards in Dutch pelagic fisheries. Although the data are few, a ratio of discards per unit mass of herring caught was derived by summing all catch data listed for the North Sea in Corten (1991).

Kirkegaard (1991) gives percentages of discards per mass unit of target fish (herring, mackerel) caught in Danish pelagic fisheries. There are some differences between seasons and fishing gear (trawl, purse seine). For calculations, we used an average of 5% discards if herring were caught and 20% discards for mackerel.

The calorific values of discards and offal vary considerably with time of year, fish length (e.g. Hislop et al. 1991) and study. Hence, it was impossible to obtain precise values for all organisms or occasions during the experimental discarding sessions. Table 2 lists the energetic equivalents employed in this study.

Assimilation efficiency in seabirds varies according to the food eaten: from Jackson (1986), Castro et al. (1989) and Brekke & Gabrielsen (1994) we obtained efficiences of 75% for fish and offal and 65% for invertebrates.

Bryant & Furness (1995) measured basal metabolic rates (BMR) for 11 species of Scottish seabird, ranging in size from the black-legged kittiwake to the northern gannet (see Table 6 for scientific names of bird spe-

Table 1. Estimated biomasses and landings of fish species in the North Sea. Only species with a biomass of ≥ 50000 t are listed. Landings of saithe, mackerel and horse mackerel include the Skagerrak, landings of herring include the Channel. Biomass estimates of herring include the Skagerrak. In all cases, the additional subareas represent only a minor proportion of the total value

Species	Biomass ($\times 10^3$ t)	Source	Landings ($\times 10^3$ t)	Source
Herring *Clupea harengus*	3428	3	550	3
Sandeels *Ammodytes* sp. and others	2081	4	763	2
Dab *Limanda limanda*	1620	4	7	6
Horse mackerel *Trachurus trachurus*	1585	4	112	5
Mackerel *Scomber scombrus*	720	4	341	5
Haddock *Melanogrammus aeglefinus*	559	1	48	1
Plaice *Pleuronectes platessa*	532	1	149	1
Norway pout *Trisopterus esmarcki*	527	2	183	2
Whiting *Merlangius merlangus*	390	1	46	1
Saithe *Pollachius virens*	315	1	93	1
Cod *Gadus morhua*	310	1	96	1
Sprat *Sprattus sprattus*	252	4	102	3
Starry ray *Raja radiata*	252	4	5	6[a]
Long rough dab *Hippoglossoides platessoides*	241	4	0	6
Lemon sole *Microstomus kitt*	226	4	6	6
Grey gurnard *Eutrigla gurnardus*	146	4	39	6[b]
Blue whiting *Micromesistius poutassou*	131	4	34	6
Sole *Solea solea*	91	1	33	1
Thornback ray *Raja clavata*	86	4	0	6
Poor cod *Trispoterus minutus*	55	4	0	6
Other species	502	4	62	6
Total	14049		2669	

[a]All skate and ray species. [b]All gurnard species

Sources: (1) Anonymous (1994a), mean values for 1990–1992; (2) Anonymous (1994b), mean values for 1990–1992; (3) Anonymous (1994c), mean values for 1990–1992; (4) Sparholt (1990), mean values for 1983–1985 of the higher of 2 estimates; (5) Anonymous (1993b), mean values for 1990–1992; (6) Anonymous (1992)

cies). From these measurements they derived the following equation for BMR of North Sea seabirds: BMR (kJ d^{-1}) = 2.30(body mass)$^{0.774}$. BMR covers only a part of the energy expenditure of birds. The total costs are encompassed in the field metabolic rate (FMR), which includes energy costs of thermoregulation, digestion, moult, reproduction and activity. Following Anonymous (1994d), we used an FMR of 3.9 BMR during the breeding season (= spring, surveys were carried out mainly in April/May) and 2.5 BMR during other periods of the year (winter, summer and autumn).

Table 2. Energetic equivalents employed in this study of discarded organisms. Equivalents were derived from values provided by Cummins & Wuycheck (1971), Daan (1975), Furness et al. (1988), Hislop et al. (1991) and Sidwell (1981)

Type of discard	Energetic equivalent (kJ g^{-1})
Offal	9
Clupeid	6.5
Mackerel	6.5
Gadids	4
'Other' roundfish	4
Flatfish	4
Elasmobranchs	4
Crustaceans	3.5
Echinoderms	2
Molluscs	1.5

Here, we define an 'average scavenger community' as the typical composition of those 8 common seabird species known to consume fishery waste regularly. It is calculated in proportion to the numerical and seasonal abundance of the species in the North Sea.

Anonymous (1994d) listed mean densities for all common seabirds per month and subregion in the North Sea. From those data we calculated totals of the scavenging species per subregion and month and multiplied these figures with the energetic requirements of the respective species, correcting for assimilation efficiency. These energetic requirements are compared with the energy equivalents of the discard totals.

In field studies (Camphuysen et al. 1995), fishery research vessels engaged in the IBTS (Anonymous 1990) were joined by ornithologists during all 4 seasons. Fresh subsamples of the catch consisting of roundfish, flatfish, elasmobranchs, offal and benthic invertebrates were taken from each haul to be used for experimental discarding. Items were identified, measured to the nearest cm in length and thrown overboard singly from the stern of the vessel. Attempts by

seabirds to pick up and swallow the item were recorded, noting the species and (if possible) age class of the bird and whether the item was consumed, dropped or stolen. If it was stolen or dropped, the same notes were made for the second and subsequent birds, until the item was finally lost (sunk) or swallowed. Experimental discarding was usually conducted when vessels were stationary as the net was lifted and brought on deck, during discarding the bulk of the catch by the vessel's crew, and also occasionally during towing or steaming

RESULTS

Quantities of discards

The 3 main sources of discards and offal in the North Sea were demersal trawlers and seiners catching gadids, pelagic trawlers and seiners and beam trawlers. Comparatively small amounts of discards and offal are produced by the *Nephrops* fishery, as is also true of set net and long-line fisheries (Kirkegaard & Poulsen 1990, Camphuysen et al. 1995). Industrial fisheries are expected to produce no offal and only few discards, because they usually keep all the fish caught onboard, but the leakage of fish when the catch is pumped onboard must be an important, but unquantified, source of food for seabirds.

In all commercial fisheries, intestines and livers are removed from marketable roundfish and flatfish and the offal is discarded, except in some Norwegian vessels which have found a market for byproducts (Camphuysen et al. 1995). About 62800 t was discharged into the North Sea in 1992 (11000 t in beam trawl fisheries, 51800 t in other fisheries).

The beam trawl fishery is the dominant fishery in the southern and southeastern North Sea. It is carried out mainly by Dutch trawlers, with lesser effort by Belgian, German and UK vessels (Anonymous 1993a). The main target species is sole, but plaice and other flatfish species are also of commercial interest. The heavy gear used by these ships penetrates considerably into the sediment and the unwanted proportion of the catch is therefore high. Recently, some studies have focused on the amount and type of discards in this fishery. The most recent study (Fonds 1994) estimated a total of 270000 t of dead fish discards and 120000 t of dead invertebrates in 1992 for the sole fishery in the southern North Sea. This figure comes close to the 260000 t of fish discards estimated by van Beek (1990) for 1989 and 1990. Expressed as a ratio, this fishery produced between 6 and 10 kg of fish discards per kg of sole landed in the late 1980s and early 1990s. Assuming a proportion of 93% of flatfish and 7% of roundfish in the discards (Garthe 1993), totals of 19000 t of roundfish and 251000 t of flatfish result from the total given by Fonds (1994).

Demersal fisheries for gadids are carried out by all North Sea coastal nations, with various gear. Based on regular sampling of the Scottish seine, trawl and light trawl fisheries, the Roundfish Working Group has estimated that 56000 t of haddock and 36000 t of whiting has been discarded yearly between 1991 and 1993 by North Sea fisheries for gadids (Anonymous 1995). The amounts were much higher in the 1970s and also in the first half of the 1980s, and have declined due to the reduction of many gadid stocks in the North Sea (cf. Daan et al. 1990). Knowledge about other commercially exploited species in these fisheries is incomplete. Van Beek (1990) estimated 7800 t of cod and 4700 t of plaice was discarded by Dutch otter and pair trawl demersal fisheries in 1989/1990. From the data of van Beek (1990), Kirkegaard & Poulsen (1990), Ehrich (1994) and the total landings in the North Sea, we estimate that about 15000 t of cod and about 10000 t of plaice is discarded annually by demersal fisheries for gadids.

Further data are given by Jensen et al. (1994) for discards of fish species of little economic interest in Scottish and Danish demersal trawl and seine fleets. They come to 22900 t of discards on average for 1990 to 1991. Extrapolating the Scottish and Danish data to the whole North Sea by a factor of 2.1 as suggested by Jensen et al. (1994), 15000 t of roundfish (chiefly grey gurnard and norway pout), 23000 t of flatfish (chiefly dab, long rough dab and lemon sole) and 10000 t of elasmobranchs (chiefly starry ray) was discarded on average in 1990 and 1991 by demersal trawl and seine fisheries.

Pelagic fisheries by trawlers and seiners have been studied little with regard to discards. The only published data which allow some extrapolation for the North Sea originate from Corten (1991) for Dutch trawlers and Kirkegaard (1991) for Danish trawlers, both of which were fishing for herring and mackerel.

According to the data given by Corten (1991), 38 kg of discards (chiefly undersized makerel, herring and saithe) result per 1000 kg of marketable herring. Due to fisheries policy during the sampling period, Corten (1991) did not believe that the discarding performed by the crew was typical for the whole fleet. Therefore, he supposed that higher amounts of discards are produced when observers do not take part on cruises.

In general, very little or no discards of species other than the target species were observed (Kirkegaard 1991). Consequently, the amount of discards was estimated on the basis of catch data for 1990-1992 (Anonymous 1994c, 1993b) at 95000 t (27000 t of herring and 68000 t of mackerel).

Table 3. Proportion of the fleet of beam trawlers and non-beam trawlers in 6 subregions in the North Sea (from Camphuysen et al. 1995, modified). See Fig. 1 for locations of subregions

Subregion	Beam trawlers (%)	Non-beam trawlers (%)
NW	0.9	22.5
NE	1.5	21.8
CW	3.9	10.7
C	21.0	18.1
CE	23.7	18.1
S	49.0	8.8

The *Nephrops* fishery (*N. norvegicus*, Crustacea: Astacura) in the North Sea is concentrated off the northeast of England. As in the sole fishery, the target species comprises only a small part of the whole catch. Evans et al. (1994) estimated that *Nephrops* landings represented only 12% of the total catch mass. They calculated that 7.7 kg of fish and invertebrates is discarded per kg of *Nephrops* landed (some fish caught were also landed). Based on the calculation by Evans et al. (1994) and the total catch of 9852 t of *Nephrops* in the North Sea in 1988 (Anonymous 1992), a total of 26200 t of roundfish, 15300 t of flatfish, 5000 t of elasmobranchs and 29700 t of invertebrates (incl. undersized and damaged *Nephrops*) discards is produced annually.

Beam trawl fisheries, which produce about half the discards and offal discharged into the North Sea, are concentrated in the southern and southeastern North Sea. Systematic surveys in 1994 showed that 93.5% of all beam trawlers are concentrated in the Southern Bight, Central North Sea and German Bight (Table 3; Camphuysen et al. 1995). Because beam trawlers are easily separated from all other types of fishing vessels, and because the composition of discards in beam trawl fisheries is quite different from that in other fisheries, the amount of discards reported in this article was split into 6 subregions of the North Sea on the basis of the

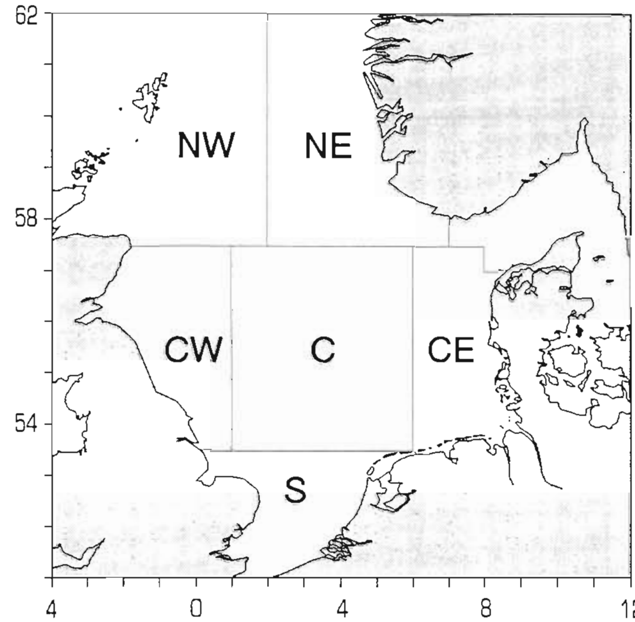

Fig. 1. Map of the 6 subregions in the North Sea

presence of beam trawlers and non-beam trawlers (Table 4, Fig. 1). Due to the geographical distribution of beam trawl fisheries and their huge amounts of discards, the highest density of all discards (4.06 t km^{-2} yr^{-1}) is available in subregion S, the lowest density (0.58 t km^{-2} yr^{-1}) in subregion NW (Fig. 2).

Number of seabirds potentially supported by fishery waste

The total amount of discards and offal in the North Sea in 1990 was estimated at 62800 t of offal, 262200 t of roundfish, 299300 t of flatfish, 15000 t of elasmobranchs and 149700 t of benthic invertebrates (Table 4). Converted into energy values, this can be considered as the amount of fishery waste on which scavenging animals can theoretically be sustained.

Table 4. Estimated quantities of discards and offal in 6 subregions in the North Sea in 1990 (in tonnes). For assumptions and sources see text

Subregion	Roundfish	Flatfish	Elasmobranchs	Benthic invertebrates	Offal	All
NW	54890	13130	3380	7760	11750	90910
NE	53310	14290	3270	8270	11450	90590
CW	26760	14960	1610	7860	5970	57160
C	48010	61450	2710	30580	11690	154440
CE	48520	68230	2710	33820	11990	165270
S	30710	127240	1320	61410	9950	230630
Total	262200	299300	15000	149700	62800	789000

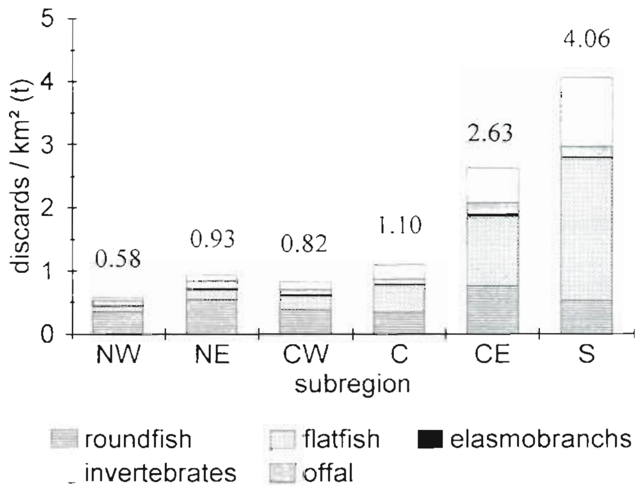

Fig. 2. Amounts of discards and offal per area in 6 subregions in the North Sea

Using the specific values for the energy content of the different discard items, a total calorific value of 3.4×10^{12} kJ results (Table 5).

Camphuysen et al. (1995) estimated the number of scavenging seabirds in the North Sea at between 1.4 and 3.4 million birds in winter and between 3.0 and 6.0 million birds in autumn. The percentage of individuals known to feed regularly on fishery waste comprises 66% of the total North Sea avifauna in summer and 53% in winter. Expressed in biomass, scavengers account for 66% of the total seabirds-at-sea biomass in summer and 52% in winter (numbers of birds from Skov et al. 1995, body mass values from Bezzel 1985). In order to calculate the number of scavenging seabirds which could be sustained solely by fishery waste in the North Sea, we first assumed that the relative abundances of the most common species would be similar to those found by Camphuysen et al. (1995). We then estimated the energy requirements of an individual of each species (see 'Methods' for assumptions). Correcting by the mean assimilation efficiencies for fish and invertebrates by seabirds as stated in the 'Methods', the total energy available for birds in the North Sea is estimated at 2.5×10^{12} kJ. This amount was then split up according to the respective abundances and energy requirements of the bird species. Consequently, the number of seabirds that could potentially be supported by fishery waste is presented in Table 6 and amounts to 5.9 million individuals in an average scavenger community (these figures assume that all offal and discarded organisms were consumed by seabirds, which was actually the case in some discard experiments). The largest fraction of seabirds is supported by fishery waste in subregion S, the smallest fraction in subregion CW (Table 6).

On a North Sea scale, fishery waste is sufficiently available to satisfy the energy demands of all scavenging species (Table 7). The distributions of both discards and seabirds are, however, different from each other Therefore, in subregions NW and CW, discards and offal are not numerous enough to balance the energy budgets of all scavengers. In contrast, this is possible in all other subregions, especially in CE and S.

Such calculations presuppose that discards and offal are evenly available in time. Although difficult to show, this does not appear to be the case. For example, in beam trawl fisheries in the southeastern North Sea, the highest catches of sole were obtained by small German trawlers close to the coast in the second quarter of the year, as was the case for large Dutch trawlers operating further off the coast in the third quarter (S. Garthe & U. Damm unpubl.). Landing statistics of other fish species suggest that, in general, catches and amounts discarded fluctuate considerably between seasons.

Furthermore, even for a large number of seabirds, it is often not possible to swallow the whole bulk of fish, offal and invertebrates when discharged. This can be due to the high amount of waste thrown overboard within a short period of time or due to immediately sinking items (sea urchins, hermit crabs *Pagurus bernhardus*), but also due to ship manoeuvring, the avoidance distance of the birds from the ship etc., all of which prevent the birds from consuming the total amount discarded.

Table 5. Energetic equivalents ($\times 10^9$ kJ) of discards and offal in 6 subregions in the North Sea. For sources of energetic equivalents see Table 2

Subregion	Roundfish	Flatfish	Elasmobranchs	Benthic invertebrates	Offal	All
NW	274	53	14	16	106	463
NE	266	57	13	17	103	456
CW	133	60	6	16	54	269
C	236	246	11	61	105	659
CE	238	273	11	68	108	698
S	144	509	5	123	90	871
Total	1291	1198	60	301	566	3416

Table 6. Calculation of the number of seabirds theoretically supported by discards and offal in the North Sea. Relative abundances of species were derived from the estimates given by Camphuysen et al. (1995). Base values for energetics of seabirds and calorific values of discard items are given in the text. Values in this table are rounded. Number of seabirds supported in the 6 subregions: NW, 800000; NE, 800000; CW, 500000; C, 1100000; CE, 1200000; S, 1500000

Species	Relative abundance	Yearly energy requirement per individual (kJ)	Total energy of fishery waste divided according to relative abundance and energy requirement of species (in million kJ)	Number of individuals supported
Fulmar *Fulmarus glacialis*	151	414700	1315700	3200000
Northern gannet *Morus bassanus*	10	1179900	247900	210000
Great skua *Catharacta skua*	1	663100	13900	21000
Common gull *Larus canus*	4	245200	20600	84000
Lesser black-backed gull *Larus fuscus*	6	419300	52800	130000
Herring gull *Larus argentatus*	32	525700	353400	670000
Great black-backed gull *Larus marinus*	12	722500	182200	250000
Black-legged kittiwake *Rissa tridactyla*	64	233100	313400	1300000
Total			2500000	5900000

Table 7. Energetic requirements of scavenging seabird species and energetic equivalents of discards in the North Sea ($\times 10^9$ kJ). For assumptions and base values see text and Tables 5 and 6

Subregion	Energetic requirements of scavengers (= required)	Energetic equivalents of discards (= available)	Index: required/ available
NW	899	463	1.9
NE	312	456	0.7
CW	364	269	1.4
C	322	659	0.5
CE	120	698	0.2
S	175	871	0.2
Total	2192	3416	0.6

Quantities of discards and offal consumed by seabirds

The proportions of fishery waste consumed by seabirds varied between discard types and areas and with season (Table 8). Overall, offal and roundfish were consumed in the highest percentages. Flatfish, elasmobranchs and benthic invertebrates were taken only in minor amounts. Using the percentages for the different subregions listed in Table 8, the mass of discards and offal consumed by birds during our study amounted to slightly more than 300000 t in the whole North Sea: 55000 t of offal, 206000 t of roundfish, 38000 t of flatfish, 2000 t of elasmobranchs and 9000 t of benthic invertebrates. Summed up, 39% of all discard items theoretically available is consumed by birds.

Generally, beam trawl fisheries discharge discards at the highest rates of all fishing fleets. Because of the clear dominance of flatfish in the discard fraction of this fishery, seabirds have to select carefully the few roundfish or have to take the less favoured flatfish (Tables 8 & 9). The opposite holds true for pelagic and gadid fisheries: there, the amounts of discards are less, but the type of discard available is more appropriate for seabirds.

The consumption percentages of discards given in Table 8 are of the same magnitude as results of previous studies (Table 9). However, discard experiments on board commercial trawlers (Hudson & Furness 1988, Camphuysen 1994) suggest slightly lower proportions of discards consumed in the northern North Sea but not in the southern North Sea if compared to fishery research vessels (e.g. Garthe 1993, Garthe & Hüppop 1994). Hence, experiments on research vessels will probably lead to an overestimate of consumption percentages because items were mostly discarded one after the other and not only when normal discarding took place. Thus, birds feeding in such situations had no choice between different types of fish. Also, rapidly sinking particles were consumed less frequently when discarding took place on a larger scale. The rather small differences between experiments on research vessels and commercial trawlers suggest, however, that the values obtained during our study are of the correct order of magnitude. Further studies could improve the consumption percentages by work on commercial trawlers.

DISCUSSION

The amounts of fish and other organisms discharged into the North Sea are considerable. This becomes evident if the values are compared with the total biomass

Table 8. Percentage of experimental discards and offal consumed by birds in 6 subregions (all seasons) and 4 seasons (all subregions), respectively, in the North Sea (from Camphuysen et al. 1995, modified)

	Roundfish	Flatfish	Elasmobranchs[a]	Benthic invertebrates	Offal size	Sample
Subregion						
NW	90	28	12	9	99	9132
NE	89	41	12	3	98	3281
CW	84	32	12	1	92	5316
C	75	14	12	1	90	8519
CE	63	10	12	3	54	3396
S	71	8	12	4	100	1200
Season						
Winter	92	35	12	17	100	6028
Spring	76	22	12	8	94	10354
Summer	70	10	12	3	94	8526
Autumn	82	20	12	3	97	5936
Sample size	21848	2345	34	902	5715	30844

[a]Since sample sizes per subregion and season were small, we used percentage of overall consumption

Table 9. Other discard experiments in the North Sea. Consumption rates by birds are given for roundfish, flatfish, offal and invertebrates. CT: commercial trawler; RV: research vessel

Roundfish %	Roundfish n	Flatfish %	Flatfish n	Offal %	Offal n	Invertebrates %	Invertebrates n	Vessel type	Area	Time	Season	Year	Source
58[a]	6423	5[a]	1182	–	–	–	–	CT	Around Shetland	Day	Summer	1984–1985	1
83	208	67	76	–	–	–	–	RV	Off SW Norway	Day	Summer	1990	2
85	430	30	56	–	–	56	311	RV	Helgoland area	Day	Winter	1991–1992	3
79	909	30	1259	83	296	11	79	RV	Helgoland area	Day	Summer	1991–1992	3
84	13594	8	397	–	–	–	–	RV	North Sea	Day	Summer	1992	4
86	7	16	19	–	–	–	–	RV	Skagerrak/Kattegat	Day	Winter	1993	2
48	52	24	79	–	–	–	–	RV	Skagerrak/Kattegat	Night	Winter	1993	2
69	258	13	67	74	608	–	–	RV	Southern North Sea	Day	Winter	1992	5
85	642	34	387	94	642	0.3	?	CT	West of Helgoland	Day	Summer	1993	6
71	1101	31	1044	66	1217	0.3	2540	CT	Southern North Sea	Day	Summer	1993	7

[a]% values in Hudson & Furness (1988) are minimum % consumed (since many discards were of 'unknown' fate, probably many of these were also consumed)

Sources: (1) Hudson & Furness (1988); (2) Garthe & Hüppop (1993); (3) Garthe (1993); (4) Garthe & Hüppop (1994); (5) Camphuysen (1993b); (6) Camphuysen (1993a); (7) Camphuysen (1994), includes (6)

of fish and the total landings from the North Sea: fish discards (576500 t yr^{-1}; Table 4) represent roughly 4% of the total biomass of fish and 22% of the total landings of fish from the North Sea (Table 1).

It is most obvious that discards and offal provide an enormous amount of food which is exploited heavily by seabirds in all areas of the North Sea and throughout the year. The importance of fishery waste becomes evident if compared to natural sources of food. Thus, the mass of fishery waste taken by birds more than equals the 265000 t of live fish calculated to be consumed by all seabirds in the North Sea, being twice as high as the mass of 'other food' including zooplankton, cephalopods and terrestrial food (Anonymous 1994d). Most interesting, the distribution of discard density (Fig. 2) stands in contrast to the distribution of scavenging seabirds at sea, which occur in the highest densities in the northwestern North Sea more or less the whole year round (Camphuysen et al. 1995, Skov et al. 1995). The reason for this difference is that the northwestern North Sea holds the majority of the breeding pairs of most scavenging species, especially cliff-nesting species such as northern fulmar and black-legged kittiwake (Dunnet et al. 1990). The southern and southeastern part of the North Sea is well suited for flatfish trawling due to its sandy sediment and hence provides large amounts of discards. Considering the numbers of seabirds theoretically sustained by fishery waste, it becomes clear that discards and offal

may easily support all scavenging seabirds in the southern and southeastern subregion, but only half in the northwestern subregion (Table 7). The relatively high percentages of discards consumed demonstrates that discard consumption must comprise a very important part of the diet of the scavenging species.

Many findings suggest that wholly pelagic bird species such as northern fulmar, northern gannet and black-legged kittiwake do not utilize fishery waste to the same extent as large gulls (Camphuysen et al. 1995). This may indicate that these gulls are more dependent on this type of food than the pelagic species. Furness & Hislop (1981) showed that discards formed up to 70% of the diet of adult great skuas breeding in Shetland and 28% of chick diet even when their preferred prey, sandeel *Ammodytes marinus*, was abundant. When sandeel abundance declined in the late 1980s, discards formed up to 82% of adult diet and 77% of chick diet (Hamer et al. 1991). Although breeding success was much reduced in the absence of sandeels, the survival of chicks must then have been largely dependent on the supply of discards (Furness 1987). Oro et al. (1995a, b) demonstrated that the breeding success of both Audouin's gull *Larus audouinii* and yellow-legged gull *Larus cachinnans* differed significantly between years with different trawling activity in the Ebro Delta, NE Spain. Both species of gull compensated partly for the cessation in food supply (discards) by switching to other types of food after a trawl moratorium took place. However, except for great skuas on Shetland and the large gulls in the Ebro Delta in NE Spain, we have only poor evidence that fishery waste forms the essential part of the diet of any other population of seabirds. Nevertheless, the availability of discards is believed to affect feeding strategies of the scavengers. For example, Blaber et al. (1995) suspected that the greater availability of discards of similar taxa may have led to greater overlap in the diets of the seabird species of the Northern Great Barrier Reef, Australia. Also, the diet of a variety of species has changed due to the supply of discards, which holds true also for the North Sea (e.g. Hudson 1986, Camphuysen 1993c). Since fisheries are carried out throughout the whole study area and throughout the whole year, interrupted only locally in the vicinity of strong gales, we are rarely able to demonstrate any effects of fishing activities on feeding ecology and reproductive output of discard utilizers. This might be the reason for the weak link between studies showing the utilization of discards at sea and studies focusing on possible effects of fishing activities.

What can we conclude for future scenarios of fisheries practice in the North Sea? Two ways of reducing discards are likely to occur in the forthcoming years (cf. Furness 1992, Anonymous 1994e, Hubold 1994): firstly, a general reduction in fishing effort and hence a general reduction in discards, and secondly an increase in the mesh size used in fishing gears. These measures will have different effects on scavengers. A general reduction would lead to more interactions and thus would probably shift the foraging efficiency further in the direction of the species with the highest potential for kleptoparasitism. In other words, black-legged kittiwake, other small gulls and northern fulmars (cf. Camphuysen et al. 1995) could suffer greatest. An increase in mesh size does not necessarily decrease the amount of smaller fish caught, due to counteracting measures taken by fishermen as has been shown by Reeves et al. (1992). However, if this measure is obeyed accurately, the proportion and amount of small fish would decrease considerably: Furness (1992) calculated reductions in the mass of discarded fish of 52% (haddock) and 65% (whiting) if the mesh size increased from 90 to 120 mm in North Sea fishing fleets. This increase would principally reduce the small discards (Furness 1992). Hence, a deterioration of the feeding conditions for, in particular, black-legged kittiwake, black-headed gull and common gull, which utilize the smallest fish from the discards (Camphuysen et al. 1993, Garthe & Hüppop 1994), would result. Finally, both measures could reduce feeding profitabilities for immature individuals since adults are generally more successful than immature individuals of the same species (see Wunderle 1992 for review). Furthermore, immature individuals would perhaps be forced to switch to less favourable lengths of discards (Garthe 1993). In conclusion, immature individuals, especially birds in their first year of life, could suffer from higher mortality. Nevertheless, measures to reduce discards are highly desirable in spite of these apparent disadvantages for birds.

Summarizing, the practise of discarding unwanted fish and invertebrates at sea has a significant effect on seabirds. Not only is the amount of discards high when compared to the standing stock and the total landings of fish, but also fishery waste comprises an important, sometimes even essential, part of the diet of several seabird species.

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