Biological Oceanography Committee **ICES CM 1997/L:3**

REPORT OF THE

WORKING GROUP ON SEABIRD ECOLOGY

Glasgow, UK
24–26 November 1996

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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 INTRODUCTION

1.1 Participation

The following nominated members of the Working Group participated in the meeting:

R.T. Barrett	Norway
P.H. Becker	Germany
C.J. Camphuysen	Netherlands
G. Chapdelaine	Canada
P. Fossum	Norway
R.W. Furness (Chair)	UK
S. Garthe	Germany
S.P.R. Greenstreet	UK
G.L. Hunt Jr	USA
O. Huppop	Germany
M.F. Leopold	Netherlands
W.A. Montevecchi	Canada
J. Reid	UK
M.L. Tasker	UK
U. Walter	Germany
P. Wright	UK

1.2 Terms of Reference

At the 83rd Statutory meeting, it was agreed that:

a). The 1993 and 1994 Study Group reports be published in the ICES Cooperative Research Report Series in a volume edited by G.L. Hunt, M.L. Tasker and R.W. Furness.

b) An ICES Symposium on 'Seabird Ecology and Distribution in Relation to the Marine Environment' will be held in Glasgow from 22-24 November 1996 with M.L. Tasker as convenor. Scientific steering group will include G.L. Hunt, J. Reid, R.W. Furness and C.J. Camphuysen. The Seabird Group and JNCC will cosponsor the Symposium.

c) The Working Group on Seabird Ecology should produce a report and that the Working Group should meet in Glasgow from 22-26 November 1996 (2.5 days). The terms of reference were:

i) Evaluate the role of discards in supporting bird populations and their effects on species composition of seabird communities.

ii) Explore the short- and medium-term consequences of a reduction in the quantities of fish discarded.

iii) Review data related to the cause and consequences at the population level of mass mortalities of seabirds.

iv) Expand the analyses of the spatial concordance of reproductive parameters between seabird colonies and relate patterns to physical oceanographic conditions and prey stocks.

v) Prepare data on seabird predation on fish by size group on as detailed temporal and spatial scale as possible in the North Sea.

vi) Review issues related to seabird consumption of fish and shellfish stocks, discards and mariculture as well as the trophic role and ecology of seabirds and waders.

vii) Assist the Working Group on Environmental Assessment and Monitoring Strategies in its investigations with regard to the monitoring of contaminants in eggs of six seabird species.

1.3 Health Warning

The mandate and working time frame of our Working Group were such that data base manipulations and calculations were made over a few days with minimal time available for rigorous checking and full discussion of data sources and analytical procedures. Thus the values and data presented and the interpretations should be taken as preliminary and subject to revision.

1.4 Overview

As requested at the 83rd Statutory meeting, work of the 1993 and 1994 meetings of the Seabird-Fish Interactions Study Group was published in ICES Cooperative Research Report No. 216 'Seabird/Fish Interactions, with Particular Reference to Seabirds in the North Sea'. This 87 page report was edited by G.L. Hunt Jr and R.W. Furness, and was published in November 1996. All 25 copies of the report brought for sale at the ICES Symposium in Glasgow 22-24 November 1996 were sold at that meeting.

As also requested, an International Symposium cosponsored by ICES, The Seabird Group and JNCC, was held in Glasgow from 22-24 November 1996 with M.L. Tasker as convenor. The scientific steering group comprised C.J. Camphuysen, R.W. Furness, G.L. Hunt, J. Reid and M.L. Tasker. Over 100 scientists from 17 countries, including from as far as New Zealand, attended the meeting, at which 22 oral papers and 26 poster papers were presented. The Opening Address was given by Alain Maucorps. The majority of the papers presented will appear in a special issue of ICES Journal of Marine Science, guest edited by Dr J. Reid.

The Working Group on Seabird Ecology met for 2.5 days (24-26 November 1996) immediately after the Symposium, and was attended by 16 appointed participants from six countries. We reviewed and report in some detail below on topics i, ii, iii, v, vi from our terms of reference. Topic iv (spatial concordance of reproductive parameters between seabird colonies) is being dealt with at present by Dr K.R. Thompson (JNCC), Dr R.W. Furness and Dr S.P.R. Greenstreet with the aim of preparing a manuscript to submit for publication in an international journal early during 1997. We were unable at this Working Group meeting to carry this analysis forward beyond the level reported in Hunt and Furness (1996), in particular because we still await some of the 1996 raw data to reach JNCC from fieldworkers. However, we plan to carry out the necessary analyses in January/February 1997. Topic vii in the Terms of Reference was dealt with by telephone between the respective Working Group Chairmen. In the report below, Terms of Reference topics map onto report sections as follows: i = Section 2, ii = Section 3, iii = Section 4, v = Section 5, vi = Section 6.

1.5 Acknowledgements

The Working Group wishes to thank the University of Glasgow and specifically the Division of Environmental and Evolutionary Biology for providing rooms for our meetings, computing and photocopying facilities.

2 EVALUATION OF THE ROLE OF DISCARDS IN SUPPORTING BIRD POPULATIONS AND THEIR EFFECTS ON THE SPECIES COMPOSITION OF SEABIRDS IN THE NORTH SEA

2.1 Introduction

In this report, we use the term discards to describe the animal waste generated by fishing operations which is jettisoned at sea. This therefore includes undersized fish and shellfish, fish which cannot be taken to market because quotas are exceeded or the catch is of low relative value to other hauls etc., offal and waste from cleaning fish at sea and other biota such benthos.

The amounts of discards (including offal) from offshore fisheries in the North Sea have been evaluated by several workers. Recent evaluations were summarised by ICES (1996). Garthe *et al.* (1996) compiled information from a variety of sources on the amounts discarded in six sections of the North Sea (Table 2.1.1).

Table 2.1.1. Estimated quantities of discards and offal in six sub regions (see Figure 2.4.1) in North Sea offshore trawl fisheries in 1990 (in tonnes) (Garthe *et al.*, 1996, see also ICES, 1996) and the SE North Sea shrimp fisheries (see section 2.1.1 for calculations).

	Roundfish	Flatfish	Elasmo-branchs	Benthic invertebrates	Offal	Total
NW	54,890	13,130	3,380	7,760	11,750	90,910
NE	53,310	14,290	3,270	8,270	11,450	90,590
CW	26,760	14,960	1,610	7,860	5,970	57,160
C	48,010	61,450	2,710	30,580	11,690	154,440
CE	48,520	68,230	2,710	33,820	11,990	165,270
S	30,710	127,240	1,320	61,410	9,950	230,630
SE shrimp fishery	10,800	8,000	0	137,800	0	156,600
Total	273,000	307,300	15,000	287,500	62,800	945,600

2.1.1 The shrimp fishery off Niedersachsen, Germany

Shrimping is the most important fishing activity off Niedersachsen. The fleet consists of 118 cutters (Prawitt, 1995), which fish between March and November/December (Gubernator, 1994) for the brown shrimp *Crangon crangon* (5-8 cm body length). Shrimping is carried out with beam trawls close to the coast and inside the Wadden Sea. Large numbers of undersized shrimps, other benthic invertebrates and fish species are incidentally caught owing to the poor selectivity of the fine meshed shrimp nets (minimum mesh opening 20 mm).

In order to quantify total amounts discarded in three categories (undersized shrimps, other invertebrates and fish) the discard to commercial shrimp mass ratios in 103 unsorted catch samples (November 1992 - November 1993) were analysed (Walter, in prep.). These ratios, combined with the landings statistics of brown shrimps for the same month, was used as a basis to estimate the total amount of discards from the shrimp fleet of Niedersachsen in the main part of the fishing season of 1993.

Shrimps of marketable size comprised 11 % of mass of the catch, the remainder was mostly undersized shrimps (64 %), other invertebrates (8 %) and fish (11 %). The most abundant fish were flatfish such as plaice *Pleuronectes platessa*, flounder *Platichthys flesus* and dab *Limanda limanda*, and roundfish such as clupeids and gadoids. Among the invertebrates, shore crab *Carcinus maenus* and swimming crab *Liocarcinus holasadus* were most frequent (Walther, in prep.).

The monthly median of the ratio of undersized to marketable shrimps varied considerably (between 1:2 - 1:10), with the lowest value in spring and the highest ratio in August (Figure 2.1.1). The majority of undersized shrimp are discarded alive. The proportion of invertebrates (other than brown shrimps) to marketable shrimps varied between 0.05:1 and 1.1:1. The equivalent ratios for fish showed less variation (0.5:1 - 1.4:1) than invertebrates (excluding undersized shrimps) (Walther, in prep.).

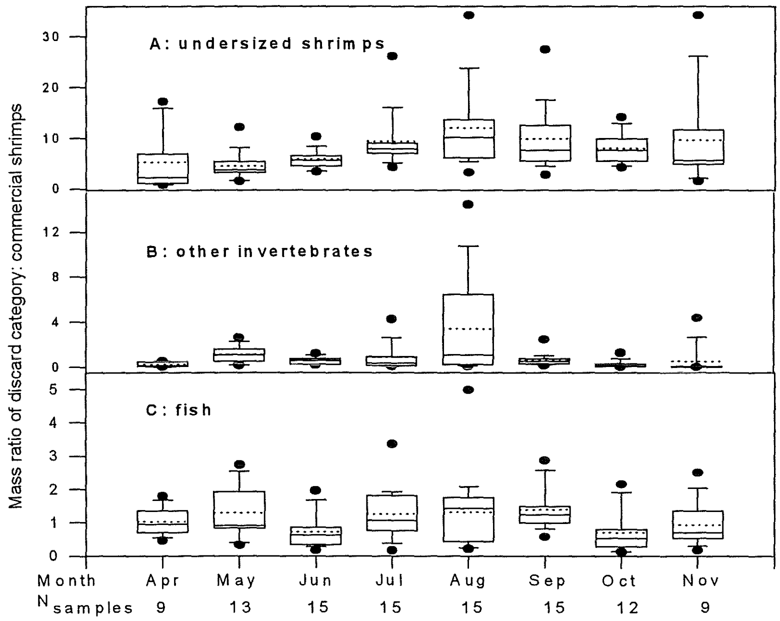

Figure 2.1.1. Average seasonal discards/commercial shrimp ratio of three main discard components, undersized shrimps, other invertebrates and fish (April - November 1993, total number of catch samples = 103) (Walter, in prep.).

Total discards of approximately 4,000 tonnes of fish (1,750 t of flatfish and 2,290 t of roundfish), 27,000 tonnes of undersized shrimps and a further 2,000 tonnes of other invertebrate species were calculated for the shrimper fleet in the main fishing season (April - November) in 1993.

There is no direct information on discards from shrimp fisheries elsewhere in the North Sea. Shrimping is carried out off the coasts of France, Belgium, England, and the three Wadden Sea countries (Netherlands, Germany and Denmark). The results of the study off Niedersachen might be extrapolated to the remainder of the brown shrimp fishery off the Wadden Sea coast of the North Sea, in order to provide an approximate estimate of total bycatch. The total landings of brown shrimps in the coastal area of the Wadden Sea average to 20,000 tonnes per year (1983 - 1992) (Lozàn, 1994). If the mean discards/marketable shrimp ratios in the catch samples off Niedersachsen (0.4 for flatfish, 0.54 for roundfish, 6.4 for undersized shrimps and 0.49 for other invertebrates) is applied to the rest of the fishery, then a total of more than 150,000 tonnes of discards would be produced by all shrimpers of the three countries (Table 2.1.1).

It should be noted that Table 2.1.1 does not include amounts discarded from a number of inshore fisheries (e.g., shrimp fisheries off countries other than those of the Wadden Sea), from static gear fisheries or from industrial fisheries (likely to be relatively small amounts). The total amount of fishery waste discarded in the North Sea probably exceeds 1,000,000 tonnes.

2.2 Consumption of discards by seabirds

2.2.1 Offshore fisheries in the North Sea

The proportion of discards consumed by seabirds in the North Sea was studied experimentally by Camphuysen *et al.* (1995) (summarised in Table 2.2.1). These proportions are broken down by species to quantify tonnages of five categories of discard (offal, roundfish, flatfish, elasmobranchs and benthic invertebrates) consumed by the most important scavenging seabird species in the North Sea (Table 2.2.2 based on Camphuysen *et al.*, 1995; Garthe *et al.*, 1996), based on the numbers of discard items consumed by birds. Calculations using discard mass as the basis would certainly lead to somewhat different results since, for instance, kittiwakes take the smallest roundfish and gannets the largest roundfish (Camphuysen *et al.*, 1995). These data are not available for the present analysis.

Table 2.2.1. Proportion of experimental discards and offal consumed by birds (in %) in six offshore regions (all seasons) and four seasons (all sub regions), respectively, in the North Sea offshore trawl fisheries (from Garthe *et al.*, 1996), and in the shrimp fishery of Niedersachsen (Walther, in prep.)

	Roundfish	Flatfish	Elasmo-branchs	Benthic invertebrates	Offal	Sample size
NW	90	28	12	9	99	9,132
NE	89	41	12	3	98	3,281
CW	84	32	12	1	92	5,316
C	75	14	12	1	90	8,519
CE	63	10	12	3	54	3,396
S	71	8	12	4	100	1,200
winter	92	35	12	17	100	6,028
spring	76	22	12	8	94	10,354
summer	70	10	12	3	94	8,526
autumn	82	20	12	3	97	5,936
sample size	21,848	2,345	34	902	5,715	30,844
Shrimp fishery	79	41		23 (excl. shrimp)		4291

Table 2.2.2. Tonnes of discards consumed by seabird species from the North Sea offshore fisheries as a whole, (based on Garthe *et al.*, 1995; Camphuysen *et al.*, 1995; Walther and Becker, in prep.)

	Offal	Roundfish	Flatfish	Elasmo-branchs	Benthic invert.s	Total
Fulmar	39,800	53,400	4,500	200	6,300	104,200
Gannet	300	35,900	15,300	200	0	51,700
Great skua	100	2,000	0	0	0	2,100
Black-headed gull	0	100	0	0	0	100
Common gull	100	800	100	0	0	900
Lesser black-backed gull	1,300	14,500	6,200	1,100	500	23,300
Herring gull	2,600	21,100	5,100	0	500	29,300
Great black-backed gull	300	12,600	4,800	200	600	18,500
Kittiwake	10,500	66,000	2,200	400	1,100	80,200
Total	55,000	206,000	38,000	2,100	9,000	310,000

2.2.2 Inshore shrimp fisheries off Niedersachsen (Lower Saxony)

In the coastal area off Niedersachsen, scavenging seabirds follow shrimp trawlers in large numbers throughout the whole fishing season (Walter and Becker, in prep.). Up to 3,000 birds may be found astern of an individual shrimper (Berghahn and Rösner, 1992; Walter and Becker, 1994, in prep.).

The main scavenging species are herring gull and black-headed gull, which together represent 93% of all recorded birds (Walter and Becker, in prep.). Both species showed the same seasonal pattern, with low numbers until June and larger numbers in late summer and autumn. Common, lesser and great black-backed gulls and common/arctic terns were less numerous than herring and black-headed gulls. Common gulls occurred throughout the whole fishing season, but only in substantial numbers behind shrimpers in March and in autumn. Lesser black-backed gulls and common/arctic terns were summer visitors and occurred in relatively low numbers between April and September. Great black-backed gulls were scarce before July, increasing slightly in numbers in late summer and autumn.

Feeding rates by number of items consumed were determined following the method of Hudson and Furness (1988). Differences between the length distribution of commercial and experimental discards were compensated for (Walter and Becker, in prep). In total, 5,500 tonnes of discards from the shrimper fleet of Niedersachsen were consumed by the birds in 1993. This comprised 41% of the discarded flatfish mass (=710 tonnes), 79% of roundfish (=1,820 tonnes), 23% of four invertebrate species (*Carcinus maenas, Liocarcinus holasadus, Asterias rubens, Allotheutis subulata*; 420 t) and 10% of the undersized shrimps (2,500 t).

2.3 Diets of seabirds that scavenge discards in the North Sea

Discards form only a proportion of the diet of seabirds in the North Sea. Full quantification of seabird diet has not been carried out, but it is known that this proportion varies by species, by location and by season. Based on a compilation of many studies, Tasker and Furness (1996) make some assumptions on diets for an input to a model of North Sea fish consumption by seabirds. Their results for the main scavenging species are summarised in Table 2.3.1.

Table 2.3.1. Foods consumed by seabirds which scavenge discards in the North Sea (after Tasker and Furness, 1996 and Walter and Becker, in prep.).

Species		Discards and offal	Other food
Fulmar	(summer)	30% offal, 30% discards	10% zooplankton, 30% sandeels
	(winter)	50% offal, 25% discards	25% zooplankton
Gannet		10% discards	30% sandeels, 30% herring, 30% mackerel
Great skua[1]		62% discards	26% sandeel, 10% birds, 2% other
Black-headed gull[2]		10% discards	50% other, 40% terrestrial food
Common gull[2]		10% discards	50% other, 40% terrestrial food
Lesser black-backed gull[2]		60% discards	40% other
Herring gull		10% offal, 30% discards	30% invertebrates, 30% terrestrial foods

Species	Discards and offal	Other food
Great black-backed gull	60% discards	20% sandeels, 20% other prey
Kittiwake IVa W (summer)		100% sandeels
(winter)	25% offal, 25% discards	25% zooplankton, 25% sprat,
IVa E, IVb, IVc (summer)		20% zooplankton, 60% sandeels, 20% sprat
(winter)	25% offal, 25% discards	25% zooplankton, 25% sprat

Notes: 1. A 16 year average from non-breeding birds, based on studies on breeding grounds (Hamer *et al.*, 1991)

2. Estimates from Arbouw and Swennen (1985), Dernedde (1993), Freyer (1995), Gorke (1990), Hartwig *et al.* (1990) Kubetzki *et al.* (in prep.), Noordhuis and Spaans (1992), Spaans *et al.* (1994).

2.4 Numbers of seabirds supported by discards in the North Sea

In order to assess how many seabirds can be sustained from discards and offal, Garthe *et al.* (1996) derived an "average scavenger community" from seabird counts (Camphuysen *et al.*, 1995). This is based on the typical composition of those eight common seabird species known to consume fishery waste regularly and is calculated in proportion to the numerical and seasonal abundance of the species in the North Sea.

There are considerable variations in the distribution of the scavengers in the North Sea, with respect to both area and season (Camphuysen *et al.*, 1995; Stone *et al.*, 1995). Fulmars are most numerous in the north (particularly around Shetland), with much lower numbers in the south and east. Highest numbers are present in late summer/early autumn. Gannets leave the North Sea in autumn and winter as do lesser black-backed gulls. Herring gulls and great black-backed gulls, in contrast, move into the North Sea during the winter. Kittiwakes are also highly numerous, but stay in the North Sea in considerable number the entire year. Common gulls are present only in winter in the south and the eastern parts, black-headed gulls are scarce in offshore areas at all times, in contrast to inshore areas of the south-eastern North Sea where they are common (Stone *et al.*, 1995; Berghahn and Rösner, 1992; Walther and Becker, in prep.).

About 5.9 million individuals in the North Sea scavenging seabird community could possibly be sustained by offshore fisheries (this figure assumes that all offal and discarded organisms are consumed by seabirds - an assumption supported only by some discard experiments(Garthe *et al.*, 1996)). Discarding is not uniform, thus different numbers of varying species might be supported in separate parts of the North Sea. Garthe *et al.* (1996) divided the offshore areas into six sub regions (Figure 2.4.1).

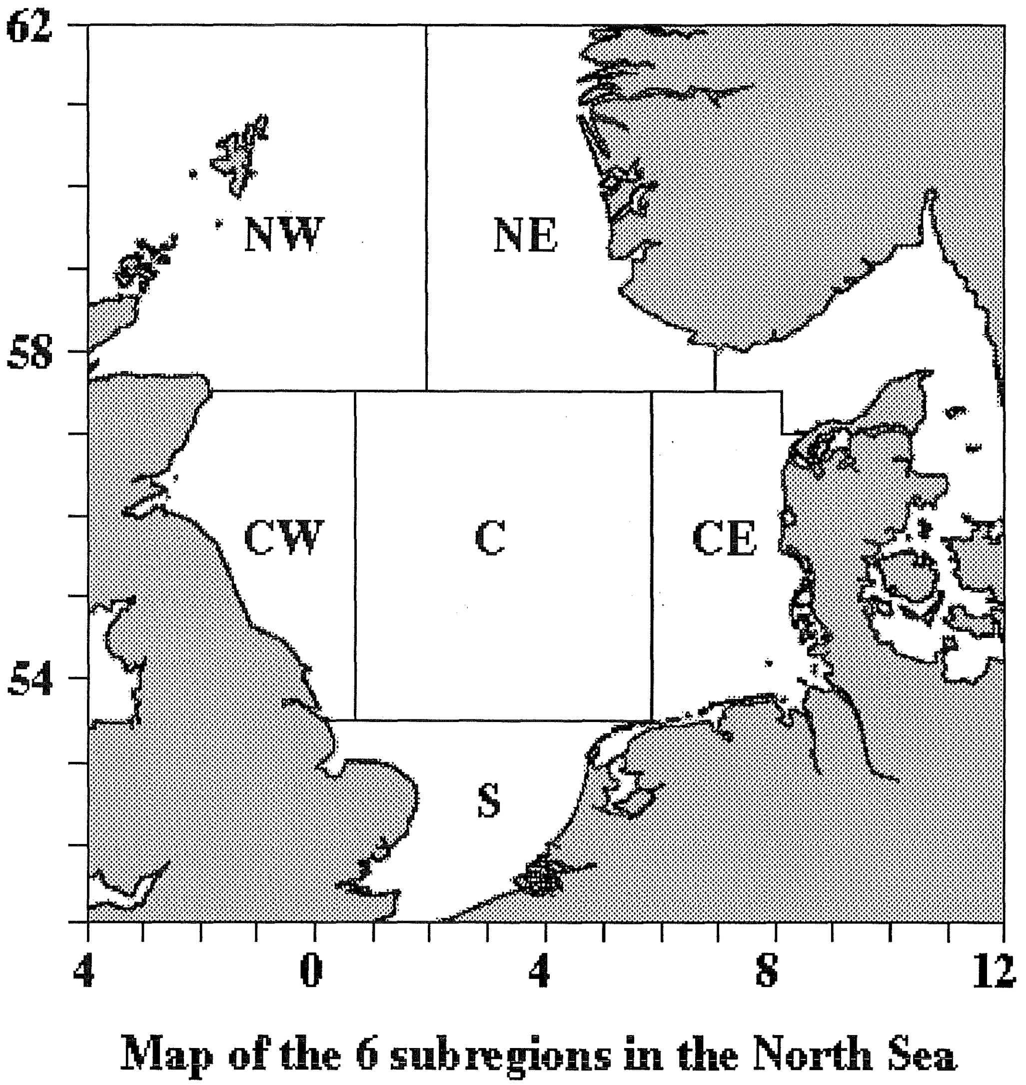

Figure 2.4.1. Map of the six sub regions of the North Sea used by Garthe *et al.* (1996).

The largest number of seabirds that could potentially be supported by fishery waste is in sub region S (1,500,000), followed by CE (1,200,000) and C (1,100,000). Lower numbers might be supported by fisheries in sub regions NW and NE (800,000 individuals in each of the two regions) and CW (500,000) (Garthe *et al.*, 1996).

Additionally, the shrimp fishery in inshore waters off Niedersachsen supports a large number of seabirds. The consumed part of the shrimper discards represents an energy value of 2.5 x 10^{13}J per year (Walter and Becker, in prep). The mean daily energy demand of a 'model' seabird (species energy demand may be weighed against their relative frequency astern the shrimpers) amounts to 1,145 kJ or to 418,000 kJ/year. A total of 60,000 birds may potentially have been supported by the discards of the fleet off Niedersachsen in 1993.

In the south-eastern North Sea shrimp fishery, consumption rates by mass were applied to the estimated discard quantities. A total consumption of 27,000 tonnes of all discard categories were calculated. The most important scavenger species were herring gulls which took 55% of all consumed discards, and black-headed gulls (39%). The other species were of minor importance. Using standardised energy content of the different discard categories (Walter and Becker, in prep) the total amount consumed by seabirds represents an energy value of 1.22 x 10^{14}J. This amount of energy is sufficient to support a potential number of about 340,000 birds (Table 2.4.1).

Table 2.4.1. Total numbers of seabird that could theoretically be supported by discards and offal in the North Sea (offshore fisheries: from Garthe *et al.*, 1996; shrimp fisheries: Walther and Becker, in prep.).

	offshore fisheries	shrimp fisheries
Fulmar	3,200,000	0
Gannet	210,000	0
Great skua	21,000	0
Black-headed gull	0	204,000
Common gull	84,000	7,000
Lesser black-backed gull	130,000	4,000
Herring gull	670,000	115,000
Great black-backed gull	250,000	0
Kittiwake	1,300,000	0
Common/arctic tern	0	9,000
Total	5,900,000	339,000

2.5 Direct effects of discard consumption on species composition of seabirds in the North Sea

2.5.1 Increase in population size of seabird species

About 30% of total food consumed by seabirds in the North Sea is estimated to be discards (including offal) (Tasker and Furness, 1996). These foods are therefore of direct importance in sustaining populations of some seabirds. Furness and 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, lesser sandeels *Ammodytes marinus*, were 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) (Table 2.5.1). Breeding success was much reduced in the absence of sandeels (Furness, 1987) and chick growth rate is considerably reduced when the proportion of discards in the diet is high (Table 2.5.2).

However, with the exception of these cases, there is limited 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 instance, Blaber *et al.* (1995) suspect 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. Blaber *et* *al.* (1995) also found that the diet of several species changed due to the supply by discards, which has occurred also in the North Sea (e.g. Hudson, 1986; Camphuysen, 1993; Walter and Becker, in prep.). Since fisheries are carried out throughout the study area and throughout the year, interrupted only locally during gales and storms, one is rarely able to demonstrate any effects of fishing activities on feeding ecology and reproductive output of discard consumers. This might be the reason for the weak link between studies showing the utilisation of discards at sea and studies focusing on possible effects of fishing activities.

The distribution of scavenging birds, both on land and at sea, is affected by the availability of discards. Fishing activity strongly enhanced the number of Audouin's gulls resting on the Columbrete Islands off east Spain (Castilla and Pérez, 1995), and herring and great black-backed gulls on Helgoland, south-eastern North Sea (Geiss, 1994; Hüppop, 1995).

The food provided by discards may be of importance particularly during periods of low natural food availability. There may therefore be positive effects on body condition, survival (including overwinter survival) of adult and sub-adult birds as well as on reproductive parameters such as the onset of laying, egg size, clutch size, chick growth, chick survival and breeding success. Discards may lower the costs of reproduction for adults, such that survival and the future reproductive potential might increase.

Table 2.5.1 Food items in pellets produced by non-breeding great skua on Foula between 1 and 15 July, for the years from 1973 to 1989 except 1985 (from Hamer *et al.*, 1991).

Year	n	sandeel (%)	whitefish (%) (mostly discard)	bird (%)	other (%)
1973	100	71	27	2	0
1974	100	24	71	5	0
1975	100	21	69	6	4
1976	100	72	26	2	0
1977	100	59	35	4	2
1978	100	64	35	1	0
1979	100	41	54	3	2
1980	100	17	74	6	3
1981	100	18	77	4	1
1982	100	13	80	3	4
1983	305	9	70	17	4
1984	100	0	74	23	3
1986	200	0	82	14	5
1987	98	9	77	10	4
1988	200	0	73	24	4
1989	247	4	62	30	4

Table 2.5.2 The relationship between an index of growth for skua chicks and the proportion of discards in their diet (data from Hamer *et al.*, 1991)

Year	% Discard	Chick growth index
1975	28	30
1976	14	-18
1977	14	0
1978	24	28
1979	24	26
1980	28	8
1981	6	-40
1982	5	15
1983	2	3
1984	33	4
1985	33	7
1986	30	5
1987	42	-44
1988	77	-129
1989	76	-62

Examples from the Mediterranean have documented various effects of the availability of discards and offal on breeding phenology, reproductive output, foraging range, diet, activity and behavioural interactions of Audouin's, yellow-legged and lesser black-backed gulls breeding on the Ebro Delta, north-east Spain (e.g., Arcos and Oro, 1996; Oro, 1995, 1996; Oro and Martinez-Vilalta, 1994; Oro *et al.*, 1995, 1996; Ruiz *et al.*, 1996).

During the late 1980s, many seabirds in Shetland failed to breed successfully due to low availability of sandeels. Only one kittiwake colony (Eshaness) fledged chicks successfully. This colony was mainly feeding on discards (Hamer *et al.*, 1993). Removal of fishing offal as a food source has been shown to be associated with lagged population declines in herring and great black-backed gulls in the Gulf of St. Lawrence, Canada (Howes and Montevecchi, 1992).

2.5.2 Population increase and changes in composition of seabird communities

There have been considerable changes in the breeding populations of seabird species in the North Sea during the past century. There have further been changes in species composition. While many species which consume discards have increased their populations, it is difficult to discriminate between the effects of discards and other factors such as enhanced bird protection and increased stocks of small fish. The populations of some species groups, such as the terns, which had been the most numerous species on the southern North Sea coasts in the beginning of the century, have decreased in size (e.g., Becker and Erdelen, 1987), which may be an indirect effect of the increase in gull numbers (see Section 2.6).

The numbers of most scavenging seabird species breeding in eastern Britain have increased markedly since at least 1900 (Table 2.5.3). In the southern North Sea, breeding numbers of offshore feeding seabirds such as kittiwakes and fulmars have shown strong population increases (e.g., kittiwakes: from a few pairs in the early 1950s to 7,460 pairs in 1995; Hüppop, 1995). Herring gull numbers increased in Germany from about 7,000 pairs in 1910 to 45,600 pairs in 1995 (Vauk *et al.*, 1989; Hälterlein and Südbeck, 1996). Herring gulls in the Netherlands increased from around 20,000 pairs in 1940 to 90,000 pairs in 1992 (Noordhuis and Spaans, 1992; Dijk and Meininger, 1995). Lesser black-backed gulls increased in the Netherlands from first breeding in the Wadden Sea in 1926 to 34,200 pairs in 1992 (Dijk and Meininger, 1995) with an additional 12,000 pairs in Germany in 1995 (Hälterlein and Südbeck, 1996). Black-headed gulls started to use the German Wadden Sea as breeding area during the 1940s. Today this gull is the most numerous seabird in the Wadden Sea (64,000 pairs in Germany in 1995; Hälterlein and Südbeck, 1996; 170,000 pairs in the Netherlands in 1992, including inland colonies; Dijk and Meininger, 1995).

Fisher (1953) and Tuck (1961) considered that the discards of factory trawlers on the Grand Bank of Newfoundland were responsible for the increase in fulmars and kittiwakes in the British Isles prior to the 1950s.

Table 2.5.3 Numbers of pairs of scavenging seabirds breeding on North Sea coasts (Furness, 1992).
a) Northeast Britain (Shetland, Orkney, Caithness to Cruden Bay)

Year	Fulmar	Gannet	Great skua	Lesser black-backed gull	Herring gull	Great black-backed gull	Kittiwake	All species
1900	600	3500	41	(3000)	(2000)	(1000)	(26000)	(37000)
1910	1760	3500	82	(2000)	(3000)	(1500)	(34000)	(46000)
1920	5200	3500	193	(1500)	(4000)	(2000)	(48000)	(64000)
1930	11600	3500	429	(1500)	(5000)	(3000)	(68000)	(93000)
1940	28200	8000	745	(1500)	(10000)	(4000)	(90000)	(142000)
1950	53000	8800	1350	(1500)	(20000)	(6000)	(120000)	(211000)
1960	66000	10000	2100	(1500)	40000	8000	160000	290000
1970	190000	14000	4000	1500	82000	9600	230000	531000
1980	280000	20000	6300	2500	43000	9900	210000	572000
1990	(350000	24000	7500	2500	40000	9900	180000	614000)

Table 2.5.3 b) East coast of Britain from Cruden Bay to the Humber

Year	Fulmar	Gannet	Lesser black-backed gull	Herring gull	Great black-backed gull	Kittiwake	All species
1900	0	2800	(2000?)	(400?)	(10?)	(9000)	(14000?)
1910	0	3000	-	(800)	-	(12000)	(18000?)
1920	20	3500	-	(1500)	-	(19000)	(26000?)
1930	200	4100	-	(3000)	-	(28000)	(37000?)
1940	600	4400	-	6000	-	38000	(50000)
1950	1200	4800	4000	12000	30	50000	72000
1960	2000	6800	4000	23000	30	65000	101000
1970	5800	8100	4240	45100	31	106000	169000
1980	10000	20000	5000	40000	20	200000	275000
1990	(14000	24000	5300	35000	20	210000	288000)

Herring and black-headed gulls are the main avian consumers of the discards of the shrimp fishery. In Denmark, herring gull numbers increased five years after the development of the Danish fisheries (Møller, 1981). From 1973 to 1982 both the landings of the German shrimp fishery and the discards produced by the shrimpers increased in parallel with the gull populations (Fig. 2.5.2). Thereafter the gull populations continued to grow despite lower shrimp landings; possibly the amount of fishing continued to increase, but the catch of marketable shrimps per unit effort decreased with a consequential increase in amounts of discards.

The increase in populations of discard-feeding seabirds around the North Sea has changed the balance of seabird communities towards these species. In the German Wadden Sea in 1951, the gulls (herring, lesser black-backed, common and black-headed) comprised 40% of the seabird community (44,300 pairs) and terns (common, arctic, Sandwich and little) the remaining 60%

(Becker and Erdelen, 1987). By 1995, gulls dominated the seabirds breeding community with 83 % of the total (155,000 pairs) (Hälterlein and Südbeck, 1996).

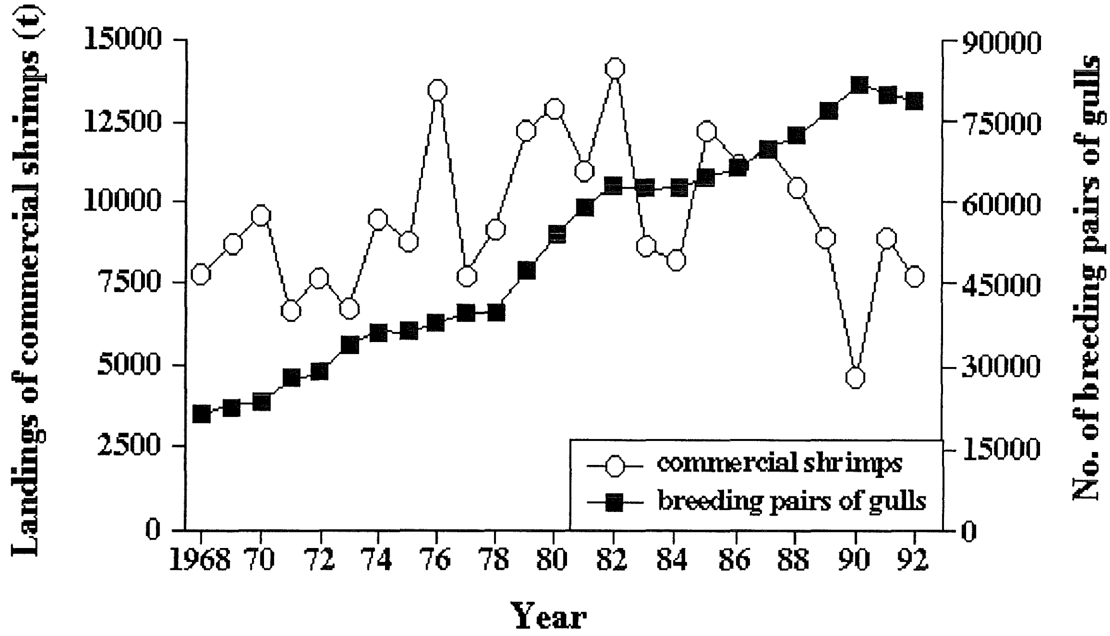

Figure 2.5.2 Development of the gull populations in 28 areas along the German North Sea coast (Becker and Erdelen, 1987, P.H. Becker, unpubl. data) and landings of edible shrimps of the fleets of Niedersachsen and Schleswig-Holstein (Tiews, 1983; Tiews and Wienbeck, 1990; Anon., 1990/94) between 1968-1992 (from Walter and Becker, 1996).

2.6 Indirect effects of discard consumption on species composition of seabirds in the North Sea

The increase in population size of gulls supported by discards may have negative effects of other species of sea- and shorebirds. This may happen through various mechanisms. Nesting gulls may physically displace other species by occupying their habitat. Larger predatory species may depredate smaller species taking eggs, young and adults (Regehr and Montevecchi, in prep.).

In the Wadden Sea the nesting habitat of shorebirds such as plovers and oystercatchers has been invaded by large gulls. Some breeding sites which are well suited for nesting by habitat or food availability may no longer be available for the terns because of the occupation by gulls earlier in the season. The Wadden Sea islands of Memmert and Mellum were important breeding sites for terns at the start of this century - nowadays more than 10,000 pairs of herring gulls and no terns breed on these islands (Becker and Erdelen, 1987). Howes and Montevecchi (1992) describe a similar situation off Canada.

Frequently, terns can only breed close to gulls, thus increasing the probability of predation. Common terns became re-established on Mellum at the end of the 1970s. This was not successful as herring gulls depredated most tern chicks which led to very low reproductive output for five years. Subsequently the colony site was abandoned (Becker, 1995). There are many other examples of reduced reproductive output of small seabird species caused by gulls feeding on eggs or chicks (e.g. Kruuk, 1964; Hatch, 1970; Montevecchi, 1977; Wanless, 1988; Hario, 1994; Thiel and Sommer, 1994; Russell and Montevecchi, 1996; Regehr and Montevecchi, in prep.).

In Shetland and Orkney, great skuas rely on discards and sandeels for most of their diet, but will switch to killing other seabirds if sandeels and discards are in short supply, threatening the viability of some seabird populations (Furness, 1997; Heubeck *et al.* in press).

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3 EXPLORATION OF THE SHORT- AND MEDIUM-TERM CONSEQUENCES OF A REDUCTION IN THE AMOUNTS OF FISH DISCARDED

3.1 Short term effects

3.1.1 Introduction

There are increasing pressures to further manage fisheries in order to make them sustainable, to reduce waste and to minimise collateral damage to the environment. A reduction in the levels of discarding seems almost inevitable through several possible policies. Two possibilities seem likely to occur in the near future, 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 may have different effects on scavengers (Furness, 1992; ICES, 1994; Hubold, 1994). Seasonal and longer-term fishery-closures are also likely to occur, as at present off Canada and Spain.

3.1.2 Loss of feeding opportunities

A general reduction in catch effort will probably lead to more competition for available discards and larger and stronger species would be more likely to benefit at the expense of the smaller, weaker species. In other words, kittiwake, other small gulls, great skuas and fulmars (Camphuysen *et al.*, 1995) would suffer, while gannets would be relatively unaffected.

An increase in mesh size does not necessarily increase the size of fish caught as fishermen may take counteracting measures (Reeves *et al.*, 1992). However, if the purpose of this potential measure was to be met, the proportion and amount of small-sized fish present in discards would decrease considerably. Furness (1992) calculated reductions in the mass of discarded whiting at 65%, while haddock discard would decrease by 52% if the mesh size increased from 90 to 120 mm in North Sea fishing fleets. This increase would principally reduce the small-sized discards (Furness, 1992). This would lead to a deterioration of feeding opportunities for the smaller gulls, such as black-headed and common gull and kittiwake which utilise the smallest discarded fish preferentially (Camphuysen *et al.*, 1993, 1995; Garthe and Hüppop, 1994).

Both measures could lead to reduced feeding opportunities for immature individuals since adults are generally more successful than immatures of the same species (Wunderle, 1992), particularly if immatures switch to less favourable lengths of discards (Garthe, 1993). Immatures, especially birds in their first year of life, could suffer from higher mortality.

3.1.3 Change in bird distribution

All those species utilising fishery waste can be assumed to be somewhat influenced by the distribution of fishing vessels. Tasker *et al.* (1987) found positive spatial correlations between many species including gulls, great skuas and fulmars and the presence of trawlers. However, there was substantial variability with respect to season and area. Camphuysen *et al.* (1995) found that great black-backed gulls, herring gulls and lesser black-backed gulls (in summer) were the only species which were clearly positively influenced by the presence of fishing vessels. There was no evidence of large-scale spatial correlations between trawlers and fulmars (Camphuysen *et al.*, 1995; Camphuysen and Garthe, in prep.)

Based on the above results, it is possible to speculate that the distribution of large gulls would be most affected by a change in fisheries effort whereas that of other species, such as gannet, would be less affected.

3.1.4 Competition at trawlers

Discharges of fishery waste from fishing vessels attract scavenging seabirds which compete for preferred items. For several species of seabirds, the preferred size and/or type of the discarded items overlaps and because the numbers of ship-followers are often high, competition for scraps is often intense. In the competition for the food resources provided by fishing boats some seabirds are more successful than others as shown by several studies (e.g., Hudson and Furness, 1989; Camphuysen *et al.*, 1995). Different species employ different strategies for obtaining discards and offal (e.g., Dändliker and Mülhauser, 1988; Hudson and Furness, 1989; Camphuysen, 1993; Walther and Becker, 1994; Camphuysen *et al.*, 1995). Small species, such as kittiwake, have to catch and swallow prey items rapidly to avoid interactions with other, physically stronger species. If these small species do not succeed with this strategy they will often lose their prey to larger, more aggressive, species.

Gannets and great black-backed gulls are least vulnerable to kleptoparasitism. For these high-ranking species, kleptoparasitism is an effective strategy for obtaining food. Large such as gannet, great black-backed gull and great skua, are virtually absent during spring and summer in the eastern and southern North Sea. Smaller species such as fulmar and kittiwake do better when robbing others in these regions and seasons. A reduction in total quantities of discards produced and discharged in commercial fisheries will probably lead to a higher frequency of kleptoparasitic interactions. The implication of these size-based dominance hierarchies is that small species, such as kittiwake, other small gulls and fulmar will suffer the most.

3.1.5 Changing diets

A reduction in the availability of, and increase in mean size of, discards will lead to a switch in foraging methods and diets in gulls. During the breeding season, herring gulls would change their feeding areas and habits and exploit food of lower energetic quality such as eggs and chicks of its own and other species (Regehr and Montevecchi, in prep.; Bukacski *et al.*, unpub.). Interactions between Audouin's and yellow-legged gulls at the colony site increase during periods with no fishing activity (Gonzalez-Solis, 1996). High densities of breeders and low food supply increases cannibalism among gulls (Parsons, 1971, 1976; Spaans *et al.*, 1987; Kilpi, 1989).

Investigations of a kittiwake colony on Great Island, Newfoundland revealed complex relationships (Regehr and Montevecchi, in prep.). A four-week delay in the inshore arrival of spawning capelin and a lack of fishery waste due to the closure of the ground fishing industry in eastern Newfoundland apparently led to food shortages in herring gulls and great black-backed gulls. These species were forced to switch to other prey, including depredation of the eggs and chicks of kittiwakes. The low availability of capelin (also an important food of kittiwakes) and the high predation pressure by herring and great black-backed gulls led to delayed breeding and led to extremely low breeding success. They showed that kittiwake reproductive success was a consequence of indirect and interactive effects of food supplies on both parents and predators.

Intra- and interspecific kleptoparasitic feeding may increase at colonies owing to reductions in the availability of discards. In windy conditions black-headed gulls steal more sandeels from Sandwich terns than during calm weather when their intertidal foraging is more successful (Gorke, 1990). In addition, kleptoparasitism increases at high tide, when foraging sites are flooded (Veen, 1977). Growth rates of tern chicks will be reduced, and the breeding success lowered in kleptoparasitised species.

3.1.6 Reproduction

Noordhuis and Spaans (1992) showed that as herring gulls changed diet and obtained fewer discards, there was a decrease in breeding success and numbers. Some examples of the dependence of seabirds on fisheries originate from the Mediterranean. Paterson *et al.* (1982) describe severely reduced breeding success in two Spanish colonies of Audouin's gulls in 1991 that resulted from a fisheries moratorium (to preserve fish stocks) during the gull's breeding season. Oro (1996) and Oro *et al.* (1995, 1996) demonstrated that the breeding success of Audouin's, yellow-legged and lesser black-backed gulls differed significantly between years with different trawling activity at the Ebro Delta, north-east Spain. The three species of gulls compensated partly for the cessation in food supply (discards) after a trawl moratorium took place by switching to other types of food. Other parameters of breeding and behaviour were affected by the availability of fishery waste.

A long-term large-scale fishery moratorium in eastern Canada has been associated with increased predatory pressure by great black-backed gulls on kittiwakes and Atlantic puffins, which has in turn reduced breeding success (Russel and Montevecchi, 1996; Regehr and Montevecchi, in prep.).

In summary, if food supply is reduced, reproduction can be impaired in several ways. The numbers of non-breeders can increase, the onset of laying can be delayed, clutch size and egg size can decrease, and hatching success, growth rate, fledging success and recruitment can will be reduced (e.g., Pons, 1992). The weakened condition of adults can lead to higher mortality and lowered reproductive ability. Mortality of adult gulls, which is highest during August after the breeding season (Coulson *et al.*, 1983), may increase due to lowered adult condition caused by the lack of food from fisheries.

3.2 Medium term effects

3.2.1 Introduction

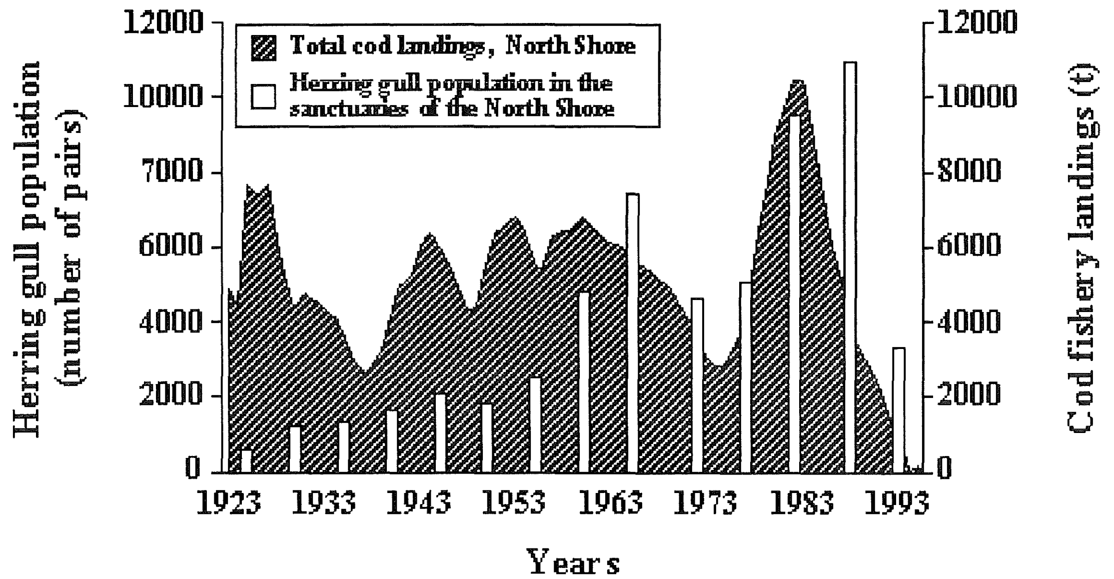
All effects listed above as short-term will tend to continue into the medium and long-term if quantities of waste discarded remain at a relatively low level. Several further medium-term effects might be expected.

3.2.2 Population size of consumer species

Short-term reductions of reproductive success and survival of the scavenging species owing to a discard reduction will over time result in population decreases if alternative foods are not available. The capacity of the environment enhanced by the anthropogenic food sources at sea will be lowered to more natural levels, and the numbers of seabirds using discards and offal will decline. But as gulls are opportunistic feeders, individuals will respond by changing their scavenging diet to other food sources, especially more terrestrial prey and garbage (Gonzalez-Solis, 1996) and may increase predation pressure on smaller seabird species. Despite this shift, however, competition between individuals could be stronger, so that populations may be reduced anyway.

As an example, on the North Shore of the Gulf of St. Lawrence the herring gull population decreased from 14,000 pairs in 1988 to 3,000 pairs in 1993 (Figure 3.2.1), corresponding with a moratorium on cod fishing (Chapdelaine and Rail, in prep.). While kittiwakes are considered to be a scavenging species, they could compensate the lack of discard provisioning because depredation by gulls will be less as gull populations decrease (Howes and Montevecchi, 1992). In turn the breeding success of smaller species should improve (Regehr and Montevecchi, in prep.).

Furness (1992) estimated a reduction of scavenging seabirds in Scotland by 500,000 individuals if the demersal trawl mesh size were to be increased from 90 to 120 cm or if fishery effort was reduced by 30%.



From Chapdelaine and Rail, 1997

Figure 3.2.1. Herring gull breeding numbers in sanctuaries on the North Shore of the Gulf of St. Lawrence in relation to total landings of cod (assumed to provide an index of the quantities of

offal and discards made available to seabirds) on the North Shore (from Chapdelaine and Rail, in press).

3.2.3 Population size and species composition

During the first years of discard reductions, those species preyed upon by the larger predatory and scavenging species are likely to experience a population decline. This could be through direct predation, or indirectly through reduced reproductive output due to predation of chicks and eggs. However, should the populations of the larger predatory species also decline, there might be some longer term recovery of the smaller species. The competition for nesting sites will be less. In consequence the quality of breeding sites for those species might improve, and areas abandoned will be resettled. Terns, for example, can reoccupy their former breeding sites and populations can recover in the longer term. Overall, in the absence of other influences, population sizes are likely to settle to different equilibria than previously.

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4 A REVIEW OF THE CAUSES, AND CONSEQUENCES AT THE POPULATION LEVEL, OF MASS MORTALITIES OF SEABIRDS

4.1 Introduction

Of the millions of seabirds that die of natural causes each year only a small proportion come ashore. However, public attention and concern is often drawn to the frequent large strandings of dead or moribund birds washed up on beaches. These "wrecks" may reflect mass mortalities of seabirds at sea, but are in fact defined as any much larger than usual concentration of seabird corpses washed ashore over a short period. The definition must be applied relative to the population sizes (perhaps considering only that part of the population within a local area from which the wrecked birds probably originate) of the species involved since 'large' numbers of an uncommon species may qualify as a wreck whereas 'large' numbers of a very common species might not. There is rarely any indication from the size of wrecks of the total mortality of birds at sea. Mass mortalities that do not result in wrecks are, by their very nature, difficult to study. The numbers and even species of bird involved may only be ascertained by the subsequent effect on the size of breeding populations. However, wrecks of seabirds are recorded sufficiently frequently to enable some, usually qualitative, consideration of their likely causes, seasonality and possible effects on population levels. This section reviews the major causes of seabird wrecks, their seasonal occurrence and the relative vulnerability of various species to different causal agents.

4.2 Presumed causes

Wrecks can be explained by several factors. These include those related to weather (for example storms, calm conditions, severe cold) food, pollution (for example oil spills, chronic oil pollution, chemical polllution), fishing activities (for example bycatch) and parasites. The most frequent causes are those due to storms, oil, severe cold weather, and food. Other, less important but perhaps widely implicated are chemical pollution, toxins, calm weather, diseases and parasites. In many cases wrecks cannot be identified as being due to one single cause. For example, adverse weather conditions may affect foraging behaviour and success and may be indirectly responsible for a wreck of emaciated birds. However, in the following treatment we distinguish between the above categories and food related causes *per se*.

Storm-related wrecks are those in which mortality has been linked with birds being blown away from favoured feeding areas or being prevented from feeding by wind. Calm weather in summer has been associated with wrecks of fulmars (Anon, 1982; Camphuysen, 1989c), possibly as a result of increased energetic costs associated with flapping flight in these birds adapted for gliding in the wind (Furness and Bryant, 1996).Oil-related wrecks may be divided into those related to major oil pollution incidents or to chronic oil pollution. Effects on birds of both types tend to be physical, disabling the birds through plumage saturation and also physiological via general toxic effects of the oil. The major oil incidents stand out because the events engender public awareness (major ship-wreck, blow-out), from which stranded birds are easily detected. Chronic oil pollution is a constant process, a more severe threat to seabirds because of a mosaic of larger and smaller oil slicks which reduces the quality of the (wintering) areas where seabirds live, most notably around busy shipping lanes and near larger harbours. Oil-related wrecks are relatively well studied, because the effects of oil pollution on seabirds has attracted attention of the ornithological community since the end of the 19th century (Bourne, 1969; Camphuysen, 1989c). Beached bird surveys are an appropriate method to identify trends in oil contamination of stranded birds, but not (necessarily) to identify trends in mortality patterns of seabirds (Heldt, 1969; Joensen, 1972; Kuyken, 1978; Vauk, 1978; Becker and Schuster, 1980; Commecy, 1982; Stowe, 1982; Heubeck, 1987; Vauk *et al.*, 1990, 1991; Camphuysen and van Franeker, 1992; Camphuysen, 1995b; Heubeck, 1995). Not fully represented in Appendix 1, are enormous lists of smaller and larger scale oil-related wrecks which have been published in association with accounts dealing with marine oil pollution (Bourne, 1969; Vermeer and Vermeer, 1974; Stowe and Underwood, 1984; Hooper *et al.*, 1987; Camphuysen, 1989c; Camphuysen and van Franeker, 1992; Camphuysen, 1995b).

Food-related wrecks are those where mortality results from starvation due to the birds' not being able to forage successfully - either through low food availability or abundance. For example, seabird mass strandings (and also large scale fluctuations in wintering distribution of seabirds) may be indicative of changes in prey stock abundance, distribution or availability. In the early 1980s, a major south and eastward shift in the wintering distribution of common guillemots, kittiwakes and razorbills occurred in the North Sea. This was consistent with a decline in sprat availability in the northern North Sea (Anon, 1986), sprats being a major prey species of these birds in winter. The change in the pattern of sprat distribution together with poor weather was implicated in a wreck of auks along the east coast of Britain in February 1983 (Blake, 1984), and multiple wrecks in the southern North Sea (Camphuysen, 1981, 1989b, 1990a,b,c,d, 1992, 1995a,b; Camphuysen and Keijl, 1994).

The rapid decline in Barent Sea capelin during the 1980s provides an even more dramatic example of a food shortage induced wreck. Thousands of emaciated common guillemots were washed ashore along the coasts of Finnmark during the winter 1986/87, and breeding populations in the Barents Sea collapsed, coincident with the decline of this important prey (Vader *et al.*, 1987).

Due to the common utilisation of many small fish species by seabirds and fisheries, fishing has often been alleged to be a contributory factor in wrecks of emaciated birds. For example, concern was expressed that the sandeel fishery off the east coast of Scotland may have been involved in the large wreck of auks and shags along the east coast of British in February, 1994. The wreck occurred over a far more extensive region than the area where the fishery operated, but it is typical of wrecks that seabirds affected disperse beyond their normal distribution. There are inadequate data to attribute a cause to this particular wreck. Wrecks due to bycatch in fishing nets of various sorts (set nets, gill nets) are locally important.

Other, apparently less common causes of seabird wrecks include mortality due to natural toxins (for example botulism, red tides, paralytic shellfish poisoning). Botulism may hit coastal seabirds that utilize freshwater bodies for drinking or bathing in summer, but as yet there is little evidence that this is a major problems for seabirds. Epizootics, involving e.g. Noctiluca in red-tides have been reported to kill a variety of seabirds (Coulson *et al.*, 1968; Armstrong *et al.,* 1968; Wrånes, 1988). Toxins inducing paralytic shellfish poisoning are known to affect gulls in the USA that take contaminated shellfish (Kvitek, 1991) and there are suggestions that such poisoning might be responsible for recent die-offs of common guillemots in the Baltic (Hario, 1994). In the light of the transport of biota in ballast water of ships, or willing introductions of foreign species of shellfish into European waters, this problem will remain of interest.

Occasionally, other less common factors may cause wrecks. For example, the production of an oily substance by a plankton bloom in the southern German Bight in spring 1996 resulted in strandings of red-throated divers, due to plumage contamination (Camphuysen, 1996c).

4.3 Frequency and seasonal occurrence of wrecks

During the first session of the wrecks sub-group, a first attempt to produce an inventory of wrecks was made. This inventory was meant to identify major patterns in these wrecks, supporting a more guided discussion in future meetings. A first literature search led to identification of over 100 wrecks, or events, in European waters, and a very incomplete list of events elsewhere in the world. Wrecks were roughly classified as:

- pollution related wrecks (oil, chemicals, netting, ...)
- weather related wrecks (storm, calm or cold weather, ...)
- food related wrecks (post-fledging, starvation, ...)
- other types

It needs emphasizing that the effect of severe winters on marine and estuarine birds is not fully addressed here, although it is an important factor behind mass mortality. Several case studies indicated that, indeed, very large numbers of seabirds suffer from cold stress and starvation in association with severe winter weather (Crisp, 1964; Schoennagel, 1980; van Gompel, 1987; Meininger *et al.*, 1991; Suter and van Eerden, 1992; Beukema, 1994; Camphuysen *et al.*, 1996). Yet, the literature search in this area needs further attention.

Wrecks, as described earlier, were identified in the first place through stranded birds and influxes of birds in areas where they do not normally occur in large numbers. Some of these birds showed clear signs which pointed in the direction of what had caused the event (oil, starvation, ...). However, particular the mass mortalities as a result from drowning and entanglements in fishing gear are easily overlooked if the corpus delicti was not found (i.e. the net in which the birds had drowned. In the literature, or rather before the stage on which things get written up, there is considerable speculation as to why such birds had died (good condition, non-oiled, no adverse weather, but still dead in large numbers). Although such events were possibly caused by netting incidents, such as fishermen throwing out of their nets all the birds which had drowned, in such cases a firm conclusion as to the cause cannot be reached. While we are aware of several areas in which potential 'conflicts' between seabirds and fishermen in terms of unwanted bycatch of birds exist, there is very little factual evidence available, and several wrecks in such areas may have been mis-interpreted.

It is important to stress that an analysis of wrecks such as this is inherently biased towards scarce species, and in other words to relatively rare events. Strandings of very common birds are often taken for granted and will not become subject of further study or be published in the ornithological literature. As a result, a thorough literature search will lead to a relatively complete picture of little auk wrecks (Camphuysen & Leopold, 1996; Stenhouse & Montevecchi, 1996), but a very incomplete idea of e.g. post-fledging mortality in herring gulls. Phalarope strandings will be reported even if only very few individuals were found, whereas common guillemot strandings get noticed only when many hundreds wash ashore over short lengths of coast.

A conclusion which might be drawn is that some (causes of) wrecks get more attention than others because the underlying factors are more obvious. In the absence of adequate data relating to the underlying factors of most (reported) mass-strandings of seabirds, this first analysis should only be considered as a first attempt to discuss wrecks. A method needs to be developed following which the literature will have to be searched again and following which the events can be lifted out, categorized into different types, analysed as to frequency of occurrence and (un-certainties with respect to underlying factors, leading to firm conclusions as to which species are more vulnerable to others and as to what type of wrecks.

A final aspect which needs to be addressed before the frequency of wrecks is discussed is the possible overlap of cause of wrecks, or the accumulating effect of a number of factors which lead to mass mortality. Where we refer to storm-driven or food-related wrecks, starvation of the birds found dead is a key point, while strong winds were more obvious in the first type. It is easy to understand that while wind may have been an important factor in reducing the availability of food for certain species, a wind-driven event may be also food-related. It has been suggested that starving birds are more susceptible to the effects of oil pollution, while netting as a factor behind mass mortality of auks in the Skaggerak region had increased after a displacement of wintering auks due to poor feeding conditions in their more usual wintering areas (Peterz and Olden, 1987).

From our first analysis, oil-related and storm driven wrecks occur very frequently. A preliminary analysis resulted in 30 events of the former type and 41 of the latter, while the list which is compiled only took into account major events (Appendix 4.1). On the scale of the north-east Atlantic, both types of wrecks occur probably annually, but many have a rather local or regional character. Oil-related wrecks include those caused by shipping accidents and blow-outs, but very many more small wrecks occur as a result of chronic oil pollution due to deliberate, operational discharges of oil (see that section). Storm-driven events overlap with 17 wrecks that were temporarily labelled as 'food-related', because both types comprise stranded birds that are seriously emaciated and apparently died as a result of starvation (see above). Fewer wrecks appeared to have been related to bycatch of seabirds in fishing nets (7), parasites (3), chemical pollution (2), exceptionally calm weather (2), plankton bloom (1). Not very well addressed so far were wrecks which occurred in severe winter weather (now only 4 events listed), which is in fact a common type under coastal and estuarine species, or the post-fledging mass mortalities (now one event). Post-fledging wrecks can only be studied after having set clear criteria from which 'wrecks' (as unusually large numbers of birds which died) may be separated from the background noise.

Wrecks did not occur evenly over the year, and different types of wrecks appeared associated with different seasons (Tables 4.1, 4.2). Obviously, post-fledging wrecks of young birds and wrecks due to cold-stress occurred in one season only, being summer and winter respectively. Food-related and storm-driven wrecks were basically an autumn and winter phenomenon. Oil-related wrecks occurred through the year, but incidents due to chronic oil pollution were concentrated in the winter half year (Bourne, 1969; Stowe and Underwood, 1984; Camphuysen, 1989c). An overall conclusion of a first inventory of wrecks is, that the types of mass-mortality events which are considered here occur seldom in summer, and most frequently in autumn and winter.

Table 4.1 Frequency distribution of different types of North Atlantic wrecks in different seasons (see Appendix 4.1 for a review of wrecks)

Category	type	spring	summer	autumn	winter	Totals
Pollution	oil	9	1	5	15	30
	chemicals				2	2
	bycatch				7	7
	plankton	1				1
Weather	storm			24	17	41
	cold				4	4
	calm	1	1			2
	winddrift				1	1
Food	food'adults'		1	2	14	17
	post-fledging		1			1
Other	parasites		2		1	3
	unknown	2	1	1		4
Totals		13	7	32	61	113

Little auk wrecks and influxes, which were studied in considerable detail, occurred rather frquently, but not randomly during the last odd 150 years (Camphuysen & Leopold, 1996). In Europe, over 60 influxes/wrecks were recorded since 1840, but these events appeared to occur in clusters (Runs test, t_s= -2.30, n_1= 62, n_2= 94, $P< 0.05$). A detailed analysis of the most recent influxes demonstrated that the events were in fact related to major shifts in wintering distribution of little auks. Hence, wrecks may occur if the North Sea is used as a wintering area and not, or not be recorded, when the birds were wintering elsewhere. These wrecks were often wind-related, and stormy weather was usually suggested to have actually caused the wreck by preventing the birds from feeding, but several little auk influxes took place under calm conditions.

Table 4.2 Frequency distribution of wrecks in the North Atlantic for different groups and species of birds (see Appendix 1 for a review of the wrecks; review papers and non-European wrecks were excluded for this analysis)

Species/group	spring	summer	autumn	winter	Totals
divers	1		1	2	4
grebes	1			2	3
storm petrels			7	1	8
shearwaters		1	1		2
Fulmar	4	2	2	3	11
Gannet	1		1	2	4
cormorants	1		1	5	7
seaduck	5	3	1	16	25
phalaropes			1		1
smaller skuas			7		7
Great Skua					0
Larus-gulls	2	1	1	5	9
Sabine's Gull			1		1
Kittiwake	2	4	2	7	15

Species/group	spring	summer	autumn	winter	Totals
terns	1	1			2
Common guillemot	4	1	5	24	34
Brunnich's Guillemot				2	2
Razorbill	1	1	2	17	21
Puffin	1		1	8	10
Little Auk			9	11	20
Black Guillemot	1			3	4

4.4 Vulnerability of seabird species to wrecks

Most species of seabird are subject to wrecking (Tables 4.2, 4.3) but some are more vulnerable than others. For example, auks tend to be wrecked more often than Procellariiformes while grebes are rarely wrecked. Of course there is variation in the degree to which different species and groups of species are vulnerable to different types of wreck, their preferred food (fish/plankton) being one component of this vulnerability.

Of course, species do have different vulnerabilities towards the different causes of wrecks (Table 4.3). Birds spending long time swimming such as divers, grebes, duck and auks are especially vulnerable towards oil pollution (Stowe, 1982; Averbeck *et al.*, 1993; Camphuysen, 1989c, 1995, 1996c), whereas small species flying a lot may be wrecked as a consequence of severe storms, e.g. storm petrels, fulmar, kittiwake, little auk (Pashby and Cudworth, 1969; Threlfall *et al.*, 1974; Doumeret, 1979, 1980; Nakamura, 1983; Teixeira, 1987; Camphuysen & Leopold, 1996). On the other hand, the energy expenditure of fulmars at sea increases with decreasing wind speed (Bryant & Furness, 1996), hence they may run into energetic bottlenecks during periods of calm weather which may end in a wreck. Diving birds are especially vulnerable to entanglement and drowning in fishing gear (Brewka *et al.*, 1978, 1985, 1989; Barrett and Vader, 1984; van Eerden and Bij de Vaate, 1984; Peterz and Olden, 1987; Kies and Tomek, 1990; Hüppop, 1996).

Table 4.3 Frequency distribution of different types of wrecks in the North Atlantic for different groups and species of birds (see Appendix 4.1 for a review of the wrecks; review papers and non-European wrecks were excluded for this analysis)

Species/group	oil	storm	food	other	Totals
divers	4				4
grebes	3				3
storm petrels		8			8
shearwaters		1	1		2
Fulmar	4	2		5	11
Gannet	2	1		1	4
cormorants	4		2	1	7
seaduck	15		2	8	25
phalaropes		1			1
smaller skuas		6	1		7
Great Skua					0
Larus-gulls	5	2	1	1	9
Sabine's Gull		1			1
Kittiwake	5	6	1	3	15

Species/group	oil	storm	food	other	Totals
terns	1		1		2
Common guillemot	17	1	10	7	35
Brunnich's Guillemot	2				2
Razorbill	9	1	7	5	22
Puffin	5	1	4		10
Little Auk	4	12	3		19
Black Guillemot	4				4

4.5 Consequences to populations

Possible consequences of wrecks are hard to detect. Further, the number of birds wrecked is not a good indicator of the true number of birds affected. As has been shown, wrecks often happen outside the breeding season. This means that birds from different populations and colonies may occur together. Consequently, due to the large numbers of most seabird species, severe effects affecting populations or even on single colonies are rare. With regards to oil contamination, there is no evidence that chronic pollution has had a long-term effect on populations. Major effects of wrecks caused by oil contamination could be detected only after a small proportion of major oil spills and only at the colony level. Examples are only a few big accidents near the breeding season and close to the breeding colonies, such as the wreckages of the Torrey Canyon (Land's End), Amoco Cadiz (Brittany), Sea Empress (Wales), Braer (Shetland), and Exxon Valdez (Alaska) (Bourne *et al.*, 1967; Bourne, 1970; Jones *et al.*, 1978; Anon, 1993; Heubeck *et al.*, 1995; Paine *et al.*, 1996).

However, there are cases where effects at a population level have been detected following a wreck. For example, severe and long lasting effects were observed during and following a period of pollution involving chlorinated hydrocarbon insecticides in the Wadden Sea. Sandwich terns and common eiders were the most affected birds although declines in populations of all coastal birds of the Wadden Sea were recorded (Koeman *et al.*, 1968, 1969, 1972; Swennen, 1972). The Sandwich tern colony at Vlieland collapsed from 20,000 pairs to less than 1,000 pairs within a few years. At the main eider colony on the island of Vlieland numbers of breeding females dropped from c. 4000 to 800 pairs (Swennen 1972, Furness & Camphuysen, in press).

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Appendix 4.1. List of wrecks. Shown are a rough indication of the locality (loc) including Europe (Eur), North Atlantic USA (NAA), or elsewhere (Oth), authors, year of publication, type of wreck (*e.g.* storm, oil incident, severe winter, food shortage), region of occurrence, season and species.

No	Loc	Author	Year	Wreck	Region	Season	Species
1	Eur	Andersen	1996	storm	Scandinavia	autumn	auks
2	Eur	Anker-Nilssen ea	1988	oil	Skagerrak	winter	auks
3	Eur	Anker-Nilssen & Ro/stad	1983	oil	Norway	autumn	guillemot
4	Eur	Anomymous	1976	storm?	UK-east	winter	auks
5	Eur	Anomymous	1982	calm	Netherlands	spring	fulmars
6	Eur	Anonymous	1912	storm	UK	autumn	auks
7	Eur	Anonymous	1979	oil	Spain-AT	winter	
8	Eur	Anonymous	1985	food	Netherlands	winter	auks
9	Eur	Barrett	1979	oil	Norway		auks
10	Eur	Barrett	1982	oil	Norway-north		auks
11	Eur	Bibby & Bourne	1971	bycatch	UK?	winter	auks
12	Eur	Bodenstein	1956	storm	G-Bight	winter	kittiwake
13	Eur	Bourne	1979	oil	Norway	winter	seaduck,auks
14	Eur	Bourne	1990	food	UK-northeast	winter	auks
15	Eur	Boyd	1954	storm	Europe	autumn	storm petrels
16	Eur	Brewka ea	1978	bycatch	Poland	winter	seaduck, auks
17	Eur	Byrkjeland	1989	oil	Norway		auks
18	Eur	Campbell ea	1978	oil	UK-east	winter	grebes
19	Eur	Camphuysen	1989b	food	Netherlands	winter	auks
20	Eur	Camhuysen	1990b	oil	Netherlands	spring	auks
21	Eur	Camphuysen	1996b	food	Netherlands	autumn	auks
22	Eur	Camphuysen	1987	calm	Netherlands	summer	fulmars
23	Eur	Camphuysen	1989	postfiled	North Sea	summer	kittiwake
24	Eur	Camphuysen	1990	food	Netherlands	winter	auks
25	Eur	Camphuysen	1995	oil	Netherlands	autumn	auks
26	Eur	Camphuysen	1996	food	Netherlands	winter	seaduck
27	Eur	Camphuysen ea	1988	oil	Netherlands	winter	grebes, auks
28	Eur	Camphuysen & Derks	1989	cold	Netherlands	winter	grebes
29	Eur	Camphuysen & Keijl	1990	oil	Netherlands	autumn	auks
30	Eur	Camphuysen & Leopold	1996	storm	Europe-63	aut/winter	auks
31	Eur	Camphuysen & van IJzendoorn	1988	food	Europe	autumn	skuas
32	Eur	Clarke	1895	storm	UK-northeast		auks
33	Eur	Cobb	1976	bycatch	UK?	winter	divers, auks
34	Eur	Craik	1992	food	UK-west	summer	mixture
35	Eur	Debout	1982	storm	France-Atl	winter	mixture
36	Eur	Doumeret	79 / 80	storm	France-Atl	autumn	procellariif
37	Eur	Dreckhahn	1969	oil	G-Bight	autumn	seaduck
38	Eur	Durinck ea	1993	bycatch	Denmark	winter	seaduck
39	Eur	Eber	1958	storm	G-Bight	winter	gulls
40	Eur	Engelen	1987	oil	Wadden	winter	seaduck
41	Eur	Evans	1892	storm	UK-north	autumn	storm petrels
42	Eur	Furphy ea	1971	?	Irish Sea	autumn	auks
43	Eur	Furtado & LeGrant	1979	storm	Azores	winter	auks
44	Eur	Geroudet	1991	food	Europe		seaduck
45	Eur	Gill ea	1967	oil	UK-southwest		mixture
46	Eur	Greenwood ea	1971	oil	UK-northeast	winter	auks
47	Eur	Grenquist	1970	parasite	Finland	winter	seaduck
48	Eur	Haila	1970	oil	Finland		seaduck
49	Eur	Hanssen	1982	oil	Baltic		seaduck
50	Eur	Harris ea	1991	food	Shetland	winter	auks
51	Eur	Harris & Wanless	1996	food	UK-east	winter	cormoran, auks
52	Eur	Haverschmidt	1930	storm	Netherlands	winter	auks
53	Eur	Hesse	1912	storm	G-Bight	autumn	skuas
54	Eur	Heubeck	1991	food	Shetland	winter	auks
55	Eur	Heubeck	1994	oil	Shetland	winter	mixture
56	Eur	Heubeck & Richardson	1980	oil	Shetland	winter	mixture

No	Loc	Author	Year	Wreck	Region	Season	Species
57	Eur	Heubeck & Suyddaby	1991	food	Shetland	winter	auks
58	Eur	Holdgate	1971	food	Irish Sea		auks
59	Eur	Huppop	unpub	post-fl	Helgoland	summer	kittiwake
60	Eur	Joensen	1961	?	Denmark		fulmars
61	Eur	Jones ea	1970	oil	Irish Sea	spring	auks
62	Eur	Jones ea	1978	oil	Channel	spring	mixture
63	Eur	Kennedy ea	1954	storm	Ireland	autumn	skuas
64	Eur	Kies & Tomek	1990	bycatch	Poland	winter	grebe, duck, auks
65	Eur	Larsson	1960	?	Sweden	spring	fulmars
66	Eur	Leopold ea	1986	cold	Netherlands	winter	seaduck
67	Eur	Leopold & Camphuysen	1992	oil	Netherlands	winter	fulma, gann, auks
68	Eur	Lloyd ea	1974	food	Irish Sea	winter	mixture
69	Eur	Lonnberg	1927	storm	Sweden		kittiwake
70	Eur	Louzis ea	1984	storm	Channel	winter	kittiwake
71	Eur	MacPherson	1892	storm	UK	autumn	storm petrels
72	Eur	Mathiasson	1963	?	Sweden	spring	fulmars
73	Eur	McCartan	1957	storm	UK	winter	kittiwake
74	Eur	Mead	1974	storm	Irish Sea		
75	Eur	Meek	1985	oil	Orkney		seaduck
76	Eur	Mehlum	1980	oil	North Sea		fulm, gulls, auks
77	Eur	Meininger ea	1991	cold	Netherlands	winter	grebes, seaduck
78	Eur	Mudge ea	1992	food	UK-northeast	inc-4	
79	Eur	Nelsen	1880	storm	UK	autumn	skuas
80	Eur	Nelson	1911	storm	UK-east	autumn	skuas, sabigull
81	Eur	Olden ea	1986	bycatch	Sweden	winter	auks
82	Eur	O'Donovan & Regan	1950	storm	Ireland-west	autumn	auks
83	Eur	Parrack	1966	oil	UK-northeast	winter	auks
84	Eur	Partridge	1993	oil	Channel	winter	auks
85	Eur	Pashby & Cudworth	1969	storm	North Sea	winter	fulmars
86	Eur	Poulsen	1957	storm	Denmark	aut/win	auks
87	Eur	Proger & Paterson	1913	storm	UK-west	winter	auks
88	Eur	Rittinghaus	1978	oil	G-Bight	spring	seaduck, terns
89	Eur	Robinson	1909	storm	Irish Sea	autumn	storm petrels
90	Eur	Sage	1979	oil	Shetland		seaduck
91	Eur	Sage & King	1959	storm?	UK	autumn	storm petrels
92	Eur	Selkopf	1955	storm	G-Bight	winter	gulls
93	Eur	Sergeant	1952	storm	UK	aut/winter	auks
94	Eur	Soikkeli & Virtanen	1972	oil	Finland		seaduck
95	Eur	Swann & Butterfield	1996	food?	UK-northeast	winter	auks
96	Eur	Swennen & Smit	1991	parasite	Netherlands	summer	seaduck
97	Eur	Swennen & Spaans	1970	oil	G-Bight	winter	seaduck, auks
98	Eur	Swennen & van den Broek	1960	parasite	Netherlands	summer	seaduck
99	Eur	Tasker	1994	wind	UK-east	winter	mixture
100	Eur	Teixeira	1985b	storm	Portugal	winter	storm petrels
101	Eur	Teixeira	1985	bycatch	Portugal	winter	auks
102	Eur	Teixeira	1987	storm	Portugal	autumn	storm petrels
103	Eur	Underwood & Stowe	1984	food	UK-east	winter	auks
104	Eur	Van der Ham	1989	storm	Netherlands	autumn	skuas
105	Eur	van der Ham ea	1991	storm	Netherlands	winter	auks
106	Eur	Wheeler	1990	storm	North Sea	autumn	auks
107	Eur	Witherby	1912	storm	UK-east	autumn	auks
108	Eur	Wranes	1988	cold?	Norway	winter	seaduck
109	Eur	Wynne-Edwards	1953	storm	UK-north	autumn	storm petrels
110	Eur	Wynne-Edwards	1963	storm	UK-east	autumn	skuas
111	Eur	Zoun	1991	chemical	Netherlands	winter	gannets, auks
112	Eur	Zoun ea	1991	chemical	Netherlands	winter	seaduck, auks
113	NAA	Brewster	1906	storm	N-Am-Atl	autumn	auks
114	NAA	Cramer	1932	storm?	N-Am-Atl		phalaropes
115	NAA	Eliot	1939	storm	N-Am-Atl		storm petrels
116	NAA	Murphy & Vogt	1933	storm	N-Am-Atl	winter	auks
117	NAA	Snijder	1953	storm	N-Am-Atl	winter	auks
118	NAA	Sprunt	1938	storm	N-Am-Atl	autumn	auks
119	NAA	Stenhouse & Montevecchi	1996	storm	N-Am-Atl (27)	aut/winter	auks

No	Loc	Author	Year	Wreck	Region	Season	Species
120	NAA	Stone	1965	storm	N-Am-Atl	winter	auks
121	NAA	Stone	1965	storm	N-Am-Atl	autumn	phalaropes
122	Oth	Bailey & Davenport	1972	food	Alaska	winter	auks
123	Oth	Batchelor	1981	?	S-Africa	spring	petrels
124	Oth	Bond	1971	storm	N-Am-Pac		phalaropes
125	Oth	Bourne	1981	storm?	S-Pac	spring	petrels
126	Oth	Carter	1985	?	Australia	inc	diving petrels
127	Oth	Crochett & Kearns	1975	food?	New Zealand		penguins
128	Oth	Crochett & Reed	1976	storm	New Zealand		fulmars
129	Oth	Gabrielson & Jewett	1970	storm?	N-Am-Pac		phalaropes
130	Oth	Jury	1991	storm	S-Africa	winter	
131	Oth	Nakamura ea	1983	storm	Japan	autumn	storm petrels
132	Oth	Nevhaev	1993	?	Sakhalin	summer	fulmars, auks
133	Oth	Piatt & Lensink	1989	oil	Alaska	winter	mixture
134	Oth	Ryan ea	1989	storm	S-Africa	winter	petrels
135	Oth	van Heezik	?	food	New Zealand		penguins
136	Oth	van Pelt & Piatt	1995	food?	Alaska	winter	auks
1937	Oth	Vernon	1988	?	S-Africa	winter	storm petrels

5 SEABIRD PREDATION ON FISH BY SIZE GROUP

5.1 Estimates

To understand fully the flow of energy or carbon through marine ecosystems and to evaluate the level of natural mortality experienced by particular species, all major predator-prey interactions have to be taken into account. There are 20,000,000 seabirds in the North Sea and hundreds of millions in the North Atlantic. These predators consume a considerable biomass of fish and other prey. Although coverage of the north sea has been relatively robust, coverage of other regions has been less. For example, high numbers of seabirds breed in Iceland and they harvest considerable prey (Lilliendahl & Solmundsson 1997). Data on the sizes of prey consumed by Icelandic seabirds (Lilliendahl & Solmundsson unpubl.) need to be incorporated into evaluations of the size selectivity of seabirds.

Attrition of various prey species from predation by seabirds may be significant at certain times of year in some years and in certain areas. Such considerations may be of critical importance when management decisions affect large fisheries which operate at fairly restricted spatial and temporal scales, for example, sandeels (*Ammodytes marinus*) and some sprat (*Sprattus sprattus*) fisheries. Sandlance and clupeids are the most important prey for seabirds during the breeding season (Furness and Tasker 1996). This is the period during which almost all of the information on seabird diets have been collected (see below).

Table 5.1 is a preliminary effort to collate the available information on the species and sizes of fishes consumed by seabirds in different ICES areas. The table is presented as a working document for further development. Virtually all of the information on prey eaten by seabirds is based on chick diets. However, parental seabirds, especially those that carry food in the bill (e.g. common guillemots, Atlantic puffins), may deliver different foods to chicks than they consume themselves (e.g. Halley *et al.* 1995), so studies of adult diets are needed. It is also important to investigate winter diets when birds are under greater thermal and energetic stresses, when surface waters are rougher, and when prey may be at greater depths.

The species and sizes of prey consumed by seabirds change during the course of a breeding season and over the course of the year (e.g. Blake *et al.* 1985; Barrett *et al.*1987; Rodway and Montevecchi 1996), and seabirds consume different sizes of prey in different years, possibly as a result of changes in age-class proportions of prey on or differences in length-at-age in different years (Montevecchi and Myers 1996). When available, different prey lengths harvested by the same seabird species at the same sites are presented. Reference to original sources will give details of multiple prey size listings for the same sites and of dates of prey collections.

Table 5.1 Summary of particular prey sizes taken by different avian predators.

Prey Species	Bird Predator	Prey Size Range (mm)	Number of studies
Gadidae	Shag	143	1
	Atlantic puffin	45	1
Cod	Common guillemot	122	1
	Atlantic puffin	41-57	2
Haddock	Atlantic puffin	68-107	3
Whiting	Northern fulmar	50	1
	Atlantic puffin	55	1
Saithe	Northern gannet	226	1
	Common guillemot	120	1
	Atlantic puffin	53-95	4
Unid. Clupeid	Razorbill	60	1
	Common tern	65	1
	Arctic tern	50	1
Herring	Northern gannet	263	1
	Guillemots	128-130	2
	Atlantic puffin	51-115	2
	Kittiwake	124	1
Sprat	Common guillemot	65-122	6
	Razorbill	60	1
	Atlantic puffin	99	1
Norway Pout	Common guillemot	85	1
Sandeel	Shag	95-150	6
	Cormorant	90	1
	Northern fulmar	60-120	2
	Northern gannet	large 0' & 1' gp	1
	Common guillemot	100-170	12
	Brunnich's guillemot	140	1
	Razorbill	53-80	5
	Black guillemot	100-180	1
	Atlantic puffin	40-120	13
	Herring gull	80-140	1
	Gt.black-backed gull	80-140	1
	Kittiwake	70-150	6
	Arctic tern	30-80	2
	Great skua	100-140	2
	Arctic skua	60-140	1
Capelin	Common guillemot	139-148	2
	Brunnich's guillemot	139-155	2
	Razorbill	115	1
	Atlantic puffin	92-99	2
	Kittiwake	114-127	2
Blue Whiting	Common guillemot	38-90	1
Poor Cod	Common guillemot	80	1
Plaice	Cormorant	90	1
Dab	Cormorant	50	1
Sole	Cormorant	100	1

Prey Species	Bird Predator	Prey Size Range (mm)	Number of studies
Flounder	Cormorant	80	1

Research needs -

1) Research studies of the diets of seabirds in winter are needed in order to generate realistic models of trophic interactions and energy flow.

2) Studies of adult diet during the breeding season, when possible using stomach pumping techniques for species that regurgitate food to offspring (e.g. Gales 1988).

3) The sizes of fishes consumed by Icelandic seabirds may be available (Lilliendahl & Solmundsson unpubl.). These data and other data from elsewhere in ICES areas (e.g. Greenland) need to integrated into the present data base.

4) Analyses of spatial and temporal patterns of prey harvests by seabirds need to be made from a more complete database.

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Appendix 5.1: Sizes of fish prey taken by avain predators by ICES region and cited study.

Prey Species	Bird Predator	Prey Size Range (mm)	ICES Region	Reference
Gadidae	Shag	143±29	I	Barrett & Furness 1990
	Atlantic puffin	45±6	I	Barrett & Furness 1990
Cod	Common guillemot	110-137	IIa	Anker-Nilssen & Nygård 1987
	Atlantic puffin	57±?	IIa	Myrberget 1962
	Atlantic puffin	41±SE 3	IVb	Harris & Wanless 1986
Haddock	Atlantic puffin	88±21	IIa	Anker-Nilssen 1987
	Atlantic puffin	107±13	IIa	Anker-Nilssen & Lorentsen 1990
	Atlantic puffin	60-75	IVa	Barrett et al. 1987
Whiting	Northern fulmar	50±?	VIa	Thompson et al. 1995
	Atlantic puffin	55±SE 3	IVb	Harris & Wanless 1986
Saithe	Northern gannet	226±20	IIa	Montevecchi & Barrett1987
	Common guillemot	120±20	IVa/b	Blake et al. 1985
	Atlantic puffin	66±SE 5	IIa	Barrett et al. 1987
	Atlantic puffin	87±?	IIa	Myrberget 1962
	Atlantic puffin	95±12	IIa	Anker-Nilssen & Lorentsen 1990
	Atlantic puffin	53±SE 10	IVb	Harris & Wanless 1986
Mackerel	Northern gannet			
Unid. Clupeid	Razorbill	60	IVb	Harris &Wanless 1986
	Common tern	65±28	IVc	Frick & Becker 1995
	Arctic tern	50±30	IVc	Frick & Becker 1995
Herring	Northern gannet	263±16	IIa	Montevecchi & Barrett 1987
	Guillemots	128±10	I	Barrett & Krasnov 1996
	Guillemots	130±30	IVa/b	Blake et al. 1985
	Atlantic puffin	(0gp) 51±4	I	Barrett & Krasnov 1996
	Atlantic puffin	(1gp) 115±11	I	Barrett & Krasnov 1996
	Atlantic puffin	75±11	IIa	Anker-Nilssen & Lorentsen 1990
	Kittiwake	124±32	I	Barrett & Krasnov 1996
Sprat	Common guillemot	122±SE 1	IVb	Harris & Wanless 1985
	Common guillemot	65±15	IVa/b	Blake et al. 1985
	Common guillemot	65±10	IVc	Blake 1984
	Common guillemot	113±SE 2	VIa	Harris & Wanless 1985
	Common guillemot	92±SE 2	VIIg	Harris 1970
	Common guillemot	104±SE 1	VIIg	Birkhead 1977
	Razorbill	60±10	IVc	Blake 1984
	Atlantic puffin	99±SE 8	IVb	Harris & Wanless 1986
Norway Pout	Common guillemot	85±20	IVa/b	Blake et al. 1985
Sandeel	Shag	102±17	I	Barrett & Furness 1990
	Shag	124±?	IIa	Barrett et al. 1990
	Shag	90 to 100 ±30	IVb	Harris & Wanless 1993
	Shag	100-150 (modal)	IVa	Furness 1990
	Shag	120±?	IVa	Furness & Barrett 1991

Prey Species	Bird Predator	Prey Size Range (mm)	ICES Region	Reference
	Shag	111±?	IVa	Barrett et al. 1990
	Cormorant	~90	I	Barrett et al. 1990
	Northern fulmar	80±25	IVa	Fowler & Dye 1987
	Northern fulmar	60-120 (modal)	IVa	Furness 1990
	Northern gannet	large 0' & 1' gp	IVa	Martin 1989
	Common guillemot	140±20	I	Barrett & Furness 1990
	Common guillemot	100-140	IVa	Bailey et al. 1991
	Common guillemot	100-160	IVa	Blake et al. 1985
	Common guillemot	126±SE 13	IVa	Harris & Riddiford 1989
	Common guillemot	150±SE 2	IVa	Furness 1983
	Common guillemot	140-170 (modal)	IVa	Furness 1990
	Common guillemot	130-160	IVb	Harris & Wanless 1985
	Common guillemot	100-130	IVb	Pearson 1968
	Common guillemot	126±11	IVb	Harris & Wanless 1986
	Common guillemot	141±SE 16	VIa	Harris & Wanless 1985
	Common guillemot	141±SE 4	VIa	Harris & Wanless 1985
	Common guillemot	122±?	VIIg	Harris 1970
	Brunnich's guillemot	140±20	I	Barrett & Furness 1990
	Razorbill	60-80	IVa	Furness 1990
	Razorbill	*53-79*	VIIg	Harris 1970
	Razorbill	*53-79*	VIIg	Corkhill 1973
	Razorbill	*53-79*	VIIg	Ashcroft 1976
	Razorbill	*53-79*	VIIg	Lloyd 1976
	Black guillemot	100-180 (modal)	IVa	Furness 1990
	Atlantic puffin	114±22	I	Barrett et al. 1987
	Atlantic puffin	82±10	IIa	Barrett et al. 1987
	Atlantic puffin	78±?	IIa	Myrberget 1962
	Atlantic puffin	60-80	IVa	Barrett et al. 1987
	Atlantic puffin	40-85	IVa	Harris & Riddiford 1989
	Atlantic puffin	80-120	IVa	Furness 1990
	Atlantic puffin	90±2	IVa	Harris & Wanless 1986
	Atlantic puffin	73±SE 21	IVa	Martin 1989
	Atlantic puffin	80-120 (modal)	IVa	Furness 1990
	Atlantic puffin	66±?	IVb	Harris & Hislop 1978
	Atlantic puffin	56±?	VIIg	Corkhill 1973
	Atlantic puffin	61±?	VIIg	Ashcroft 1976
	Atlantic puffin	72±?	VIa	Evans 1975
	Herring gull	80-140	IVa	Hudson 1986 (discards?)
	Gt.Black-backed gull	80-140 (modal)	IVa	Furness 1990
	Kittiwake	70±?	IVa	Pearson 1968
	Kittiwake	80-100	IVa	Furness 1983
	Kittiwake	80±?	IVa	Harris & Riddiford 1989
	Kittiwake	80-100 (modal)	IVa	Furness 1990
	Kittiwake	133±?	IVb	Galbraith 1983
	Kittiwake	150±?	IVb	Wanless & Harris 1992
	Arctic tern	70±20	IVa	Ewins 1985
	Arctic tern	30-80 (modal)	IVa	Furness 1990
	Great skua	140±20	IVa	Furness & Hislop 1981
	Great skua	100-140 (modal)	IVa	Furness 1990
	Arctic skua	60-140	IVa	Furness 1990
Capelin	Common guillemot	148±SE 1	I	Erikstad & Vader 1989
	Common guillemot	139±19	I	Barrett & Furness 1990
	Brunnich's guillemot	155±SE 2	I	Erikstad & Vader 1989
	Brunnich's guillemot	139±14	I	Barrett & Furness 1990

Prey Species	**Bird Predator**	**Prey Size Range (mm)**	**ICES Region**	**Reference**
	Razorbill	115±21	I	Barrett & Furness 1990
	Atlantic puffin	99±18	I	Barrett et al. 1987
	Atlantic puffin	92±36	I	Barrett & Furness 1990
	Kittiwake	127±SE 14	I	Barrett Unpublished
	Kittiwake	114±40	I	Barrett & Furness 1990
Blue Whiting	Common guillemot	38-90	IIa	Anker-Nilssen & Nygård 1987
Poor Cod	Common guillemot	80±20	IVa/b	Blake et al. 1985
Plaice	Cormorant	90±30	IVc	Damme 1995
Dab	Cormorant	50±15	IVc	Damme 1995
Sole	Cormorant	100±40	IVc	Damme 1995
Flounder	Cormorant	80±40	IVc	Damme 1995

6 A REVIEW OF ISSUES RELATED TO SEABIRD CONSUMPTION OF FISH AND SHELLFISH STOCKS, DISCARDS AND MARICULTURE AS WELL AS THE TROPHIC ROLE AND ECOLOGY OF SEABIRDS AND WADERS

6.1 Introduction

The Working Group on Seabird Ecology interpreted this recommendation of the Biological Oceanography Comittee as a request for an assessment of the issues most likely to be raised within the ICES community concerning the foraging ecology of seabirds and waders, and the potential interactions between these groups of birds and fisheries. In responding to this recommendation, the Working Group on Seabird Ecology has listed a number of issues likely to be of importance. The Working Group recognized that each of these issues by itself is potentially the subject for new research and/or for a major review. Given the time available, the Working Group elected to restrict itself to the identification of issues at this time, and to use this list as the basis for developing possible future reports by the Working Group on Seabird Ecology, singularly, or in co-operation with other ICES Working Groups or Committees.

In the present listing of issues, we have grouped issues into several large subcategories, but we have not ranked either the issues or the subcategories by importance, which is probably not feasible except on a local or species-specific basis. In the first subcategory we list issues related to the use of seabirds and waders as indicators of conditions within the ecosystems of which they are a part.These issues include the distribution and abundance of prey organisms, the presence of pollutants and the need to calibrate the signals received from the birds with the absolute values of the parameters of interest.

There are also important issues that focus on the basic ecology of seabirds that are of interest (Hunt *et al.* 1996), particularly insofar as they illuminate processes that control the structure and energy flow within marine ecosystems. In the second subcategory, we focus on the use of seabirds as model systems for investigating processes in marine ecosystems that are of broad interest, and for which seabirds may be useful windows into processes that are otherwise difficult to study.

In the remaining subcategories, we list issues concerning the effects of seabirds and waders on fisheries, and conversely, the effects of fisheries on seabirds and waders. It should be noted that, in the cases where birds and the fishing industry utilize the same resource, there is the possibility that either, or both, the birds and the fishery can be harmed by competition or other trophic interactions. As these questions and issues are addressed, both experimental approaches within the North Sea and comparisons with fisheries experience elsewhere in the world will be required.

6.2 Seabirds as Indicators

1) Changes in the distribution, abundance, species composition and breeding biology of seabirds can indicate changes in the distribution, abundance, and size classes of their preferred prey (reviewed by Montevecchi 1993).

a) Seabirds may be sensitive indicators of interannual and seasonal variation in the timing of life history events in prey stocks.

b) Seabird diets may provide indications of changes in the biodiversity of prey populations not otherwise monitored by fisheries managers (Springer *et al.* 1984 cited in Montevecchi (1993)).

c) There is a need to calibrate the relationship between the responses of seabirds and the variations in abundance or recruitment in prey stocks of concern.

2) Seabirds accumulate a wide variety of organic chemicals and heavy metals and provide an indication of the prevalence of these pollutants in the marine ecosystem.

a) As wide ranging top predators, seabirds provide sampling opportunities that integrate pollutant transfers up food chains which is especially useful in the monitoring of lipophilic pollutants. They provide a better indication of possible hazards to humans than does sampling from low trophic levels. Because their biology is generally well known, the interpretation of pollutant burdens is easier. By integrating over time and spatial scales they permit more cost effective sampling. (see reviews in Furness & Greenwood 1993).

b) The pathways of pollutant to seabirds may be traced by using stable isotope analyses and fatty acid tracers to identify the trophic pathways and carbon source areas supporting seabird populations.

6.3 Processes Affecting the Trophic Ecology of Seabirds

1) How does the abundance of fish predators relative to the abundance of their prey influence the availability of food to seabird populations?

a) Evaluate the evidence that the removal of large piscivorous fish by the fishery has enhanced prey availability to seabirds and thereby caused a related increase in seabird populations.

b) Evaluate the evidence that changes in the species composition of predominant fish consumers of zooplankton has affected seabird populations.

2) At the population level, is most seabird foraging concentrated in a few critical areas where birds are present in high concentrations, or is most seabird foraging accomplished by widely dispersed individuals (e.g. Wright *et al.* 1996)?

a) Are preferred foraging areas, with seabird aggregations, characteristic of some species or regions, but not of others?

3) Given that certain forage fish species show strong relationships to bottom type and other species may respond to physical processes that concentrate planktonic prey, what is the importance of bottom sediment type versus hydrographic processes and structures in determining foraging location, foraging success and the role of seabirds in trophic transfer?

a) Can we determine or predict where the highest concentrations of foraging seabirds are likely to be found, and the temporal stability of these preferred foraging locations?

4) What are the winter foods of seabirds at sea?

a) Are there seasonal changes in the species or types of prey taken, and if so, are these changes more marked for planktivorous than for piscivorous seabirds?

5) What influences the vertical distribution of forage fish, in particular their abundance in the upper water column, since many species of seabirds are restricted to forage in the top 2 m?

6) What are the consequences for seabirds (and other marine predators) of prey switching as a consequence of changes in the availability of preferred prey? How are adult survival and reproductive performance affected?

7) Evaluate evidence for decadal-scale variation in the population sizes, reproductive ecology or food habits of seabirds in the North Atlantic. Can these changes be related to the North Atlantic oscillation and other long-term cycles?

6.4 Seabird and Wader interactions with Mariculture

1) Shellfish

a) Mussel consumption by waders, especially oystercatchers, gulls, and seaducks, especially eiders and scoters, on both natural and artificial mussel beds in competition with mussel fisheries (e.g., Wadden Sea, coastal UK, Baltic).

b) Cockle consumption by oystercatchers and eiders that compete with cockle fisheries (e.g., Wadden Sea, Camphuysen *et al.* 1996).

c) Spisula consumption by scoters and eiders (e.g., German and Southern Bight).

d) What are the population-level and local consequences for seabirds, seaducks and waders of the availability of commercial stocks of shellfish, and what changes in these avian populations would be predicted should the commercial stocks of shellfish no longer be available to these birds? This topic was briefly reviewed in the previous meetings of the Study Group (Leopold *et al.* 1996).

2) Finfish Mariculture

a) Salmon consumption by cormorants, gulls, grey herons, ospreys and other birds taking fish from penned stock.

b) What are the local population-level consequences to birds of the availability of farm-raised fish?

6.5 Seabird Impacts on Recruitment of Fish Stocks

Seabirds predominantly consume small fish, particularly 0-group fish. We believe that in almost all situations the local impact of this predation is likely to be less than that from predatory fish, and mostly trivial in terms of fish stock dynamics, but in some situations it has been suggested that recruitment to fish stocks might be affected by seabird predation rates.

a) Consumption of pre-recruit gadoids by cormorants and shags (Norway, Barrett *et al.*, 1990).

b) Consumption of juvenile herring by puffins and other seabirds (Norway, Anker-Nilssen 1992).

c) Consumption of o-group flatfishes by cormorants and other seabirds (van Damme 1995).

d) Consumption of salmon smolt by gulls, cormorants and other seabirds (West coast, Alaska, USA). Although not within the ICES geographical area, the situation in western North America provides a useful example of predator build-up at an artificial feeding opportunity. Similar problems for released smolts may arise in Canada, the west of Scotland and in Norway (Greenstreet *et al.* 1993). Examination of food samples from gannets, which consume low levels of salmon, has yielded important information about the salmon migration routes in eastern Canada (Montevecchi *et al.* 1988).

e) Consumption of forage fish by seabirds and the potential for competition with fisheries for these stocks, particularly when local stocks near seabird colonies are depleted (e.g., sandeels near Shetland; Sprat near Firth of Forth, juvenile herring in German and Southern Bight).

f) How does the rate and total take of the commercial harvest of forage fish stocks impact their availability to seabirds? This question is most likely to be an issue in ICES IVa west and possibly in ICES Ivb (Tasker & Furness 1996, Wright & Tasker 1996, Wright *et al.* 1996).

g) Are the perceived problems for seabirds indicative of similar problems for other marine predators?

h) consumption of freshwater fish stocks by cormorants and sawbill ducks (Russell *et al.* 1996).

6.6 Mortality of Seabirds

The key question is: What are the relative impacts, at the population level, of various anthropogenic and natural sources of seabird mortality at sea? In particular in our context: What is the relative impact of fisheries-related mortality compared to other sources of mortality? We appreciate that these topics are to some extent included in the remit of the Working Group on Ecosystem Effects of Fisheries.

1) Wrecks.

Wrecks or mass mortalities of seabirds may occur for a variety of reasons, one of which can be acute local food shortage. This issue was considered in greater depth earlier in this report (Section 4).

2) Mariculture
    a) Drowning of cormorants, shags and other birds in fish pens.

3) Net Fishing
    a) Entanglement of seabirds in set nets, drift nets and fish traps.

b) Are there specific areas of the oceans where seabirds are present in high densities, and thus particularly vulnerable to entanglement?

4) Long Line Fishing
    a) Hooking and subsequent death of seabirds, in particular fulmars, great skuas and gulls in long-line fisheries.

4) Other sources of mortality (e.g., oil, chemical pollution, weather, etc.). Such effects often act in synergy. Are these influences greater or less than effects attributable to fisheries activities, and are synergies evident?

6.7 Discards and Offal

Much of the following is addressed in greater detail earlier in this report in Sections 2 and 3 on Discards.

1) To what extent are present populations of seabirds dependent on discards and offal?

2) What impacts on seabird and other predator populations would be expected if food from discards and/or offal become reduced or unavailable? What secondary and tertiary impacts might be anticipated (e.g., gull predation of other seabirds in Newfoundland; increased predation on fish populations of value).

3) Do discards and offal play different ecological/trophic roles?

4) Given that different fisheries produce different proportions of discards and different ranges of fish sizes in the discards, to what extent do seabirds show preferences between fisheries, and how does the rate of dumping of discards after a trawl affect their fate? Are seabirds feeding on discards that might otherwise survive?

5) Is there a seasonal variation in the importance of discards to seabirds?

6) Effects of fishing moratoria/ closed areas/ discard bans require to be evaluated as these present valuable experiments permitting responses of seabirds to be studied.

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7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

7.1.1 Discards form only a proportion of the diet of seabirds in the North Sea. This proportion is particularly high for fulmars, great skuas, lesser black-backed gulls, great black-backed gulls and kittiwakes.

7.1.2 If all discards in the North Sea were consumed by seabirds then this food supply could theoretically sustain about 5.9 million seabirds using offshore fishery discards and 339,000 seabirds using discards from shrimp fisheries. In practice, rather lower numbers are sustained by these as not all discards are consumed by seabirds.

7.1.3 Around 70-90% of discarded roundfish in the North Sea are consumed by scavenging seabirds, whereas only 10-40% of discarded flatfish, 12% of discarded elasmobranchs and 1-23% of discarded benthic invertebrates are consumed by seabirds. Around 55-99% of discarded offal is consumed by seabirds. Consumption rates are highest in winter and in the northwestern North Sea.

7.1.4 Seabirds in the North Sea consume about 55,000 t of offal, 206,000 t roundfish, 38,000 t flatfish, 2,100 t elasmobranchs, and 9,000 t of benthic invertebrates discarded from offshore fisheries each year. About 5,500 t of discards from shrimpers in Niedersachsen are also consumed.

7.1.5 Numbers of seabirds in the North Sea have increased. Increases in recent decades have been most pronounced among scavenging seabird species. Several studies show the importance of discards in maintaining high breeding success and population growth of scavenging seabirds, even though discards may be less suitable for chick food than are sandeels, sprats or juvenile herring.

7.1.6 Scavenging seabirds now represent a much higher proportion of North Sea seabird communities than used to be the case, and this may have indirect consequences for other bird species.

7.1.7 Reductions in discarding can be anticipated to have impacts particularly on the smaller scavenging seabird species since these are less able to compete with larger seabirds, especially for larger discards. Gull distributions in the North Sea may be particularly affected. Populations of scavenging seabirds would be expected to decline, particularly those of smaller scavengers and those most dependent on discards. Increased predation on other seabirds can be anticipated in the short term.

7.1.8 Mass mortalities ('wrecks') are a natural feature of seabirds, and can be due to a variety of causes, but some taxa are more susceptible than others.

7.1.9 The most frequent causes of wrecks appear to be storms, food shortage or oil pollution. Weather and food shortage may often interact. Different causes vary in seasonality, with food-related wrecks most frequent in autumn/winter. Few wrecks occur in summer.

7.1.10 Most seabird species are subject to occasional wrecks, but auks, seaducks, fulmars and storm petrels are more susceptible to such events than are gannets, gulls, skuas or terns.

7.1.11 Sizes of fish eaten by seabirds (excluding discards) vary with seabird size. Sandeels from 70-150 mm are taken by most seabirds in the North Sea, but terns tend to take sandeels of 30-80 mm (Table 5.1).

7.1.12 We identify as important issues relating to seabirds (Section 6) the topics: seabirds as indicators; ecological processes affecting seabird feeding; interactions with mariculture; seabird impacts on recruitment of fish stocks; wrecks and fishery-induced mortality of seabirds; influences of discards and offal on seabird populations and community structure.

7.2 Recommendations

The Working Group makes the following proposals:

1. That an ICES minisymposium be held during the Annual Meeting in Oslo in September 1999 on the theme 'Processes influencing trophic transfer to top predators'. That this minisymposium consists of about eight papers, three on seabirds, two on marine mammals and three on predatory fish. That a committee be set up consisting of Professor G.L. Hunt Jr., Professor J. Harwood, and a leading predatory fish ecologist, to organise this minisymposium. The aim of this minisymposium should be to look at the similarities and differences in the ecological processes affecting the different groups of top predator.

2. That the Working Group on Seabird Ecology should meet at ICES Headquarters from 30 March to 1 April 1998 to undertake the following work:

> i) Review the consumption of pre-recruit fish by seabirds and evaluate the extent to which this may provide an indicator of recruitment.

Many seabirds feed predominantly or exclusively on very small fish, and thus their diet composition could possibly provide indications of the strength of pre-recruit classes of fish. The Working Group felt that this possibility required examination.

> ii) Review evidence for annual, seasonal and spatial variation in the species and size of prey fish taken by seabird predators, and where possible relate these to variations in the prey populations. Such a review should also consider selection of prey according to body condition and the problems, if any, of extrapolating adult diets from food fed to chicks.

Many studies of seabird diet focus almost exclusively on food fed to chicks, and the extent to which different diets are taken by adults has not been reviewed. While it may be difficult to relate diet composition at a particular seabird colony to local fish abundance because of the difference in scales over which stocks are assessed and seabirds forage, there are probably now enough data from colonies in different parts of the North Sea over a long enough run of years to make such a comparison worthwhile.

iii) Review evidence for decadal scale variations in seabird distributions, population sizes, reproduction and food habits, and evaluate the extent to which these may be linked to the North Atlantic oscillation and other physical cycles.

The long runs of data on seabird numbers and breeding performance, covering several decades in some cases, would permit an analysis of these data in relation to long term patterns in the physical environment and as yet no such analysis has been made except to show correlations between kittiwake numbers/performance and climate.

8 ANNEXES

8.1 Names and Addresses of Participants

Table 8.1 Address list for participants in the Glasgow meeting of the ICES Working Group on Seabird Ecology, 22-26 November, 1996.

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8.2 Scientific names of eabird species mentioned in text

Common name	Scientific name
red throated diver	*Gavia stellata*
fulmar	*Fulmarus glacialis*
cormorant	*Phalacrocorax carbo*
shag	*Phalacrocorax aristotelis*
gannet	*Sula bassana*
grey heron	*Ardea cinerea*
common eider	*Somateria mollissima*
osprey	*Pandion haleaetus*
oystercatcher	*Haematopus ostralegus*
phalarope	*Phalaropus sp.*
great skua	*Catharacta skua*
Arctic skua	*Stercorarius parasiticus*
black-headed gull	*Larus ridibundus*
common gull	*Larus canus*
Audouin's gull	*Larus audouini*
herring gull	*Larus argentatus*
yellow-legged gull	*Larus cacchinans*
lesser black-backed gull	*Larus fuscus*
great black-backed gull	*Larus marinus*
Sabine's gull	*Xema sabini*
kittiwake	*Rissa tridactyla*
common tern	*Sterna hirundo*
Arctic tern	*Sterna paradisaea*
Sandwich tern	*Sterna sandvicensis*
little tern	*Sterna albifrons*
common guillemot	*Uria aalge*
Brunnich's guillemot	*Uria lomvia*
razorbill	*Alca torda*
little auk	*Alle alle*
black guillemot	*Cepphus grylle*
puffin	*Fratercula arctica*