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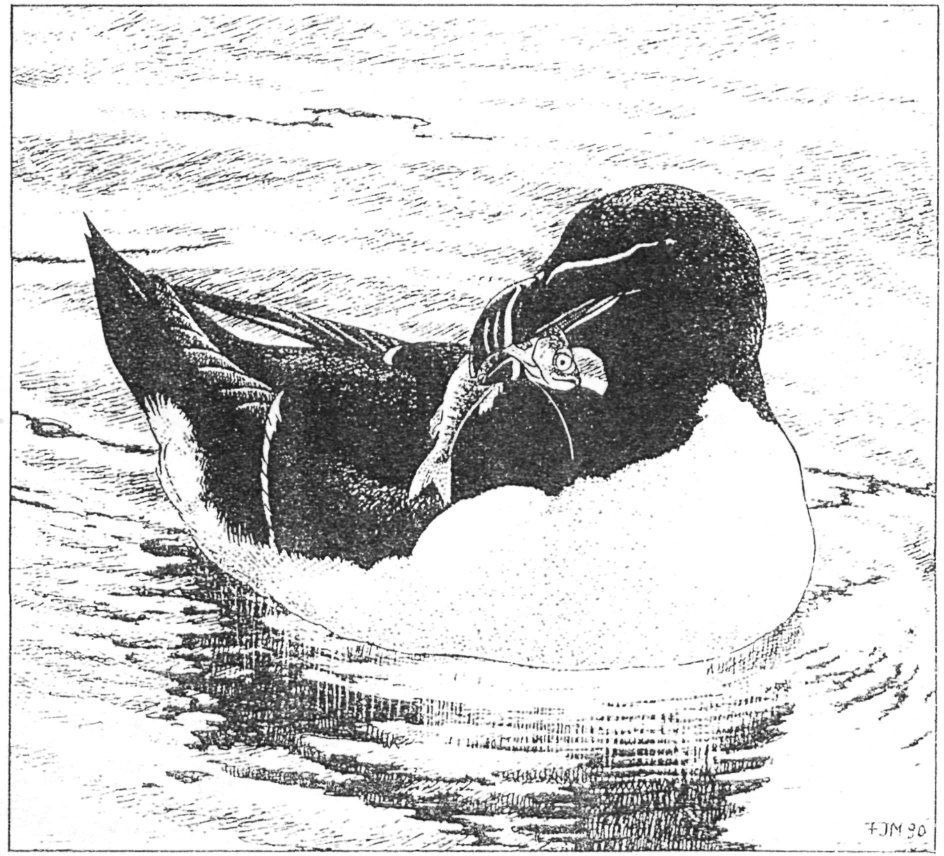
Fish stocks, fisheries and seabirds in the North Sea

Feasibility study for an analysis of interactions between fish stocks, fisheries and wintering seabirds



C.J. Camphuysen

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Address of author: Perim 127, 1503 GB Zaandam

Editors: Jan Andries van Franeker, Eduard R. Osieck
Word processing: Kees Camphuysen, José van Doorn (Vogelbescherming)
Cover design: Ten Have Reklamestudio, Zoelen
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Abbreviations and terms used in this report

AON	Apparently occupied nest or site
AOT	Apparently occupied territory
benthic	bottom-living
BMR	Basal Metabolic Rate
clupeoid fish	Herring, Sprat, or Pilchard fish of this family
commercial fishery	any fishery whose catch is sold directly for human consumption
CPUE	Catch Per Unit Effort
demersal	close to the seabed (demersal fisheries, demersal fish)
gadoid fish	Cod, Haddock, Whiting, Norway Pout or other fish from the Cod-family
guanays	Peruvian Cormorants *Phalacrocorax bougainvillii*
ICES	International Council for the Exploration of the Seas
IKMT	Isaacs-Kidd Midwater Trawl; fishing gear used in sampling programmes for fish larvae
industrial fisheries	any fishery whose catch is not sold directly for human consumption (i.e. the catch is usually converted into oil or fish meal)
IYFS	International Young Fish Survey
IYHS	International Young Herring Survey
MSY	Maximum Sustainable Yield
mesopelagic	living in the middle layers of the open sea
monophagous	feeding on one sort of prey only
MSVPA	Multi-species VPA (see below)
O-group	term for fish age: immature fish after metamorphosis, less than 1 winter old; also 1-group (one winter old), 2-group (two winters old), etcetera. The precise age will depend on the month of metamorphosis from egg to larva. This timing varies between species.
otolith	earbone of fish, consisting of calcium carbonate and otoline, used for identification of fish species in dietary studies of seabirds and marine mammals or to age a fish using differences in growth rate in summer (rapid) and winter (slow).
pelagic	living at the surface of the sea (pelagic fisheries, pelagic fish)
piqueros	Peruvian Boobies *Sula variegata*
recruitment	recruitment of immatures into the mature stock, or recruitment to a fishery (when the fish becomes vulnerable to the fishing gear ordinarily in use)
recruitment fishery	fishery of which the catch in any one year is highly dependent on that year's recruitment to the adult stock
TAC	Total Allowable Catch
VPA	Virtual Population Analysis

SAMENVATTING

1. De jaren tachtig kenden een alarmerende groei in aantallen dode zeevogels die 's winters op de kust van Nederland en van enkele andere landen rond de Noordzee aanspoelden. Hoewel olievervuiling zeker een rol speelt bij de sterfte van vogels in dit gebied, bestaan er aanwijzingen dat de toename in sterfte mogelijk in verband staat met veranderingen in het voedselaanbod voor de vogels. Vele vogels van de Noordzee leven van kleine vissoorten die ook door de groeiende tak van industriële visserij worden gevangen.

2. Deze ontwikkelingen waren voor Vogelbescherming aanleiding een beter inzicht te verkrijgen in de relaties tussen visbestanden, visserij en zeevogels op de Noordzee. Gezien de grote omvang en de complexiteit van dergelijk onderzoek, werd besloten een voorstudie te laten verrichten die zou moeten leiden tot
(1) een inventarisatie van beschikbare gegevens en
(2) een advies omtrent de mogelijkheden en gewenste aanpak van gericht onderzoek.

3. Dit rapport geeft een overzicht van relevante literatuur en geeft inzicht in hetgeen er beschikbaar is aan gegevens over zeevogels, visbestanden en visserij op de Noordzee. Het rapport bevestigt de suggestie dat de toegenomen aantallen zeevogels op onze kust te maken hebben met gewijzigde voedselomstandigheden. De gegevens worden voldoende geacht voor verder onderzoek, maar er zijn ook belangrijke beperkingen.

4. In tegenstelling tot aantallen broedende zeevogels rond de Noordzee is de totale omvang van op de Noordzee *overwinterende* populaties zeevogels nauwelijks bekend. Ook de totale omvang van visbestanden is veelal niet goed bekend, en nog veel minder de invloed van de visserij op die visbestanden. Een kwantitatieve analyse waarin de totale voedselbehoefte van vogels wordt vergeleken met de aanwezige vispopulaties en de daarop uitgeoefende druk door visserij, zal daarom geen concreet resultaat kunnen opleveren.

5. Waar absolute gegevens ontbreken is wel vaak informatie te vinden die een indruk geeft van relatieve wijzigingen in de loop van de tijd. Wijzigende verspreidingspatronen van vogels op zee zijn te reconstrueren uit tellingen vanaf schepen, vliegtuigen en telposten langs de kust. Wijzigingen in visbestanden zijn deels af te lezen uit vangststatistieken, maar verspreiding en dichtheden zijn nog veel beter te reconstrueren dank zij internationaal gestandaardiseerde programma's voor de bemonstering van visbestanden. Een "trend-analyse", waarin verbanden worden onderzocht, tussen relatieve wijzigingen in aantallen en verspreiding van vogels en vissen, behoort dus tot de mogelijkheden. Bestaande gegevensbestanden geven daarvoor in principe genoeg uitgangsmateriaal. Als voorbeeld is een aanzet tot een dergelijke trend-analyse gegeven voor de Zeekoet (3.8.4). Een probleempunt blijft het leggen van *oorzakelijke* verbanden tussen visserijdruk of andere factoren en de grootte en/of verspreiding van vispopulaties.

6. De conclusies van het rapport (hoofdstuk 6) kunnen als volgt worden samengevat. Voor een onderzoekproject naar de relaties tussen zeevogels en visbestanden is het verstandig zich te beperken tot Zeekoet, Alk en Drieteenmeeuw. Deze drie soorten hebben duidelijk te kampen met vergelijkbare problemen: zij waren de belangrijkste slachtoffers van de massastrandingen in de jaren tachtig en vertonen vergelijkbare wijzigingen in winterverspreiding en in afname of instabiliteit van broedpopulaties rond de Noordzee. Voor deze soorten zou een trendanalyse uitgevoerd kunnen worden, die wijzigingen in hun aantallen en verspreiding tracht te correleren met ontwikkelingen in de populaties van de voor hen belangrijke prooivissen. De belangrijkste vissen zijn Sprot, zandspieringen en Kever, en jonge exemplaren van Haring, Kabeljauw, Schelvis en Wijting. Onderdeel van de analyse moet zijn een onderzoek naar de herkomst van gestorven vogels: alleen op die wijze kan de toegenomen sterfte in de Noordzee in verband worden gebracht met populatie-ontwikkelingen in broedgebieden. Verwacht mag worden dat het hier gesuggereerde onderzoek op zijn minst aannemelijk kan maken dat wijzigende visbestanden in de jaren tachtig hebben geleid tot een wijziging in overwinteringsgebieden van diverse soorten zeevogels en daarmee tot een dermate verhoogde sterfte dat broedpopulaties worden bedreigd.

7. Het lijkt in dit stadium minder zinvol om vervolgonderzoek diepgaand te richten op een eventueel oorzakelijk verband tussen visserij en wijzigingen in vispopulaties. Deze complexe, en naar het schijnt onontwarbare materie hoort thuis bij gespecialiseerde visserij-instituten. Wel kan het hierboven genoemde onderzoek aanwijzigingen opleveren voor mogelijke relaties en daarmee voor zeer gerichte onderzoekvragen aan dergelijke instituten. De kans op concrete resultaten neemt daardoor sterk toe. Het geadviseerde onderzoek dient te worden uitgevoerd door een marien ornitholoog met gedegen kennis van vissen en visserij op de Noordzee. De benodigde tijd voor onderzoek en rapportage wordt op ongeveer 32 maanden geschat (hoofdstuk 7).

1. INTRODUCTION

1.1 Background

Beached bird surveys in the Netherlands and in the Federal Republic of Germany have drawn attention because of a dramatic increase in numbers of stranding seabirds in the southern North Sea since 1980 (Camphuysen 1989, Vauk *et al.* 1987). A massive wreck of auks was recorded on Britain's east coast in February 1983 (Underwood & Stowe 1984), but mass-strandings in winter 1982/83 in the southern North Sea were only one peak in a series running from 1980/81 to 1985/86. It later appeared that the 1983 wreck in Britain, plus the southern North Sea strandings, were the peak event in a series of mass mortality incidents, particularly occurring in the southern and southeastern North Sea, with Kittiwakes *Rissa tridactyla*, Guillemots *Uria aalge*, and Razorbills *Alca torda*, most notably involved (Camphuysen 1989).

Nearly all beached auks and Kittiwakes on Dutch and German beaches were oil contaminated, but it was noted that the casualties were all severely emaciated (Camphuysen 1983, van Franeker 1983). Most stranded birds in Britain in 1983 were unoiled and were also severely emaciated. Blake (1984) suggested that the British wreck was caused by local food shortages, perhaps exacerbated by adverse weather. The observed mass mortality in the southern and southeastern North Sea could not be explained by changes in the occurrence of oil pollution at sea in these waters. It appeared that more auks and Kittiwakes were wintering in the southern North Sea than previously (Camphuysen 1989). It has been suggested that major shifts in the availability of fish in the early 1980s in several parts of the North Sea led to a changing winter distribution of these species.

Changing fish stocks Fastly developing commercial fisheries during this century have resulted in widespread increases in the exploitation of certain fish stocks (Bailey & Hislop 1978). Depletion of stocks of Herring *Clupea harengus*, Cod *Gadus morhua*, Mackerel *Scomber scombrus* and several flatfishes were the result of overexploitation in the North Sea and other parts of the eastern North Atlantic. More recently, industrial fisheries have been developed exploiting also smaller species, such as Sprat *Sprattus sprattus*, Norway Pout *Trisopterus esmarkii*, sandeels *Ammodytidae*, and Capelin *Mallotus villosus*, usually for the fishmeal industry. Many fish stocks have suffered from the extensive fisheries during this century, others were found to profit from the overexploitation of predatory fish. The fishing industry also made large quantities of fish available to seabirds as discards (unmarketable size) or offal. In all considerable changes have taken place in the fish stocks, and hence in the availabity of prey fish for seabirds. Changes due to environmental factors, fisheries, or a mixture of these factors have occurred and are still taking place.

Fish stock depletion and the effect on seabirds The adverse effects of overfishing have been obvious in a number of bird populations world wide. Repeated breeding failures of Puffins on the Lofoten Islands in northern Norway (Lid 1981), unsuccessful recovery of the population of Peruvian seabirds after El Niño events (Duffy 1983, Nelson 1978), and population crashes of Guillemots in the Barents Sea (Vader *et al.* 1988) are only some of the most spectacular examples.

On the other hand, fishery-induced changes in the marine ecosystem may also favour certain seabird populations (Anderson & Ursin 1977, Cohen *et al.* 1989, Furness 1984a).

In the North Sea, the exploitation of pelagic shoaling fish, especially of Herrings, is intense, so that commercial fisheries are in direct competition with seabirds (Furness & Ainley 1984). The rapid development of industrial fisheries on species which were previously not utilized, such as sandeels, Norway Pout and Sprat (Goodlad 1989, Daan *et al.* 1990) and which are important as food for seabirds in both summer and winter, poses a serious threat for the seabird populations in the North Sea. Breeding failures in Shetland and Orkney in the 1980s have shown that seabirds now find it difficult to catch sufficient prey for their chicks (Heubeck 1989, Monaghan *et al.* 1989). The massive wrecks of auks and Kittiwakes in the early 1980s are still largely unexplained (cf. Blake 1984, Camphuysen 1989). Indeed, several reports indicate changes in wintering distribution or expanding wintering areas of these species (Camphuysen 1987, Harris 1984, Peterz & Olden 1987). It seems logic to seek for the explanation of a changing winter distribution of seabirds in changes in the availability of food (declines in fish stocks or changes in the distribution of fish concentrations). The birds found dead in the Netherlands and in Germany (oiled and unoiled) were severely emaciated, which may indicate food shortage. However, Swedish birds, which were drowned in gill-nets, were very fat (Peterz & Olden 1987).

Furness & Ainley (1984) listed the North Sea as one of the areas in the world where seabirds and fisheries interactions may be most intense. As threatened seabirds they listed auks, terns and Kittiwakes. Recognizing the significance of fish stock depletion by commercial or industrial fisheries for seabirds all over the world, the ICBP Seabird Specialists Group (1984: 778)) recommended research on fisheries competition as:

(1) Research the nature and significance of competition between seabirds and commercial fisheries especially in the north Atlantic, Peru and south-western Africa.

(2) Assess the consequences of overfishing to seabirds and propose measures to reduce these effects.

(3) Evaluate seabirds as potential indicators of the status of commercially fishable resources.

In order to make sensible statements about influences of fishery exploitation on particular seabird species, Ainley & Furness (1984: 706) recommended to collect further information on:

(1) The importance of offal and discards in the breeding ecology of species that have adapted to utilize waste fish and offal from fishing vessels.

(2) Diets and energy requirements of seabirds, and their foraging ranges and activity budgets, so that seabirds may be added to models of marine ecosystem energy flows.

(3) Long term influences of food availability on the dynamics of seabird populations.

Finally, Furness & Ainley (1984) suggested that we should attempt to make fisheries biologists aware of the possible use of seabirds as indicators of fish stock condition, and of their integral role as natural predators of commercially valuable stocks.

1.2 This report

The effects of fish stock depletion by industrial and commercial fisheries on breeding success of seabirds and associated population trends have received more and more attention in recent years (e.g. Anker-Nilssen 1987, Heubeck 1989a, Lid 1981, Monaghan *et al.* 1989, Nelson 1978, Nettleship *et al.* 1984, Tasker *et al.* 1989, Vader *et al.* 1988). However, studies on adverse effects of overfishing on wintering seabirds are scarce. There are reasons to believe that such effects may occur outside the breeding season (cf. Duffy *et al.* 1987). It was therefore concluded that the massive seabird wrecks in the early 1980s deserved more detailed study. The Netherlands Society for the Protection of Birds formulated the following questions:

(1) What are the energy requirements of wintering seabirds in the North Sea, particularly the most abundant species (Fulmar, Gannet, Kittiwake, Razorbill and Guillemot)?

(2) How large are the fish stocks which are utilized by these seabirds and what developments in stock size and fisheries have occurred in recent years (at least 1970 until today)?

(3) How is the fishery pressure on these stocks and what other factors influence the stock size?

(4) Is there a clear link between fish stock depletion by fisheries or fish stock changes due to other factors and the observed seabird wrecks in the early 1980s?

As it was unclear whether literature and unpublished data would provide adequate information to answer these questions, it was decided to conduct a feasibility study into the potential of a larger project. Questions that had to be answered by the feasibility study were:

(1) Which species of fish are important as prey for the most abundant seabirds in the North Sea, how large are the fish taken by the respective seabirds and what age-groups are mainly utilized?

(2) What sort of data are available on fish stocks, fisheries and the fish distribution in the North Sea?

(3) What sort of data are available on breeding seabirds in the North Sea (population size, reproduction, trends)?

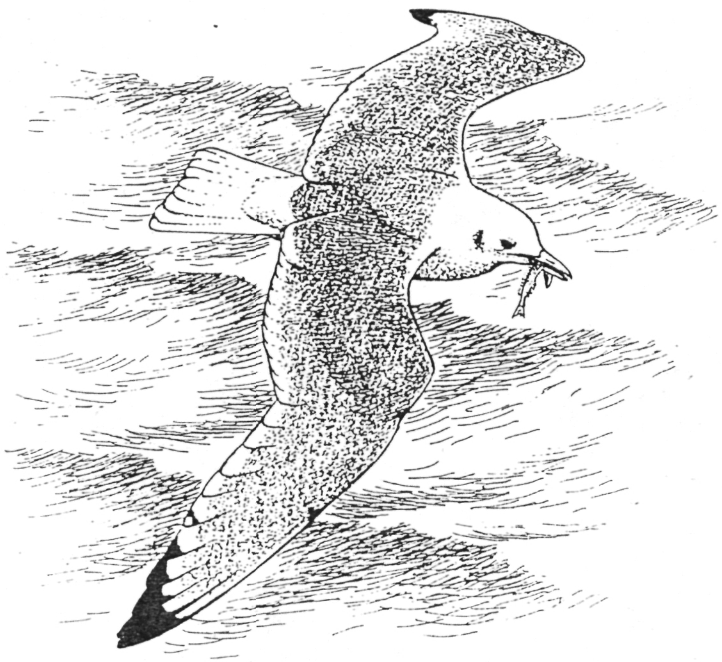
(4) What sort of data are available on populations of seabirds wintering in the North Sea?

(5) Would it be possible to identify causal relationships between changes in fisheries, fish stocks and wintering seabirds in the North Sea?

(6) Which recommendations can be made for a thorough study in terms of research planning, time budget and expenses?

The feasibility study was thus meant to find out what data are available rather than to fully explore these data. It was thought useful to limit this study to the most numerous North Sea seabirds and their food. Emphasis was put on pelagic seabirds, especially those involved in the major wrecks of the 1980s (Kittiwake, Razorbill, and Guillemot). Secondly, attention has been focussed on the years 1970-85 for both seabirds data and information on fish stocks and fisheries. Thirdly, because of the limited time span for this feasibility study, not all important aspects or data sets could be studied and discussed in the same detail. The main aim of this report is to show what data are available, what is missing,

and what can or cannot be done with them. I do not claim to be complete at any level, although I have tried to do so.



2. METHODS

2.1 Study area

The study area for this project in the North Sea, defined as the area between 51° and 62° N including the Shetland and Orkney Islands in the west and the Skagerrak area in the east. Attention in this preliminary report has been focussed on the southern North Sea (south of 56° N). Certain subsectors have been used if necessary to pool data in larger units. Subsectors for fisheries data have been adopted from ICES when possible, while subsectors for seabird data have often been adopted from SAST.

2.2 Selection of bird and fish species

For this feasibility study the most abundant seabirds and fish were selected. In later stadia of the work it was found useful to focus on 5 pelagic seabirds (Fulmar *Fulmarus glacialis*, Gannet *Sula bassana*, Kittiwake *Rissa tridactyla*, Razorbill *Alca torda*, and Guillemot *Uria aalge*) and on their main prey species (Herring *Clupea harengus*, Sprat *Sprattus sprattus*, Cod *Gadus morhua*, Whiting *Merlangius merlangus*, Norway Pout *Trisopterus esmarkii*, sandeels *Ammodytidae*, and Mackerel *Scomber scombrus*). Terns were not selected because they leave the North Sea in winter. *Larus*-gulls were excluded because most species spent much time on land or on inshore waters and because a significant part of their diet at sea consists of offal and discarded fish. The most pelagic gull species, the Lesser Black-backed Gull *Larus fuscus*, leaves the North Sea in winter. Shag *Phalacrocorax aristotelis* and Black Guillemot *Cepphus grylle* were not selected because these are sedentary species occurring mainly inshore. Both species are rare in the southeastern North Sea. Also the Puffin *Fratercula arctica* was not selected because this species is scarce in the southern North Sea.

Of the most abundant fish species in the North Sea only those species were selected which were thought to be important as prey fish for seabirds. Flatfish, rays and sharks were ignored. Besides looking at Herring, Sprat, Cod, Whiting, Norway Pout, sandeels and Mackerel during the extensive surveys in libraries, related species were studied briefly but these were not worked out in this report. In chapter 6 an evaluation of the species selection is presented, together with recommendation for species selection in a future project.

The available data could impossibly be explored fully and it was therefore decided to examplify the possibilities for future study by a more detailed analysis of data for clearly very important species (Guillemot and Sprat).

2.3 Selection of data sets

A further selection was the choice which data sets were to be explored in detail and which were to be largely ignored at this stage. For breeding seabirds, attention was focussed on breeding areas where Dutch wrecked Fulmars, Gannets, Kittiwakes and auks were thought to originate: Britain and Ireland, Iceland, the Faeroes and Norway. Information on the small populations on the

Iberian peninsula, in France and in the Baltic was not collected. Many of the auks found in the Netherlands, considered to be representative of the 'pool' wintering in the southern North Sea, originated from Scottish colonies (Camphuysen in prep., De Wijs 1985). Therefore information on Scottish breeding populations was explored in more detail.

Seabird studies at sea are just set up in most countries around the North Sea and since data are largely unpublished, their use is restricted. Most of the information on seabird distribution at sea had to be taken from Scottish, published sources. Seawatching and strandings data were mainly taken from Dutch sources because these were easily available. Dietary studies selected for this project were preferably those carried out in winter at sea. However, few studies have been published and to obtain an idea of the seabird diets in general, studies at colonies and in the breeding season were included.

In fisheries data, attention has been focussed on information on small fish and younger age-groups. Much attention was paid to surveys carried out by fisheries institutes, particularly to the International Young Fish Surveys because of the time of the year (February) and the sort of information (distribution, densities, length and age of fish). When surveys from fisheries institutes were not available or insufficient, an analysis of landings statistics was chosen instead. The most recent accounts were usually selected, or older papers and proceedings in which an analysis of long-terms trends in fisheries statistics was presented.

2.4 Sources of information

Sources of information were data collected by the International Council for Exploration of the Seas (ICES), published in reports, papers and working group reports. All data on fish stocks and fisheries used in this report were readily available in the library of the Netherlands Institute voor Fisheries Research (RIVO, IJmuiden). Information on seabird populations and trends in Britain were taken from published accounts and preliminary information available from the Seabird Colony Register and in Nature Conservancy Commissioned Research reports. Information on seabird distribution at sea was mainly taken from published work from the Seabirds At Sea Team in Aberdeen. Information on seabird wrecks was taken from published accounts and from the files of the Dutch Beached Bird Survey (Nederlands Stookolieslachtoffer Onderzoek, NSO)". Dietary studies were summarized, both from published work and unpublished studies (NSO files).

2.5 Acknowledgements

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3. SEABIRDS IN THE NORTH SEA: ABUNDANCE, TRENDS, DIET, AND FEEDING HABITS

In this chapter, a description is given of data sets and publications dealing with the status of breeding seabirds in the North Sea, population trends and wintering distribution. Access is given into the vast amount of papers and reports. Chapters 3.4-3.8 give a detailed description of current status and population trends, feeding habits and diets of five seabird species selected for this study. The Guillemot is worked out in more detail to examplify what is available for one species. Even in this species the analysis of the existing literature must be considered as preliminary.

3.1 Breeding numbers

During the last 20 years most of the important seabird breeding areas in the North Atlantic have been visited and numbers of most breeding seabirds here are now reasonably well known (Cramp *et al.* 1974, Cramp & Simmons 1977, 1983, Cramp 1985, Croxall *et al.* 1984, Lloyd *et al.* in press, Nettleship & Evans 1985). Recent estimates of the numbers of seabirds breeding in the North Sea have varied considerably, from 1,987,000 (including Baltic; Bourne 1978) to 4,527,000 pairs (including seabirds breeding on Scottish and English west coast; Dunnet 1987). For 25 seabird species breeding in the North Sea area, recent population estimates have been summarized by Tasker *et al.* (1987) and Dunnet *et al.* (1990) as in table 3.1. The most common breeding species are Fulmar, Herring Gull, Kittiwake and Guillemot.

The breeding numbers of seabirds in the North Sea have been studied quite well after the pioneer work in Britain in the late 1960s/early 1970s (Cramp *et al.* 1974). Detailed mapping and counting of seabirds have also taken place in Norway (Barrett & Vader 1984, Røv 1984), Denmark (Danielsen *et al.* 1986), West Germany (Becker & Erdelen 1987) and the Netherlands (SOVON 1987, Teixeira 1979). However, not in all countries regular monitoring programmes have been established to assess status and trends in recent years. Seabird numbers in arctic regions are, generally speaking, not very well known, and many colonies have not even been accurately censused, let alone that population trends have been assessed (Bakken & Mehlum 1988, Evans 1984ab, Mehlum 1984, Mehlum & Fjeld 1987, Norderhaug *et al.* 1977). The work on breeding populations in northwestern Europe can be summarized as follows:

Iceland with its vast seabird breeding population, is not yet counted completely. Population trends are largely unknown (Evans 1984b, Gardarsson 1982).

Seabird numbers on the *Faeroe Islands* are not particularly well known. Several reports indicate recent declines (Bloch & Sørensen 1983, Dare 1966, Evans 1984b, Joensen 1966, Meltofte 1973, 1975, Olsen 1982, Olsen & Permin 1974). Status and trends of *Danish* seabird colonies are reasonably well known (e.g. Danielsen *et al.* 1986, Dybbro 1985, Joensen 1982, Møller 1975, 1979).

Table 3.1. Recent estimates of numbers of breeding seabirds on North Sea coasts (after Tasker *et al.* 1987 and Dunnet *et al.* 1990).

Species	Breeding numbers	
Red-throated Diver *Gavia stellata*	793	pairs
Fulmar *Fulmarus glacialis*	307,599	pairs
Manx Shearwater *Puffinus puffinus*	250	pairs
Storm Petrel *Hydrobates pelagicus*	>1,000	pairs
Leach's Petrel *Oceanodroma leucorhoa*	>1,000	pairs
Gannet *Sula bassana*	43,778	pairs
Cormorant *Phalacrocorax carbo carbo*	2,222	pairs
Shag *P. aristotelis*	19,804	pairs
Arctic Skua *Stercorarius parasiticus*	3,194	pairs
Great Skua *S. skua*	7,303	pairs
Black-headed Gull *Larus ridibundus*	129,342	pairs
Common Gull *L. canus*	73,332	pairs
Lesser Black-backed Gull *L. fuscus*	49,311	pairs
Herring Gull *L. argentatus*	237,114	pairs
Great Black-backed Gull *L. marinus*	24,436	pairs
Kittiwake *Rissa tridactyla*	415,427	pairs
Little Tern *Sterna albifrons*	2,335	pairs
Arctic Tern *S. paradisaea*	74,729	pairs
Common Tern *S. hirundo*	61,487	pairs
Roseate Tern *S. dougallii*	36	pairs
Sandwich Tern *S. sandvicensis*	30,547	pairs
Guillemot *Uria aalge*	680,434	individuals
Razorbill *Alca torda*	73,115	individuals
Black Guillemot *Cepphus grylle*	23,741	individuals
Puffin *Fratercula arctica*	225,957	individuals
Total (25 species)	about 4 million	individuals

In *Norway* some very large colonies are not visited frequently, but in recent years, partly in response to certain serious declines, much attention is paid to Norwegian seabirds, their status, trends, and breeding success (Anker-Nilssen *et al.* 1984, Bakken & Mehlum 1988, Barrett 1982, 1983, 1984, 1985, Brun 1969, 1979, Folkestad *et al.* 1984, Godø 1985a, 1985b, Munkejord *et al.* 1981, Norderhaug 1983, Strann & Vader 1987, Toft 1983). In order to gather more coherent data concerning population changes of Norwegian seabirds, a detailed national monitoring of Kittiwakes, Guillemots and Puffins was started in 1980 under the aegis of the Norwegian Directorate of Wildlife and Freshwater Fish (Trondheim). Due to limited funds this work has been restricted to three main colonies: Runde (West Norway), Røst (Lofoten) and Hornøy (North Norway) (Barrett 1985). In broad terms, the population trends of breeding seabirds in Norway in 1980 were described as "positive" for northern Norwegian colonies (Øst-Finnmark), "unknown" in Troms and West-Finnmark, "problematic" in western Norway (More & Romsdal to Nordland) and "stable" in southern and southwestern Norway (Folkestad 1984b).

In the *Federal Republic of Germany* the status and changes in numbers of seabirds are studied quite well and what is known is frequently updated (e.g. Becker & Erdelen 1987, Berndt 1981, Fleet 1984, Moritz 1980, Prüter 1983, Taux 1984, 1986, Vauk 1982, Vauk-Hentzelt, Schrey & Vauk 1986).

In the *Netherlands*, where only terns and gulls breed, it is hard to obtain recent updates of numbers and trends. Locally the situation is often quite well known, but few general accounts appeared in recent years (e.g. SOVON 1987, Teixeira 1979). More specific accounts can be found in regional avifaunas, but these offer often rather old data. Recent trends in breeding numbers and breeding success of gulls and terns are published in various papers (e.g. Arbouw 1985, Meininger 1986, Nolet 1988, Rooth 1985, 1989, SOVON 1988, Wanders 1985)

The largest colonies of pelagic seabirds in the North Sea can be found in *Great Britain and Ireland*. In recent years the British Seabird Group and the Nature Conservancy Council have cooperated to recount all British seabird colonies for the Seabird Colony Register (Lloyd *et al.* in press). Monitoring programmes have been developed to detect and measure changes in numbers of breeding seabirds and to describe (national) trends. The monitoring procedures are now fairly standardized, taking account of differences between species, but substantial problems remain in the statistical and biological interpretation of these data (Dunnet *et al.* 1990). The most recent counts, and certain trends in numbers, can now be obtained via the Seabird Colony Register (in Aberdeen). However, important trends and many of the new counts are published instantly in papers or Nature Conservancy Council Commissioned reports (e.g. Benn, Tasker & Webb 1987, Benn *et al.* 1987, Benn, Murray & Tasker 1989, Benn & Tasker 1985, Beveridge 1986, Harris 1989b, 1989c, Harris, Wanless & Smith 1987, Heubeck, Richardson & Dore 1986, Heubeck, Harvey & Okill in prep., Lloyd 1988, Lloyd, Tasker & Partridge in press, Lloyd & North 1987, Monaghan & Zonfrillo 1986, Mudge 1986, 1988, Mudge & Crooke 1986, Richardson *et al.* 1989, Stowe & Harris 1984, Swann 1989, Wanless & Kinnear 1988, Wanless 1987, Wanless, Reynolds & Langslow 1983).

Relatively new are studies to assess the breeding success of seabird populations on a regular basis, often in study plots (Anker-Nilssen 1987, Baber 1989, Barrett *et al.* 1987, Harris 1989ac, Heubeck 1989a, Heubeck *et al.* 1987, Lid 1981, Okill 1989, Rikardsen 1984). It has been shown that breeding success can be extremely low or even nil for prolonged periods (Lid 1981, Anker-Nilssen 1987) before a collapse in the breeding stocks can be noted. Several seabird populations decreased when breeding success was reduced (Heubeck 1989a, Heubeck, Richardson & Dore 1986, Heubeck, Harvey & Robertson 1987). It has also been noted that population declines occurred despite good breeding success (e.g. Swann *et al.* 1989).

References Anker-Nilssen 1987, Anker-Nilssen *et al.* 1984, Arbouw 1985, Baber 1989, Bakken & Mehlum 1988, Barrett 1982, 1983, 1984, 1985, Barrett & Vader 1984, Barrett *et al.* 1987, Becker & Erdelen 1987, Benn 1985, Benn, Tasker & Reid 1987, Benn *et al.* 1987, Benn, Murray & Tasker 1989, Benn & Tasker 1985, Berndt 1981, Beveridge 1986, Bloch & Sørensen 1983, Bourne 1978, Brown & Nettleship 1984, Brun 1969, 1979, Coulson 1983, Cramp 1985, Cramp *et al.* 1974, Cramp & Simmons 1977, 1983, Croxall *et al.* 1984, Danielsen *et al.* 1986, Dare 1966, Dobson & Dobson 1986, Dunnet 1987, Dunnet *et al.* 1990, Dunnet & Ollason 1978, Dybbro 1985, Evans 1984ab, Fleet 1984, Folkestad 1984b, Folkestad, Follestad & Valde 1984, van Franeker *et al.* 1986, Gardarsson 1982, Godø 1985ab, Golovkin 1984, Griffiths 1984, Harris 1989abc, Harris *et al.* 1987, Harvey *et al.* 1989, Heubeck 1989, Heubeck *et al.* 1986, 1987, in prep., Hudson 1985, Isenmann 1976-77, Joensen 1966, 1982, Lid 1981, Lloyd 1988, Lloyd *et al.* (in prep.), Lloyd & North 1987, Mehlum 1984, Mehlum & Fjeld 1987, Meininger 1986, Meltofte 1973, Møller 1975, 1979, Monaghan & Zonfrillo 1986, Moritz 1980, Mudge 1986, 1988, Mudge & Crooke 1986, Munkejord, Folkedal & Halvorsen 1981, Nelson 1978, Nettleship & Evans 1985, Nolet 1988, Norderhaug 1983, Norderhaug, Brun &

Mollen 1977, Okill 1989, Ollason & Dunnet 1983, Olsen 1982, Olsen & Permin 1974, Prüter 1983, Richardson et al. 1989, Rikardsen 1984, Rooth 1985, 1989, Rov 1984, Salomonsen 1971, SOVON 1987, 1988, Spaans & De Wit 1986, Stowe & Harris 1984, Strann & Vader 1987, Swann 1989, Swann et al. 1989, Tasker 1983, Tasker, Moore & Schofield 1988, Taux 1984, 1986, Teixeira 1979, Thomas 1988, Toft 1983, Tschanz & Barth 1978, Vader & Barrett 1982, Vauk 1982, Vauk-Hentzelt, Schrey & Vauk 1986, Wanders 1985, Wanless & Kinnear 1988, Wanless 1987, Wanless et al. 1983, Ward 1987.

3.2 Migration and wintering

Systematic seabird studies at sea in the North Sea are relatively new. W.R.P. Bourne & T.J. Dixon have studied seabird distribution, particularly in the northern North Sea, during 1971-73. Few published data are available from this work (e.g. Bourne 1976), and those that have been produced are of limited use for comparative purposes (Blake et al. 1984). It was not until 1979 that the start was given for a new, much more systematic approach when the Seabirds At Sea Team (SAST) was founded (Blake et al. 1980). A very important step forward meant the establishment of a uniform method of observing and recording birds at sea from a ship (Tasker et al. 1984). When their final report appeared, in 1984 (Blake et al. 1984), the first true atlas of seabird distribution in the North Sea was available. SAST 2 was the follow-up for this project, mainly to fill in gaps. In the mean time more and more countries around the North Sea became interested in systematic seabird studies at sea. It was in the late 1980s that Norwegians, Danes and Dutch researchers "set out to sea', and a wealth of information on the distribution of seabirds at sea can be expected in the near future. Few of the data are now published, apart from the Scottish investigations in SAST 1 and SAST 2 (e.g. Blake et al. 1984, Blidberg 1986, Camphuysen & Platteeuw 1988, Danielsen et al. 1987, Durinck et al. 1987, Leopold 1984, Tasker et al. 1985, 1986, 1987), but many more contributions may be expected within the next few years.

Besides ship-based surveys, seabirds are counted from the air (e.g. Baptist 1988, Tasker et al. 1987, Webb & Tasker 1988) and from fixed installations at sea (e.g. Camphuysen et al. 1982, Dixon 1980, Grimminger 1981, van der Ham 1988b, Hope Jones 1979ab, den Ouden & Camphuysen 1983, Platteeuw et al. 1985, Tasker et al. 1986). Results from a long established scheme in the Netherlands, counting seabirds from the air in the Dutch sector of the North Sea (H.J.M. Baptist, Dienst Getijdewateren, Rijkswaterstaat), will hopefully be published soon. This scheme, together with the much more recently started ship-based surveys organised by the Club van Zeetrekwaarnemers (Camphuysen & Platteeuw 1988) and the Nederlands Instituut voor Onderzoek der Zee (Mardik Leopold), can be important in the reconstruction of the apparently changeing status of wintering seabirds in the southern North Sea in the late 1980s. The Scottish (SAST) data provide information covering the early 1980s and these data are considered vital for such an analysis. Unfortunately, the late 1970s were not or only poorly covered (cf. Tasker et al. 1987).

Another important source of data are seawatching results. Since 1973 seawatching is carried out extensively in the Netherlands. A first analysis was published covering 1974-79 (Camphuysen & van Dijk 1983), and several updates have been prepared since (list of CvZ reports and papers in Van der Ham 1988a). This set of data can be used to demonstrate differences in seabird

numbers in the southern North Sea between the 1970s and the 1980s. Seawatching is carried out in Britain, Denmark, France and elsewhere, but seldom on a scale and with an uniform approach which can be compared with the Dutch (e.g. Hope Jones & Tasker 1982, Meltofte & Fjaldborg 1976, many Danish, British, Swedish, French reports, not listed here). However, also these sets may offer valuable additional information on the wintering and migration of seabirds and on changing patterns. Important sites of which data could be compared are Blåvandshuk (Denmark), Hondsbossche Zeewering (Netherlands), Cap Gris Nez (France), and Flamborough Head (England).

Wintering populations are largely unknown because so few attention is given to this aspect. From densities, derived from systematic surveys at sea, it is possible to calculate the number of birds present in a given area. Despite all effort, complete cover of all of the North Sea area has not been achieved in any year with ship-based surveys, and estimates of the North Sea wintering populations from these surveys are therefore difficult to make. It is quite possible, however, to select certain study areas where adequate cover exists and to calculate the number of birds in such an area.

Immigration into the North Sea is known to exist in winter as good as birds are known to leave the North Sea for wintering "grounds" further south or in the open Atlantic. Ringing programmes could indicate to what extend immigration takes place or at least where the birds from different colonies can be found outside the breeding season. However, substantial ringing took place in very few of the arctic and subarctic colonies and little is therefore known from the wintering areas of important populations such as breeding birds from Iceland, northern Norway and the Faeroes. Estimates of the North Sea wintering populations are not simply "breeding adults + newly fledged birds + immatures" of the North Sea stock, but these should also take immigration and emigration into account. In each of the species account in this report the problems in assessing wintering numbers will be briefly discussed.

References Baptist 1988, Benn 1985, Benn et al. 1988, Blake et al. 1984, Blidberg 1986, Blake et al. 1980, 1984, Boer 1971, Bourne 1976, Burton et al. 1987, Camphuysen et al. 1982, Camphuysen & van Dijk 1983, Camphuysen & Platteeuw 1988, Danielsen et al. 1987, Dixon 1980, Durinck et al. 1987, Grimminger 1981, van der Ham 1988ab, Hauge & Folkedal 1980, Hope Jones 1979ab, Hope Jones & Tasker 1982, Joiris 1978, 1983ab, Leaper et al. 1988, Leopold 1984, Meltofte & Faldborg 1987, Oliver 1976, den Ouden & Camphuysen 1983, Platteeuw et al. 1985, Schonart 1978, Tasker 1980, Tasker & Pienkowski 1987, Tasker et al. 1984, 1985, 1986, 1987, Webb & Tasker 1988, Webb et al. 1985.

3.3 Diet of seabirds

Results of dietary studies are very important for the project now proposed. Unfortunately, most studies are carried out in colonies and thus in the breeding season. The reasons for this are obvious: many seabirds only return to land in that period and above that they carry "extra" loads of food onshore to feed their chick. Food samples at sea are in fact only obtained in sufficient quantities for statistical analysis by shooting (thus killing) the birds, whereas on colonies many food loads are simply dropped on land, can be obtained through regurgitations, or the contents can be seen, identified and even measured (weighed, size

estimated by comparison with bill length; Drent 1965, Gaston & Nettleship 1981) without even handling the birds. Summarized, food samples in dietary studies can be obtained by (from Dunnet *et al.* 1990):

(1) *shooting* (or otherwise killing the birds, dissection of alimentary tract; e.g. Anker-Nilssen & Nygård 1987, Bierman & Voous 1950, Erikstad & Vader in press, Morejohn *et al.* 1978, Pearson 1968, Vauk & Jokele 1975);
(2) *dissection of birds found dead* on the beach, drowned in nets or in colonies (e.g. Blake *et al.* 1985, Camphuysen in press, Vauk-Hentzelt & Bachmann 1983);
(3) *stomach pumping living birds* (Gales 1987, Ryan & Jackson 1986);
(4) *collection of regurgitated food* of disturbed or simply handled birds (some species have a natural tendency to regurgitate in these circumstances; e.g. Camphuysen & van Franeker 1988, Galbraith 1983, Martin 1989), flight netted Puffins drop any fish they are carrying (Harris & Hislop 1978, Martin 1989, Vermeer 1979);
(5) *examination of pellets or faeces* (Hudson & Furness 1988);
(6) *direct observations* in the field (of food being consumed, carried, fed to chicks, or dropped at colonies; e.g. Birkhead & Nettleship 1987, Benn 1985, Beveridge 1986, Boswall 1960, Burtt 1974, Griffiths 1984, Harris 1970, Harris & Wanless 1985, Pearson 1968, Tasker 1983, Thomas 1988, Wanless *et al.* 1983, Ward 1987, Watson 1981).

All these methods have advantages and disadvantages, but more importantly it is very difficult to make comparisons between studies when different methods are used. Studies of stomach contents by dissection of the alimentary tract, especially of birds found dead rather than just killed, are seriously biased towards slow digesting remains (otoliths, squid beaks, Polychaete worm jaws), while also among these remains different rates of digestion occur (Bradstreet 1977, Blake 1984). Recording the diet in the field, through direct observations of feeding birds, is restricted to daylight conditions, while the diet may change considerably at night in response to vertical movements towards the sea surface of zooplankton, squid, or fish (Digby 1961). Some considerations, necessary for a correct interpretation of sections dealing with the diet of seabirds, are:

Regurgitated food Samples of regurgitated food provide insight into the last meal of a bird. When disturbed or handled, several seabirds readily regurgitate (e.g. Gannets, Fulmars), others must be forced to do so. From personal experience with Fulmars I know that the regurgitated food is usually only part of the contents of the proventriculus.

Stomach pumping Studies of the diet through regurgitated matter alone is usually regarded as unsatisfactory (see above) and stomach pumping (or "Water Off Loading") the birds can be an improvement. However, in several species (e.g. Procellariiformes) this method obtains only the contents of the proventriculus while hard and slow digesting items remain in the gizzard (Dunnet *et al.* 1990). The advantage of stomach pumping birds is that even remains that are usually rapidly digested may be obtained (e.g. zooplankton) in such a condition that the size of these small animals can be assessed by direct measuring or by measuring essential parts (Bradstreet 1980), without the necessity to kill the bird.

Pellets Cormorants/shags, skuas, gulls, and terns regurgitate hard parts as pellets (e.g. otoliths, bones, plastics, etcetera). There is a probability that only larger otoliths are regurgitated, while small and fragile otoliths may be voided through the intestine (Dunnet *et al.* 1990). Great Skuas regurgitate even the smallest sandeel otoliths, while Great Black-backed Gulls void all sandeel otoliths in

faeces while regurgitating otoliths from gadoids Hudson & Furness 1988).
Otoliths Otoliths, or ear stones, are unique in the sense that they are not parts of the skeleton of fish, but integral and specialised hard parts of the acoustico-lateralis system (Nolf 1985). For stomach analysis of birds these otoliths are extremely useful, not only because they are often the last remaining objects from the entire fish in the digestive tract, but especially because they are useful to identify the fish eaten, to back-calculate the size of this fish, and to determine its age (Breiby 1985, Gaemers 1974, Härkönen 1986, Jobling & Breiby 1986, Reay 1972, Werner 1963). However, when the diet is studied through otoliths alone (either from pellets, faeces or stomach contents), one should realize that the size of prey items calculated from otoliths can be unreliable because of erosion (Uspenski 1958). Studies of the composition of the diet are biased towards relatively large otoliths such as otoliths from gadoids. Of some species otoliths are tiny or fragile (e.g. clupeids, Mackerel), and these are easily overlooked. Bradstreet (1977) indicated that the number of large otoliths (such as gadoids) found in the gizzard is a reasonable index of the number of ingested fish only within 12-24 hours of death.

Pter-otic/Pro-oticbullae The presence of clupeid remains can be determined from the presence of pro- or preotic bullae (Blake 1983, Blaxter & Hunter 1982). The chance to find these bullae is considerably larger than the chance to find the tiny and fragile otoliths, especially from small Sprat or Herrings (NSO files). Apparently this is not very well known and therefore the presence of clupeid is probably overlooked in many studies.

Zooplankton Most of the zooplankton is easily digested by seabirds and little or no (identifiable) remains are found in the digestive tract within few hours. Zooplankton is not usually carried in a way that field observations alone are sufficient to study the amount and species represented in the diet. Stomach pumping or shooting/killing are necessary to have an idea of the quantities taken and of the relative proportion in the diet.

One has to be careful not be too general about the diet as this can change dramatically within a season or from place to place (Blake *et al.* 1985, Harris 1984b). Just as Dunnet *et al.* (1990) concluded: "Obtaining an accurate picture of the diet of a seabird species throughout the North Sea would require regular (e.g. monthly) shooting of samples of at least 30-50 birds at a wide variety of localities." Since this is not the present practice, our knowledge of the diet of the North Sea seabirds, particularly outside the breeding season, is extremely fragmented and incomplete.

References Anker-Nilssen & Nygård 1987, Benn 1985, Beveridge 1986, Bierman & Voous 1950, Birkhead & Nettleship 1987, Blake 1983b, 1984, Blake *et al.* 1985, Boswall 1960, Bradstreet 1977, 1980, Breiby 1985, Burtt 1974, Camphuysen in press, Camphuysen & van Franeker 1988, Digby 1961, Drent 1965, Duffy & Jackson 1986, Dunnet *et al.* 1990, Erikstad & Vader in press, Gaemers 1974, Galbraith 1983, Gales 1987, Gaston & Nettleship 1981, Griffiths 1984, Härkönen 1986, Harris 1970, 1984b, Harris & Hislop 1978, Harris & Wanless 1985, Jobling & Breiby 1986, Martin 1989, Morejohn *et al.* 1978, Nolf 1985, Pearson 1968, Reay 1972, Ryan & Jackson 1986, Tasker 1983, Thomas 1987, Uspenski 1958, Vauk & Jokele 1975, Vauk-Hentzelt & Bachmann 1983, Vermeer 1979, Wanless, Reynolds & Langslow 1983, Ward 1987, Watson 1981, Werner 1963.

3.4 Fulmar *Fulmarus glacialis*

3.4.1 North Atlantic breeding population and trends

Population The north Atlantic population of the Fulmar increased spectacularly during the last 200 years (Fisher 1952). Recent estimates of the North Atlantic breeding population are 360,000 pairs on the northeastern coasts of North America (mainly Baffin Bay and Davis Strait; Brown & Nettleship 1984), 192,000-226,000 pairs in Greenland (Evans 1984a), 305,639 pairs in Britain and Ireland, 100,000->1,000,000 in both Faeroe and Iceland (Evans 1984b), 60,000-100,000 on Jan Mayen (van Franeker *et al.* 1986), 2500-3000 in Norway (Barrett & Vader 1984), 30,000 pairs on Bear Island and 50,000-1,000,000 pairs on Spitsbergen (Evans 1984b), 12,500 on Franz Josefland and Novaya Zemlya (Golovkin 1984). Very small breed numbers in France and in the North Sea on Helgoland (36 nest sites) and in SW. and W. Norway (60 and 82 nest sites respectively; Evans 1984b, Tasker *et al.* 1987). This brings us to a maximum estimate of just over 4,000,000 pairs of Fulmars. However, it should be noted that the maxima given for the Faeroes, Iceland and Spitsbergen are wild guesses rather than accurate assessments and my personal feeling is that the 1,000,000 pairs as maxima, at least for the Faeroes and Spitsbergen, are extreme overestimates. Breeding in the British Isles (except St. Kilda) was first recorded on Foula in 1878 and a rapid colonization of Britain took place since that time. At present, the North Sea population is estimated at *c.* 310,000 occupied sites, with Shetland (208,314) and Orkney (63,358) as strongholds (Tasker *et al.* 1987).

Trends The increase in numbers has stopped in several North Sea colonies in recent years. In Orkney, numbers at study plots increased at 5.5% per annum until 1982, but have since decreased at 8.1% per annum until in 1985 they were almost back to the 1976 level (Benn *et al.* 1987). In Shetland, the number of chicks ringed in the Yell Sound islands has fallen by *c.* 60%, despite relatively constant observer effort. Systematic studies of breeding success commenced only in 1985 in the archipelago, but a decline in chicks produced has been recorded in all study plots since that time (Okill 1989). Fulmar production at five colonies around the British Isles in 1988 was lower than in 1987 (Harris 1989a). On Troup and Pennan Heads colonies (S Moray Firth), numbers increased during the 1970s, but stabalized and declined in the early 1980s (Lloyd & North 1987), apparantly in response to food shortages. On St Kilda, a breeding site of Fulmars since many centuries, seemed to increase again in recent years at 3.6% per annum (43,977 sites in 1977, 62,786 sites in 1987; Tasker *et al.* 1988). In Norway in the early 1980s numbers increased in all colonies (Finnmark, Troms, Lofoten, Trøndelag, Møre and Romsdal; Folkestad 1984b).

References Barrett & Vader 1984, Benn, Tasker & Reid 1987, Brown 1970, Brown & Nettleship 1984, Evans 1984ab, Fisher 1952, Folkestad 1984b, van Franeker, Camphuysen & Mehlum 1986, Golovkin 1984, Harris 1989a, Lloyd & North 1987, Moritz 1980, Munkejord, Folkedal & Halvorsen 1981, Okill 1989, Ollason & Dunnet 1983, Tasker *et al.* 1987, 1988.

3.4.2 Estimates of North Sea wintering population

Fulmars disperse from their breeding colonies in winter and although Fulmars are migratory, a substantial part of the North Sea breeding population probably remains in the North Sea in winter (Cramp & Simmons 1977, Tasker *et al.* 1985a). Immigration from more northerly colonies (e.g. Faeroes, Iceland) in winter is likely to occur, but arctic birds (dark phase) are relatively scarce in most winters (Tasker *et al.* 1985a). Massive wrecks have occurred in winter with many arctic birds involved (e.g. Pashby & Cudworth 1969) and major fluctuations in their pelagic distribution occur at all seasons in response to weather and probably to feeding conditions. The scale of immigration into the North Sea in winter has never been properly assessed and therefore estimates of wintering numbers are rough guesses rather then sensible estimates. Fulmars were found to occur in high densities in the northern North Sea in winter (Tasker *et al.* 1987) and a regular exchange of birds with the open ocean can be expected. Danielsen *et al.* (1986) assumed that the entire northeast Atlantic breeding population, estimated at 4,000,000 individuals, could occur in the North Sea area. My personal guess would be that indeed, wintering numbers of this highly mobile bird are millions rather than hundreds of thousands, but that fluctuations occur at such a scale as a result from mass-movements into the North Sea and out again into the North Atlantic, that we hardly can speak of "the North Sea wintering population" comparing one year with another. From seawatching results and strandings data in the southern North Sea it can be concluded that Fulmars are more numerous as scavengers behind trawlers in recent winters (1980s) than before (1970s), and that Fulmars occur in widely fluctuating numbers throughout the year but that they have probably increased as a wintering species since the 1970s (Camphuysen 1987, 1989a, CvZ reports 1974-90).

References Camphuysen 1987, 1989a, Club van Zeetrekwaarnemers (CvZ) reports 1974-90, Cramp & Simmons 1977, Danielsen, Durinck & Skov 1986, Fisher 1952, Pashby & Cudworth 1969, Tasker *et al.* 1985a, 1987.

3.4.3 Feeding methods and diet

Fulmars feed on the surface and have only very limited diving capacity (probably less than 1 metre depth). Most of the food is obtained when swimming, pecking up small particles from the surface. In the arctic Fulmars rely mainly on zooplankton and small fish occurring near the surface. They are well known as scavengers behind trawlers and Tasker *et al.* (1985a) found that North Sea Fulmars feed extensively on fish offal in winter. Also North Sea Fulmars, however, are quite capable to fish for themselves for shoaling fish near the surface. Around Foula, during daytime Fulmars are regularly splash-diving on surface shoals of sandeels (Furness & Todd 1984). Their feeding range is considerable and their diet is extremely varied. In literature the following is mentioned (references listed below):

Fish (fish offal, Gadidae (Saithe, Ling, Clupeidae (Herring, Stomiatoidei (Myctophiformes), and Ammodytidae (Raitt's sandeel))
Mollusca (Gastropoda (Pteropoda (sea-snails) *Clione limacina, Limacina limacina, Limacina arctica*), and Cephalopoda (squid, lenses and beaks via whale faeces or by taking squid themselves))
Chaetognatha (e.g. *Sagitta elegans arctica*)

Crustacea (Euphausiacea (*Thysannoessa inermis*, *Meganyctiphanes norvegica*), Amphipoda (*Hyperia*, *Gammarus*, *Parathemisto libellula*, *Parathemisto abyssorum*, *Pseadalibrotus littoralis*, *Hyperoche Kröyeri* (taken via host jellyfish ?), *Gammarus locusta*, *Euryporeia gryllus*), Schizopoda, Isopoda (*Idotea metallica*), Copepoda (*Calanus hyperboreus*, *Calanus finmarchius*), Cumacea (*Mysis oculata*, *Hymenodora glacialis*, *Gnathopausia zoea*), Decapoda (*Parapasiphaea sulcatifrons*) and crab larvae)
Annelida (Polychaeta, *Nereis spp.*)
Coelenterata (Siphonophores (Ctenophora *Beroe spp.*, Scyphozoa (*Cyanea capillata*), and Scyphomedusae)
carrion (meat and blubber of whales (*Monodon monoceros*, *Hyperoodon ampullatus*), walrus *Odobenus rosmarus*, seals, Polar Bear *Ursus maritimus*, birds (*Turdus iliacis*, *Fratercula arctica*, *Plectrophenax nivalis*))
vegetable matter as brown algae *Ascophyllum nodosum*, Scurvy grass *Cochlearia officinalis*, sedges *Carex spp.*, Alpine bistort *Polygonum viviparum*, *Potentilla spp.*, Common sorrel *Rumex acetosa*
grit and plastics and finally Fulmars have been seen drinking floating whale- or fish-oil at sea.

This list is incomplete, my own unpublished studies in arctic waters show that many species of fish and plankton can be added, but it gives an idea of the catholic feeding habits of the Fulmar. Within the North Sea much of its diet is thought to consist of offal and discards. The competition behind fishing boats is considerable, leading to the establishment of a dominance hierarchy. In the northern North Sea, Fulmars are dominant and obtain almost all the offal (Hudson 1986).

Breeding season Fulmars on Foula (Shetland) were extensively feeding on sandeels during 1971-80 and breeding success was good. In all, the identified food samples regurgitated by Fulmars on Foula in these years comprised by frequency of occurrence of sandeels (72.3%), offal (13.6%), pelagic zooplankton (10.7%; mainly Euphausids), cephalopoda (0.6%) and paper, plastics and polystyrene (2.8%; Furness 1983). In 1988, when breeding success was poor and sandeels were largely unavailable for surface feeding seabirds, they relied mainly on discards and sandeels comprised only 3% of their diet (Furness 1989b). In a comparison between diets and feeding of Fulmars breeding on St Kilda and on Foula it was found that the first relied mainly on zooplankton, the latter on fish (mainly sandeels; Furness & Todd 1984). The dietary overlap between the two colonies was only 14% by species composition. Herring or Sprat were the only fish found in diets on St Kilda, while on Foula 100% consisted of sandeels. Benthic invertebrates occurred rather frequently on St Kilda but were not found on Foula. Fowler & Dye (1987) recovered sandeel otoliths from Fulmars breeding on Shetland in 1984 and 1985 and estimated that sandeels of a size range 60-160 mm were taken. Comparison with other studies showed that sandeels taken by Fulmars were slightly smaller than those taken by Great Skuas, but slightly larger than those picked up by Arctic Terns. There was considerable overlap in the sizes of sandeels captured by Fulmars and fishermen, with a tendency for Fulmars to take the smaller end of the distribution range.

Non-breeding season Tasker *et al.* (1985a) found that Fulmars fed extensively on fish offal in winter and that the distribution of this species at sea outside the breeding season has to be considered in relation to the activities of the fishing industry. Behind trawlers Fulmars are mainly interested in offal. Discarded fish was only swallowed whole when very small. Alternatively, when there was a lull in the discharge of offal, Fulmars ripped open the bellies of discarded whole fish to feed on the liver and guts (Hudson & Furness 1989). The median length of experimentally discarded fish in a study in Shetland in summer 1985 was 28 cm

for Haddock and 29 cm for Whiting. The mean length of these fish known to have been swallowed whole by Fulmars was 23.0 ± 0.36cm for Haddock (range 15-30 cm) and 24.1 ± 0.56cm for Whiting (range 14-29cm; Hudson & Furness 1988). Hudson & Furness (1988) described which discarded fish were selected (species and size preferences). Few flatfish were taken and Red Gurnards proved to be less popular than Grey Gurnards, Whiting, Haddock and Norway Pout. From personal observation I can add that discarded Herring and Sprat is readily taken by Fulmars and often swallowed whole while gadoids of the same size is ripped apart.

Preferred fish: species and size Although an omnivore, the Fulmar in the North Sea area is likely to depend largely on fish as food. As an offal eating seabird the size of fish is of little importance. Fulmars are known to rip larger prey and carrion apart into pieces they can manage. From British breeding locations it is known that Fulmars can rely on sandeels and clupeoids. Self-captured fish are rather small, probably less than 20 cm long, shoaling species occurring near the surface. Gadoids and clupeoids are preferred from discards above flatfish and gurnards.

References Bauer & Glutz von Blotzheim 1966, Boswall 1960, Bradstreet 1977, 1978, Brown 1970, Camphuysen & van Franeker 1988, Cottam & Hanson, 1938, Cramp & Simmons 1977, Cramp, Bourne & Saunders 1974, Dementiev & Gladkov 1951, Duffey & Sergeant 1950, Fisher 1952, Fowler & Dye 1987, Furness 1989b, Furness & Todd 1984, Harrison 1984, Hartley & Fisher 1936, Hudson 1986, Hudson & Furness 1988, 1989, Köhler 1820, Kolthoff 1903, De Korte 1972, Lovenskiold 1964, Malmgren 1864, Martens von Hamburg 1675, Munsterhjelm 1911, van Oordt 1921, Oustalet 1898, Palmer 1962, Salomonsen 1950, Scoresby 1820, Stott 1936, Voous 1949, Witherby *et al.* 1940, Zelickman & Golovkin 1972.

3.5 Gannet *Sula bassana*

3.5.1 North Atlantic breeding population and trends

Population The eastern Atlantic population held 84.9% of the total North Atlantic Gannet population of *c.* 263,200 sites in 1984-85. The Gannets stronghold is Scotland, with twelve colonies including the largest Gannetry in the North Atlantic (St Kilda, 50,100 occupied sites) and major colonies on Ailsa Craig (22,800 sites) and Bass Rock (21,600 sites). Population estimates of the Gannet for 1984-85 are summarized by Wanless (1987) as follows (occupied sites unless otherwise stated): France 4,600; Channel Isles 3,850; Ireland 23,950; Wales 28,600; England 530; Scotland 132,130; Faroe islands 1,980; Iceland 25,490; Norway 2,300 nests. The East Atlantic population was estimated at 223,400. The West Atlantic population amounted to 39,800 pairs (Eastern Newfoundland 11,937, Gulf of St. Lawrence 27,835). Adding these figures the world population can be estimated at 263,200 sites.

The North Sea holds six colonies, estimated at 44,000 pairs, or 16.7% of the world population (Tasker *et al.* 1987, Wanless 1987). Large colonies are situated on Noss, Shetland (6,900 occupied sites), Hermaness, Shetland (14,400 sites) and Bass Rock (mentioned above). Small colonies are found on Foula, Shetland (210 sites), Fair Isle, Shetland (138 nests) and Bempton Cliffs, England (530 sites).

Trends The North Atlantic Gannet increased over most of its range during this century (Nelson 1978, Wanless 1987). In Britain, Ireland, France and Channel Islands the numbers are still increasing, but with a slight decrease in rate as compared to 1949-69. In the Faeroe Islands the numbers are more or less stable since 1960. Norway is colonized quite recently (1946 first breeding), and numbers are increasing rapidly. New colonies are still being founded in Norway at intervals, but the total population is now growing at a lower rate than between 1950 and 1970. In Canada, population trends are variable, with some colonies increasing, but others stable or decreasing. All in all the North Atlantic population is still increasing (2.0% per annum from 1969/70 to 1984/85). The Gannet population has increased during the widespread collapse of the Herring and Mackerel fishery (Wanless 1987). Breeding succes is still unchanged in Shetland in recent years, paralleling the increase in occupied sites (Okill 1989), despite the reduced availability of sandeels.

3.5.2 Estimates of North Sea wintering population

Gannets, especially juveniles and immatures, are highly migratory and the majority of the North Sea population is known to leave for the winter. Young Gannets move as far south as West Africa and the mediterranean, while older birds usually stay in the Bay of Biscay, the English Channel or in the North Sea (Nelson 1978). In mild winters substantial numbers of Gannets are sometimes found to stay in the immediate vicinity of the breeding colonies (cf. Robinson 1935). Usually, however, Gannet densities at sea in winter (Nov-Feb) are very low and immatures are virtually absent until May (Tasker *et al.* 1985b, 1987). There is no evidence that Icelandic or other more northerly breeding Gannets use the North Sea as an important wintering area and we may therefore expect the wintering population being considerably less than the breeding population. Considering that at least all imatures have left the North Sea, the wintering population may be as low as some 10,000 individuals or perhaps even less.

References Camphuysen 1990a, Leopold & Platteeuw 1987, Lindgren 1985, Nelson 1978, Robinson 1935, Schrey & Vauk 1987, Tasker *et al.* 1985b, 1987.

3.5.3 Feeding methods and diet

Gannets are plunge divers which occasionally perform opportunistic dives. These dives are either suddenly, or they first rise slightly, even hover, and than dive. When really among fish they dive from various heights (sometimes from over 50 m heigth) and angles, and immediately before entry they fold their wings back, entering the water like an arrow. The maximum depth reached with this method is probably no more than 10 or 15 metres, either or not aided by swimming with half-open wings in search for prey, and usually less than 5 metres. It is quite certain that Gannets dive at random, and then strike or follow fish when under water. It seems likely, and can be seen at times, that fish are seized as the bird comes up from below them. The impact of the plunge dive may well dazzle and disorientate the shoals of fish for a while. The fish is usually swallowed under water, only large individuals are brought to the surface, and Gannets rarely take

wing with their prey still in the beak. Gannets often dive solitarily, but the pure white plumage of the Gannets, together with its spectacular diving performance, are effective social signals, attracting other Gannets and other seabirds to the fishing area. Scores of a number of tens of Gannets, or even many hundreds, may assemble in areas with good fishing (mainly from Nelson 1978, 1980). Recorded prey species in the East Atlantic Ocean are (from Martin 1989, Nelson 1978, Reinsch 1969):

Herring *Clupea harengus*, Sprat *Sprattus sprattus*, Pilchard *Clupea pilcharda*, shad *Alosa spp.*, Anchovy *Engraulis encrasicolus*, salmonids *Salmo spp.*, Smelt *Osmerus eperlanus*, Capelin *Mallotus villosus*, Argentine *Argentina sphyraena*, Greater Argentine *Argentina silus*, Cod *Gadus morhua*, Haddock *Melanogrammus aeglefinus*, Whiting *Merlangius merlangus*, Blue Whiting *Micromesistus poutassou*, Poor Cod *Trisopterus minutus*, Norway Pout *Trisopterus esmarkii*, Bib *Trisopterus luscus*, Pollack *Pollachius pollachius*, Saithe *Pollachius virens*, ling *Molva spp.*, Hake *Merluccius merluccius*, eelpout *Lycodes spp.*, Garfish *Belone belone*, Red-fish *Sebastes marinus*, gurnard *Trigla spp.*, Red Gurnard *Aspitrigla cuculus*, Scad *Trachurus trachurus*, sea-breams *Pagellus spp.*, mullets *Mullus spp.*, Catfish *Anarhichas lupus*, sandeel *Ammodytes spp.*, Mackerel *Scomber scombrus*, Plaice *Pleuronectus platessa*, Dab *Limanda limanda*, Lemon Sole *Microstomus kitt*, Long Rough Dab *Hippoglossoides platessoides*.

Not all fish is necessarily caught by Gannets themselves: they are well known as trawler attendants and readily take discarded fish. Part of their success in obtaining discards is due to their ability to dive deep for fish that has already sunk (Hudson & Furness 1989). Gannets are rarely observed to take offal.

Breeding season The maximum fishing range during the breeding season is estimated to be at least 170 nautical miles (320 km; Nelson 1978). Tasker *et al.* (1985), however, found that fishing trips of North Sea Gannets rarely exceed 80 nm (150 km) and that most trips are below one-third of that distance. Martin described the changeing diet in Gannets breeding on Hermaness, Unst, Shetlands, during 1981-88 and found that sandeels was the only species in respectively 90%, 62%, 37%, 15%, 14%, and 6% of the 1981, 83, 84, 86, 87, and 88 identifiable bolus samples (regurgitated matter). Herring, and to a lesser extent gadoids and Mackerel, gained importance in the Gannet diet, particularly after 1986. In Gannet chick regurgitates on Sula Sgeir in June 1986 sandeels predominated (percentage of occurrence 75.6%), with occasionally Blue Whiting (8.9%), Herring (4.4%), Argentines (2.2%), Redfish (2.2%) and unidentified fish (Benn *et al.* 1987).

Non-breeding season Winter life of Gannets is nomadic. Adult and immatures have been observed attending the North Sea Herring fleets in Oct and Nov and wherever they find large shoals of Sprat (from the English Channel to beyond the Moray Firth), feeding flocks of several hundreds strong may be seen during winter (Nelson 1978). In a mild winter, when fish was abundant, many Gannets were found not even to leave the Bass Rock (Robinson 1935).

The spawning stocks of Herring declined all over the North Sea to a minimum in 1975 (Corten 1986). Northern North Sea Herring increased again in the 1980s after the closure of the fishery. The breeding Herring stocks around Shetland remain fairly dispersed until July, when the fish congregate in dense shoals prior to spawning in August and September (Tasker *et al.* 1985b). These spawning fish are 25-35cm or longer, and large shoals would provide ideal food for Gannets. Also the central and southern stock have increased considerably

after the minimum in the mid seventies. Exceptionally large numbers of Gannets in autumn in Dutch inshore waters in 1979, 1985, and 1986 were apparently attracted by large quantities of Herring (Leopold & Platteeuw 1987). Tasker *et al.* (1985b) recorded an apparent delay in the southward migration in the southern North Sea in Oct and Nov. It seemed likely that the Gannets were exploiting concentrations of Sprat and sandeels occurring off eastern Scotland and northeastern England.

Preferred fish species and size Nearly all common North Sea fish have been recorded at some time, but pelagic shoaling fish as Herring and Mackerel are the Gannet's main food fish, with Sprat, Saithe and sandeels being also important (Nelson 1978). Gannets can handle rather large fish and may utilize older age-groups of gadoids and Herring that other seabirds can possibly do. Fish of over 30 cm length are easily swallowed (Hudson & Furness 1989).

References Benn *et al.* 1987, Boddington 1959, Corten 1986, Friesen *et al.* 1986, Hudson & Furness 1988, 1989, Leopold & Platteeuw 1987, Martin 1989ab, Montevecchi 1986, Nelson 1978, 1980, Okill 1989, Reinsch 1969, Robinson 1935, Tasker *et al.* 1985b, Wanless 1984.

3.6 Kittiwake *Rissa tridactyla*

3.6.1 North Atlantic breeding population and trends

Population The total North Atlantic breeding population of the Kittiwake can roughly be estimated at 1,500,000-5,000,000 pairs, with some 140,000-1,150,000 pairs on Greenland (Evans 1984a), 204,000 pairs on northeastern North America (Brown & Nettleship 1984), 570,000 pairs in Britain and Ireland, 10,000-1,000,000 on the Faeroes, 100,000-1,000,000 on Iceland (Evans 1984b), 10,000 pairs on Jan Mayen (van Franeker *et al.* 1986), over 200,000 pairs on Bear Island (Evans 1984b), 510,000 pairs in Norway (Barrett & Vader 1984), 100,000-1,000,000 on Spitsbergen (Evans 1984b), and over 100,000 pairs in the USSR west of Novaya Zemlya (Golovkin 1984). Comparatively small numbers breed on Helgoland, in Denmark, Sweden, France, and Spain. Within the North Sea an estimated 415,000 pairs of Kittiwakes are breeding (Tasker *et al.* 1987): 409,000 on British North Sea coasts, 3310 on Helgoland, 2580 in Norway and Sweden and 411 in Denmark.

Trends The population trends for Kittiwakes are unknown over much of its range. Evans (1984b) indicated large increases in East English, Danish, Helgoland's, and French colonies, but stable or declining populations in areas where more substantial numbers are known to breed, particularly on the Faeroes and in the Irish Sea. Barrett & Vader (1984) described an increase in Norway during 1964-76 and that since that time several colonies were declining (e.g. Røst, smaller colonies in Troms). The Runde population fell from *c.* 100,000 pairs in 1960 to just over 50,000 pairs in 1980. However, 50 colonies in Sør Varanger, North Norway, were censused during 1975-83, and the total population was found to increase by 4-5% per annum (Barrett 1985). The relatively small population in Sogn and Fjordane (SW Norway), there established in 1955, increased rapidly at first but is now fairly stable at 2000 pairs (Godø 1985). Lloyd *et al.* (in press) indicate that numbers in Britain and Ireland are still increasing, but more slowly

than before 1969. The Kittiwake population in Britain and Ireland was estimated at 536,700 pairs for 1985-87 (Lloyd *et al.* in press), compared with 446,700 pairs in 1969-70 (Cramp *et al.* 1974). Coulson (1983) remarked that after the spectacular increase through this century, marked regional variations in trends could be noted in the late 1970s. Numbers were still rising in the North Sea, but declined overall along the western seaboard. Trends in Kittiwake numbers at regularly monitored colonies varied. Most colonies were increasing at least up to the late 1970s and subsequently stabalized or declined. Shetland colonies (excluding Foula and Fair Isle) were decreasing during 1976-86 and increased 1986-87 (Heubeck 1989b). On Foula the Kittiwake population decreased during the early 1970s to 1982 (Furness 1983). On Orkney on 5 studied colonies numbers declined during 1976-85 (Benn *et al.* 1987). Five Caithness colonies were rather stable during 1980-87 (4 declined, not significant, 1 increased, significant; Mudge 1986), colonies on Troup Head increased during 1979-83 and decreased 1983-85 (Lloyd & North 1987). Firth of Forth colonies increased at 4% per annum during 1959-86 (Harris *et al.* 1987), St Abb's Head increased 1976-85 (Da Prato 1985), an increase was recorded on Canna up till 1982 (3-5% per annum), and a decrease since that year (-4.7% per annum; Swann & Ramsay 1986). By 1989 numbers were back at the 1975 level (Swann 1989). Also on the nearby Muck numbers declined during 1982-86 (Dobson & Dobson 1986). Kittiwakes on Lundy declined during 1981-86 (Davies & Price 1987), and 6 Waterford colonies decreased while one increased 1974-84 (McGrath & Walsh 1985). Numbers on St Kilda fluctuated since 1959 (7770 nests in 1959, 11485 in 1969, 5846 in 1977, and 7829 in 1987; Tasker *et al.* 1988). On Helgoland, in the German Bight, after the recolonisation in 1938, an increase was witnessed of 31% per annum during 1952-62, 15.5% per annum during 1962-72, and 19.5% per annum during 1972-82 (Fleet 1984).

Overall conclusion seems that Kittiwake colonies showed rather consistent increases in virtually all colonies until the middle- or late seventies, followed by decreases or unstability in many colonies since about 1980.

References Barrett 1985, Barrett & Vader 1984, Benn, Tasker & Reid 1987, Brown & Nettleship 1984, Coulson 1963, 1983, Coulson & Thomas 1985, Cramp, Bourne & Saunders 1974, Davies & Price 1987, Dobson & Dobson 1986, Evans 1984a, 1984b, Fleet 1984, van Franeker *et al.* 1986, Furness 1983, Godø 1985a, Golovkin 1984, Håkansson 1979, Harris, Wanless & Smith 1987, Heubeck 1989ab Heubeck, Harvey & Robertson 1987, Heubeck, Richardson & Dore 1986, Lloyd & North 1987, Lloyd, Mathiasson 1968, Tasker & Partridge in press, MacGrath & Walsh 1985, Mudge 1986, Da Prato 1985, Swann 1989, Swann & Ramsay 1986 Tasker *et al.* 1987, 1988, Wooller & Coulson 1977.

3.6.2 Estimates of North Sea wintering population

Estimates of the North Sea wintering population are difficult to give. There must be a considerable immigration in winter of Kittiwakes from the USSR, Norway and perhaps other (arctic) breeding areas into the North sea (e.g. Vauk & Jokele 1975), while many British Kittiwakes are known to cross the Atlantic (Coulson 1966). Danielsen *et al.*(1986) estimated that over 2,750,000 Kittiwakes (i.e. total Northeast Atlantic breeding population) could occur in the North Sea, but their assumptions are not at all clear. In summer the Kittiwake is thought to be the most numerous North Sea breeding species (Dunnet *et al.* 1990, see table 3.1), with over 800,000 breeding adults. There are many reasons to believe that also in

winter the Kittiwake is one of our most abundant seabirds (Tasker *et al.* 1987) with probably a population of several millions rather than hundreds of thousands of individuals.

As a wintering bird in the southern North Sea the Kittiwake is thought to have increased considerably after winter 1979/80. As a beached bird the Kittiwake increased suddenly in the early 1980s in the Netherlands, in Belgium and in West Germany (Camphuysen 1989a). Massive wrecks were recorded in 1981, 1983, and 1984 in this area and in 1984 Kittiwakes were found wrecked in southern England, in France and in Portugal. The increase as a beached bird was thought to coincide an increase as a wintering species in the southern North Sea. This suggestion was confirmed by seawatching data (CvZ files) and "general impressions" of numbers present along the coast in winter. Camphuysen (1989a) suggested that a substantial part of the Kittiwakes washing ashore in the Netherlands originated from arctic, or at least non-North Sea colonies. More recently, post-fledging wrecks were witnessed in late summer with newly fledged Kittiwakes in starved condition dying on Continental beaches (Camphuysen 1989b). These wrecks are probably not related to the winter wrecks of the early 1980s and numbers of wintering Kittiwakes appear to have dropped again in the late 1980s (interpretation from strandings data; NSO files).

References Ainley & Moreel 1978, Bergendahl 1986, Camphuysen 1989ab, Coulson 1966, Danielsen, Durinck & Skov 1986, Dementiev 1955, Dunnet *et al.* 1990, Drury 1978, Joensen 1961, Sluys 1982, Tasker *et al.* 1987, Vauk & Jokele 1975.

3.6.3 Feeding methods and diet

Kittiwakes feed exclusively on the surface and have a very limited (plunge-) diving capacity (Belopol'skii 1961, Burtt 1974). Feeding occurs when settled on the water, but most often the Kittiwakes continue flying around and around, pecking small particles from the surface (Cramp & Simmons 1983, Hartley & Fisher 1936, Nelson 1980, Vauk & Jokele 1975). In local upwellings Kittiwakes can be seen feeding on zooplankton, either by swimming and dipping or by flying around and (shallow) plunge diving, in vast numbers (Hartley & Fisher 1936, C.J. Camphuysen). Pearson (1968) lists offal from fishing boats, surface living crustaceans and fish (post-larval and juvenile Gadidae, Ammodytidae, and Clupeidae) as most important food items. Recorded species of fish in the Kittiwake's diet are (Belopol'skii 1961, Galbraith 1983, Vauk & Jokele 1975, Vauk-Hentzelt & Bachmann 1983):

Herring *Clupea harengus*, Sprat *Sprattus sprattus*, Capelin *Mallotus villosus*, Cod *Gadus morhua*, Arctic Cod *Boreogadus saida*, Haddock *Melanogrammus aeglefinus*, Whiting *Merlangius merlangus*, Blue Whiting *Micromesistius poutassou*, Poor Cod *Trisopterus minutus*, Bib *Trisopterus luscus*, Saithe *Pollachius virens*, Viviparous blenny *Zoarces viviparus*, Stickleback *Gasterosteus aculeatus*, Nilsson's Pipefish *Sygnathus rostellatus*, unident. pipefish *Sygnathus spp.*, Hooknose *Agonus cataphractus*, Lumpsucker *Cyclopterus lumpus* (eggs), Butterfish *Pholis gunnellus*, sandeels *Ammodytidae*, Greater sandeel *Hyperoplus lanceolatus*, Sand Goby *Pomatoschistus minutus*.

Invertebrates are reported frequently, but usually in smaller quantities by weight, including Chaetognaths, Mollusca, Crustacea, Polychaetes, and Echinoderms. Plastics, grid, vegetable matter, insects, sand, crushed pieces of bivalves, and all sorts of litter are frequently encountered in Kittiwakes stomachs (Belopol'skii

1961, Camphuysen 1989b, Vauk-Hentzelt & Bachmann 1983, Vauk & Jokele 1975, NSO-files, C.J. Camphuysen).

Kittiwakes are often seen to follow trawlers in large numbers and several reports indicate their preference for both discarded fish (up to 150 mm; Watson 1981) and offal (Benn *et al.* 1988, Hudson 1988, Tasker *et al.* 1987, Watson 1978, 1981). Kittiwakes are seen to feed on offal and discards during towing and sorting, but they also take all sorts of small particles, dipping, when the net is being lifted (Watson 1981). Attempts to swallow large fish usually resulted in robbery by larger *Larus*-gulls or skuas. The competition behind fishing boats is considerable, leading to the establishment of a dominance hierarchy. Larger species tend to steal fish from smaller species and therefore Kittiwakes and Herring Gulls are often being excluded from access to discarded fish (Hudson 1986, Hudson & Furness 1988). Harvey *et al.* (1989) found trawler waste in 27% of the food samples of Kittiwakes breeding at Fair Isle in 1989; nothing other than sandeel had figured prominently in their diet before that year. Although the feeding of bread may attract Kittiwakes, and although it may indeed be taken by them (Glutz von Blotzheim & Bauer 1982), their diet and feeding habits are less catholic than that of other gulls. Kleptoparasitism by Kittiwakes received little attention in literature, probably because Kittiwakes are so often the victim of Great and Arctic Skuas chasing other birds for food. However, in the southern North Sea associations between Kittiwakes and Guillemots are very often seen at sea and there can be little doubt that Kittiwakes steal fish from the auks (C.J. Camphuysen). Kleptoparasitism by Kittiwakes is also described by Moritz (1986) and Harkness (1959).

Breeding season Breeding Kittiwakes feed on, and feed their chicks with, fish and zooplankton, but fish predominates in most studies (Drury 1978, Furness 1983, Galbraith 1983, Harvey *et al.* 1989, Vauk-Hentzelt & Bachmann 1983). Kittiwake chicks, studied on the Isle of May (Firth of Forth), were mainly fed sandeels (frequency 87.3%), clupeids (8.1%) and offal (3.4%). Occasionally squid (0.6%) and Scampi *Neophrops norvegicus* were recorded (Galbraith 1983). Kittiwakes on Foula, Shetlands, fed their chicks exclusively with sandeels when breeding success was high during 1971-80, while sandeels formed 67% of the diet when total breeding failure occurred during 1988 (Furness 1989b). Martin (1989b) described Kittiwakes on Shetland as "sandeel-reliant" and breeding failures in the 1980s were apparently related to the reduced availability of this fish. On Helgoland 78 stomachs of chicks found dead contained fish (69.0%), 22 were containing something else (19.5%), and 13 were empty (11.5%, n= 113; Vauk-Hentzelt & Bachmann 1983). Gadoids predominated in this study (55 otoliths of Gadidae, 13 Ammodytidae, 8 Clupeidae, 19 unidentified). Nereidae were apparently offered frequently (69.1% of the stomachs), but crustaceans, mollusca, and insects only occasionally (4.8% of the stomachs or less). Pearson (1968) lists sandeels as most important prey item (81% of total number of preys, 56% by weight), with Clupeidae (10 and 22%) and Gadidae (7 and 21%) ranked second and third. The Kittiwakes diet contained virtually only fish on the Farne Islands (98% by number, 99% by weight). On Foula all food samples from chicks and nesting adults (regurgitated) were found to consist of sandeels during 1977-82 (Furness 1983). Orange droppings towards the end of chick rearing might have indicated feeding on zooplankton (crustaceans). The estimated length of fish from otoliths taken from stomachs of Kittiwake chicks on Helgoland, for Saithe

and Haddock 180-320 mm, indicates that offal is also presented at their offspring. It is difficult to assess the proportion of fish taken alive and taken as discards or offal from stomach samples. Drury (1978) indicated that Kittiwakes are evidently opportunists in their feeding. They will become specialists if suitable prey is available. Whether a colony has a consistent or a "boom/bust" economy seems to depend upon the kinds and numbers of small fish and crustacea, as well as on the phenology of those organisms in the surrounding seas.

Non-breeding season Several studies deal with the diet of the Kittiwake in the breeding season but our knowledge on winter feeding appears to be extremely limited (Cramp & Simmons 1983, Glutz von Blotzheim & Bauer 1982). The most detailed account on the winter feeding of Kittiwakes is presented by Vauk & Jokele (1975), who reported on the stomach contents of some 170 Kittiwakes

Table 3.2. Occurrence of fish in 159 stomachs of Kittiwakes shot on Helgoland, November-March 1968-72 (after Vauk & Jokele 1975).

Species	Numbers of stomachs (%)		Numbers of fish (%)	
Herring	5	3.1	5	1.0
Sprat	18	11.3	20	3.9
Cod	1	0.6	1	0.2
Haddock	3	1.9	3	0.6
Whiting	3	1.9	3	0.6
Blue Whiting	1	0.6	1	0.2
Poor Cod	7	4.4	8	1.6
Bib	2	1.3	2	0.4
Saithe	6	3.8	10	1.9
Nilsson's Pipefish	1	0.6	1	0.2
unident. pipefish	2	1.3	2	0.4
Hooknose	1	0.6	1	0.2
Butterfish	1	0.6	1	0.2
sandeels	3	1.9	3	0.6
Greater Sandeel	1	0.6	1	0.2
Sand Goby	63	39.6	351	68.4
unidentified fish	73	45.9	100	19.5
Total			513	100.0

shot on Helgoland in the winters 1968-72 (Nov-Mar). Fish predominated in their samples (>90%), with Sand Gobies being most numerous (351 specimens (68.4% of all fish) in 63 stomachs (39.6% of all stomachs with food remains; see also table 3.2). Vauk & Jokele (1975) conclude that the stomach contents of the Kittiwakes shot in winter confirmed what was already thought: discarded fish is an important source of food. Tiews (1978b) indicated that indeed, gobies were the most important non-commercial fish (by number discarded) in the German Bight Brown Shrimp *Crangon crangon* fishery during 1954-73, with, in sequence of relative importance, Smelt *Osmerus eperlanus*, Hooknose, pipefishes, seasnails *Liparis spp.*, sandeels, Eelpout, Sea Scorpion *Myoxocephalus scorpius*, Stickleback, Dragonet *Callionymus lyra*, Butterfish, Five-bearded Rockling *Ciliata mustela* and gurnards *Trigla spp.* also being numerous. Many of these species were represented in the diet of the Kittiwakes in winter on Helgoland (table

3.2). According to Tiews (1978), by-catches of gobies were at a very low level during 1968-72 compared to the late 1950s and early 1960s. However, in terms of numbers of fish it were still the most numerous by-catch.

Emaciated birds found wrecked in the Netherlands were usually found not to have any substantial food remains in their stomachs (NSO-files, Camphuysen 1989b). If any, fish predominated but very few specimens have been identified. Watson (1981) reported relatively high numbers of Kittiwakes behind trawlers in the Irish Sea in Jan and Feb compared with other months. Also in the North Sea significant associations between Kittiwakes and trawlers were (only) found in Dec and Feb, suggesting that offal and discards represented a relatively important food source during winter (Tasker *et al.* 1987).

Preferred fish species and size When assessing the size of the fish taken by Kittiwakes we should distinguish between prey fished upon by the gulls and discards or offal. Unfortunately we cannot do so in most cases. Watson (1981) indicated that Kittiwakes had trouble swallowing fish in excess of 150 mm length. However, the main problem appeared that larger fish were stolen by robbing gulls rather than that these fish were to big to be swallowed. Most of the gadoids which were fed to the chicks on Helgoland, estimated range 180-320 mm, were definitely too large to have been taken by the gulls alive: the larger ones must have been offal or discarded fish of which the otoliths were transferred to the chicks. Of Whiting and Blue Whiting fish lengths of 60-130 mm were given, whereas for Herring and Sprat 100-170 and 60-80 mm respectively are estimated (Vauk-Hentzelt & Bachmann 1983). Pearson (1968) indicated that most sandeels taken by Kittiwakes measured 25-100 mm, while sandeels well in excess of 150 mm were also recorded. Most sandeels regurgitated by chicks on Foula, Shetland, measured between 80 and 100 mm (Furness 1983). Unfortunately Vauk & Jokele (1975) did not measure the otoliths in the stomachs of their Kittiwakes to assess the length of the fish taken. Most represented were Sand Gobies and Sprat, which grow never very large, but we have no idea of the length of the gadoids found in the Kittiwakes.

Small fish species as sandeels, Sprat, gobies and immature gadoids predominate in the diet of Kittiwakes. Fish in excess of 15cm length is probably of limited importance and 1-group gadoids and Herrings are probably too large. Few studies of the diet in winter are carried out, when Sprat may be more important than it can now be shown from the available data.

References Bailey 1986, Belopol'skii 1961, Benn *et al.* 1988, Brown 1988, Burtt 1974, Camphuysen 1989b, Cramp & Simmons 1983, Drury 1978, Furness 1983, 1989b, Furness, Hudson & Ensor 1988, Gabrielsen, Mehlum & Nagy 1987, Gabrielsen, Mehlum & Nagy 1987, Galbraith 1983, Glutz von Blotzheim & Bauer 1982, Harkness 1959, Hartley & Fisher 1936, Hudson 1986, Harvey, Silcocks & Howlett 1989, Hudson & Furness 1988, Martin 1989b, Maunder & Threlfall 1972, Merejohn *et al.* 1978, Moritz 1986, Myres 1963, Nelson 1980, O'Connor 1974, Pearson 1968, Tasker *et al.* 1987, Tiews 1978b, Vauk & Jokele 1975, Vauk-Hentzelt & Bachmann 1983, Watson 1978, 1981.

3.7 Razorbill *Alca torda*

3.7.1 North Atlantic breeding population and trends

Population The world breeding population of the Razorbill is currently estimated at some 300,000-1,200,000 pairs (Croxall *et al.* 1984, Nettleship & Evans 1985). The wide range is mainly because the numbers on Iceland ("at least" 500,000 pairs) are so poorly known (Evans 1984b, Gardarsson 1982). Large numbers (10,000 pairs or more) are only known to breed in Labrador (10,000 pairs), Norway (30,000 pairs), Iceland, Scotland (86,000 pairs), and Ireland (50,000 pairs) (Nettleship & Evans 1985). The most recent estimate of the British population is just over 180,000 individuals (Lloyd *et al.* in press), the North Sea numbers are currently estimated at some 73,000 individuals (Dunnet *et al.* 1990, Tasker *et al.* 1987).

Trends Trends in the vast Icelandic population are totally unknown. In northern Norway, the general decrease in the small auk populations in Sør Varanger, which was found in 1970-75 continued in 1975-83. This decline is in contrast to the nearest auk colony to this area, on Hornøy, where large increases were recorded since the early 1970s (Barrett 1985). More specific accounts on the Razorbill showed that in the early 1980s population developments and breeding success were good in Øst-Finnmark, but uncertain in Vest-Finnmark. Incompletely known were population trends and breeding success from Trøndelag (at least breeding success was good here) and Møre & Romsdal (Folkestad 1984b). Changes in Orkney colonies, as shown in study plots during 1976-85, were an increase at some 7% per annum from 1976-81 (very similar to Guillemots in Orkney) and a subsequent and rapid decline after 1981 (percentage change in all monitoring plots during 1981-85: 18.8%; Benn *et al.* 1987). Little is known about breeding success and population trends in Razorbills from Shetland (Heubeck 1989b). Breeding success of Razorbills was very poor on Foula in 1988, while it was still good in 1986 and 1987 (Furness 1989b). In eastern Scotland, on the Troup and Pennan Heads colonies (S Moray Firth), numbers increased during the 1970s, but stabilized and declined in the early 1980s (Lloyd & North 1987), apparently in response to food shortages. In the years 1980-84 the overall situation in five Caithness (Moray Firth) colonies was a decline at a rate of 5.2% per annum, but this decline was not significant (Mudge 1986). Numbers on Isle of May in 1986 were considerably higher than in 1969, but the increase was most rapidly during the 1970s and has now probably stopped (Wanless & Kinnear 1988). Harris & Wanless (1989) indicate that the number of Razorbills on Isle of May has indeed slightly declined during 1981-87, despite a consistently high breeding success. The decline seemed to result from poor recruitment due to low survival of immatures. Counts of the Razorbill population on St Kilda (3814 individuals in 1987) were rather poor in the past, so it is difficult to assess any changes now on the islands (Tasker *et al.* 1988).

References Barrett 1984b, 1985, Benn, Tasker & Reid 1987, Brun 1969b, Croxall *et al.* 1984, Dunnett *et al.* 1990, Evans 1984b, Furness 1989b, Gardarsson 1982, Harris & Wanless 1984, 1989, Heubeck 1989b, Lloyd 1976, 1979, Lloyd & North 1987, Lloyd, Tasker & Partridge in press, Mudge 1986, Nettleship & Evans 1985, Olsson 1974, Steventon 1982, Stowe & Harris 1984, Tasker *et al.* 1987, 1988, Wanless & Kinnear 1988, Webb, Tasker & Greenstreet 1985.

3.7.2 Estimates of North Sea wintering population

Razorbills, especially younger individuals, are migratory birds that move away from their breeding colonies. Southward movements are well known in Razorbills and in Portuguese waters and in the western mediterranean Razorbills outnumber Guillemots greatly (cf. Carboneras 1988, Teixeira 1986). Mead (1974) indicated that the movements of auks, as revealed by ringing, are highly complex because different age-groups, and different local populations, have different migration patterns and wintering areas. Older birds stay nearer colonies and are dispersive only (Cramp 1985). Within the North Sea, the local breeding population can be found wintering but at least part of it moves away to more southerly wintering "grounds". Baltic Razorbills enter the North Sea to some extend, but few penetrate any further than the Skagerrak (Anker-Nilssen *et al.* 1988, Camphuysen 1989a). Part of the populations from the British west coast and Ireland move into the North Sea and ringing recoveries have shown that Razorbills from Iceland and northwest USSR can be found in these waters. Ringing in Iceland has only commenced in 1981, so the extent of w....ing of Icelandic Razorbills in the North Sea is unknown. These uncertainties make an estimate of the North Sea wintering population rather difficult. Danielsen *et al.* (1986) guessed that 436,000 Razorbills could occur in the North Sea, but their assumptions are not clear. It is unlikely that the entire British population ever will be found wintering in the North Sea, but immigration from more northerly populations may be substantial. A reasonable guess would thus indeed be that several hundreds of thousands of Razorbills can be found wintering in the North Sea. Danielsen's figure may be slightly too high.

The Razorbill was one of those species which appeared suddenly in large numbers in the early 1980s in Dutch and German beached bird surveys (Camphuysen 1989a). The Razorbill was one of the most prominently represented auks in the wreck in eastern Britain in 1983 (Underwood & Stowe 1984). Seawatching results have shown that "auks" (Razorbills and Guillemots) have increased since 1980 along the Dutch coast and this would support the idea that more birds are presently wintering in the southern North Sea. The most recent Razorbill wreck was witnessed in 1990 on the Dutch coast (Camphuysen 1990b). However, Razorbills were very abundant as beached birds in few years compared with Guillemots, indicating that the increase as a wintering bird may be less structural.

References Anker-Nilssen *et al.* 1988, Baillie & Mead 1982, Camphuysen 1990ab, in prep., Carboneras 1988, Cramp 1985, Danielsen, Durinck & Skov 1986, Hope Jones *et al.* 1984, 1985, Hudson & Mead 1984, Lloyd 1974, Mead 1974, Peterz 1987, Smiddy 1987, Steventon 1979, 1982, Taylor & Reid 1981, Tasker *et al.* 1985c, 1986, 1987, Teixeira 1986, Underwood & Stowe 1984, Webb 1988.

3.7.3 Feeding methods and diet

Razorbills dive from the surface, seeking or pursuing prey for prolonged periods under water, swimming with open wings. They can reach considerable depths: Piatt & Nettleship (1985) reported on incidental catches of 9 Razorbills off Newfoundland in gill-nets and they found that Razorbills can reach 120 m. A later report from the North Sea showed that Razorbills are indeed quite capable to reach these depths. From a Perry submersible in the South Brent Field (61°N,

01°40'E), a Razorbill was observed swimming around at 130 and 140 m depth (Jury & Maguire 1988). Razorbills, just as other auks, are generally believed not to be interested in discards from trawlers. However, Carboneras (1988) reported on Razorbills attending trawlers although they kept some distance (200-500 m). The Razorbills probably dived for deep sunken discarded fish which were out of the reach of the other seabirds. They accepted small Sardines thrown to them, and first year birds were even begging for food near the trawler.

The diet of adult Razorbills, at all seasons of the year, is principally small fish, but some invertebrates (crustaceans including *Gammarus spp.* and Mysidacea, molluscs and polychaete worms) are also taken (Cramp 1985). It should be stressed that the Razorbill's diet is much less well known than the diet of Guillemots (cf. Tasker *et al.* 1987). Recorded fish species are:

Herring *Clupea harengus*, Sprat *Sprattus sprattus*, Pilchard *Clupea pilcharda*, Anchovy *Engraulis encrasicolus*, Capelin *Mallotus villosus*, Pearlsides *Maurolicus muelleri*, Cod *Gadus morhua*, Arctic Cod *Boreogadus saida*, Poor Cod *Trisopterus minutus*, Norway Pout *Trisopterus esmarkii*, Five-bearded Rockling *Ciliata mustela*, Garfish *Belone belone*, Stickleback *Gasterosteus aculeatus*, Nine-spined Stickleback *Pungitius pungitius*, Sandeel *Ammodytes tobianus*, Raitt's Sandeel *Ammodytes marinus*, Greater sandeel *Hyperoplus lanceolatus*, White Goby *Aphia pellucida*, Two-spotted Goby *Gobiusculus flavescens*, Crystal Goby *Crystallogobius linearis*. (Belopol'skii 1961, Blake 1983, Cramp 1985, Harris 1970, Madsen 1957).

Breeding season Tasker *et al.* (1987) discussed the feeding ranges from Razorbills in North Sea colonies and found that, in general, Razorbills forage close to their colonies. Razorbills on Foula were totally sandeel reliant in 1986 and 1987 and breeding success was good, although surface feeding sandeel specialists were suffering from reductions in the availability of this fish in these years. In 1988 the proportion of sandeel in Razorbill diets fell from 100 to 43% and breeding success was poor (Furness 1989b). Razorbills on Fair Isle were also found to rely on sandeels (Harvey *et al.* 1989). Of 9 samples collected of loads brought in during 19 June-6 July 1989, all fish were identified as sandeels (29 individuals). The mean load weight was 4.32 g (n= 9), while the sandeels measured on average 81 ± 3.0 mm (n= 29). On Isle of May in 1989 the food of young Razorbills (from field observations) was mainly sandeels with occasionally some Clupeidae. These observations showed that 8 single-fish loads contained 3 times medium (estimated 60 mm) and 5 times large (estimated 100 mm) sandeels, while 58 multi-fish loads, 3x contained 2 medium size sandeels, 35 times 3-6 small sandeels (estimated 50 mm) and 20x several very small sandeels (estimated 40 mm). All three samples of Razorbills breeding on Canna collected in 1989 were composed of sandeels; multi-fish loads of very small specimens and single-fish loads of "large" (80 and 87 mm) sandeels (Swann 1989).

Belopol'skii (1961) indicated that 92.0% of 75 stomachs filled with food from Barents Sea colonies contained fish, while polychaete worms, crustaceans and vegetable matter occurred more sporadically. Razorbills were mainly known as inshore feeders in the breeding season, using a wide strip of open coastal waters. The main fish prey on the Murman coast were Herring, Capelin, Sandeel, cod brood (*Gadus spp.*) and on Novaya Zemlya Arctic Cod and Cod brood (*Gadus morhua*).

Post-breeding period From Tasker *et al.* (1987) is known that the concentrations of virtually all North Sea Razorbills in waters off north-east Scotland is one of

the most marked features of Razorbill distribution in the North Sea. Most Razorbills stayed rather close inshore and there was a tendency for the highest densities of Razorbills to be inshore of most of the Guillemots and Puffins. Little is known of their diet in this period, but Tasker *et al.* (1986) recorded small herrings and 1-group Whiting in Razorbill stomachs of birds shot off Fraserburgh on 19 August 1985. Razorbills shot on Berwick Bank 10 days later were found to hold 1-group sandeels. However, since the samples were very small, little can be said about their diet composition in this period.

Winter Few studies are conducted. Blake (1983) examined shot, oiled, Razorbills in the Skagerrak in January 1981. Clupeids predominated in the samples (frequency of occurrence 56% in 39 stomachs with identifiable remains from the Swedish west coast, 77% in 26 stomachs from the Norwegian Skagerrak coast), and although not all items could be precisely identified it was believed that most were Sprat. Gobies occurred in 23% of 39 stomachs with fish from the Swedish coast and 69% in 26 stomachs from the Norwegian coast (mainly Two-spotted Gobies, fewer Crystal Gobies), and gadoids occurred in 15% and 0% respectively. Stomachs of Razorbills washed ashore in the Netherlands in April 1985 contained only sandeels (n= 3; Camphuysen unpublished), but from dissected birds stranded in January and February is known that also clupeoids, small gadoids, and other (unknown) species occurred frequently (NSO files). Blake (1984) studied the stomach contents of Razorbills wrecked in eastern Britain in February 1983. Razorbills from East Anglia (n= 90 stomachs with identifiable fish remains) contained mainly clupeids (57%, including mostly Sprat) and sandeels (64%), with very few gobies (1%) and unidentified fish (1%). Razorbills from the Moray Firth (n= 48) contained mainly clupeids (38%) and sandeels (65%), but also gadoids (8%), polychaete worms (7%) and crustaceans (2%). Razorbills collected near Newcastle (n= 63) contained virtually only sandeels (87%) and occasionally gobies (8%), Pearlsides (2%), clupeids (5%), gadoids (2%), unidentified fish (5%), polychaete worms (21%) and crustaceans (3%). All Sprat lengths calculated from otoliths were less than 100 mm, while also sandeels (max *c.* 105 mm) were very small compared to those found in Guillemots.

Size of fish Swennen & Duiven (1977) indicated that Razorbills could not handle the larger prey of Guillemots and studies in field conditions confirm that the diet of Razorbills consists of smaller fish than that of Guillemots. The maximum heigth of Herring accepted by captive Razorbills was 26 mm (44 mm in Guillemots), while the preferred heigth was only 15 mm (23 mm in Guillemots). Similar data are available for Norway Pout with maximum and preferred being respectively 23 and 15 mm (Swennen & Duiven 1977). A body depth of between 15 and 26 mm would indicate that the Razorbill's diet would include smaller immature Gadoids and larger fish of slimmer species such as sandeels.

Preferred fish: species and size From studies at colonies, which are biased towards fish brought to chicks, it can be shown that preferred fish length are *c.* 100 mm. Studies at sea and in experiments have shown that adult prey is slightly larger, but probably always less than 200 mm in length. Preferred species are sandeels, clupeids, gobies and immature gadoids.

References Belopol'skii 1961, Blake 1983b, 1984, Cramp 1985, Furness 1989b, Harris 1970, 1988, 1989c, Harris & Wanless 1986, 1989, Harvey, Silcocks & Howlett 1989, Heubeck 1989b, Jury & Maguire 1988, Madsen 1957, Piatt & Nettleship 1985, Swann 1989, Swennen & Duiven 1977, Tasker et al. 1986, 1987.

3.8 Guillemot *Uria aalge*

3.8.1 North Atlantic breeding population and trends

Population The North Atlantic population of the Guillemot was recently estimated at 4,170,000 (range 3.0-4.5 million) pairs (Nettleship & Evans 1985). Nearly 800,000 pairs breed in Britain and Ireland according to Stowe & Harris (1984), nearly 1,200,000 individuals is the more recent estimate of Lloyd *et al.* (in press). Some 2,000 pairs breed on Helgoland (Vauk 1982), and 9,400 pairs in Denmark, Sweden and Finland (Baltic Sea; Nettleship & Evans 1985). The North Sea breeding population was estimated at 680,000 individuals (counts of individuals at breeding sites in early June); all but 5,300 of these are found on northern English and Scottish coasts (Tasker *et al.* 1987).

It was demonstrated by Blake *et al.* (1980) around Fair Isle in 1980 that around 40% of the birds associated with a colony would be present on the cliffs during counts in the middle of the day. The number of fully grown Guillemots, associated with North Sea colonies, was therefore estimated at 1,700,000 individuals. After fledging of the chicks just over 2,000,000 Guillemots were expected at sea from North Sea colonies, excluding an unknown number of immatures which had not returned to the colonies in summer (Tasker *et al.* 1987). Few first year birds are likely to visit the breeding colonies, and older immatures return with increasing frequency until they are recruited in the breeding population at between 4 and 6 years old (Birkhead & Hudson 1977). Estimates of survival to breeding age for Guillemots range from 17.4-41.1% (Hudson 1985). Annual adult survival is estimated at 94% (Birkhead & Hudson 1977).

Trends The general decrease in the small auk populations in Sor Varanger, North Norway, which was found in 1970-75 continued in 1975-83. This decline is in contrast to the nearest auk colony to this area, on Hornøy, where large increases were recorded since the early 1970s (Barrett 1985).

An initial analysis of the "Seabird Colony Register" showed that Guillemots numbers in Britain and Ireland in 1985-88 are 50% higher than they were in 1969-70 ('Operation Seafarer'; Cramp *et al.* 1974). Regular counts of several colonies, however, showed that the numbers actually peaked in the early 1980s and have since declined at many sites (Heubeck *et al.* in prep., Lloyd 1988, Wanless & Kinnear 1988). Seven Shetland colonies increased 1976-early 1980s, then decreased up to 1988 (Heubeck *et al.* in prep), but on Fair Isle an increase was noted throughout 1971-87 (Lloyd *et al.* in press). On Orkney there was an increase during 1976-1980/81 and colonies here were then stable or declining up to 1987 (Benn *et al.* 1987). Caithness colonies were stable during 1980-87 (Mudge 1986), while colonies on Troup Head were increasing during 1979-82, and then stabilized (Lloyd & North (1987). On Isle of May, again, increasing up to 1982, then decreasing up to 1988 (Wanless & Kinnear 1988), and increasing colonies on St Abb's Head during 1977-88 (Da Prato 1985, Lloyd *et al.* in press). Harris & Wanless (1989) indicate that the number of Guilemots on Isle of May had indeed slightly declined during 1981-87, despite a consistently high breeding success. The decline seemed to result from poor recruitment due to lower postfledging survival. Harris & Wanless (1989) suggest that food may now be limiting during the winter. Breeding Guillemots on Canna have been monitored since 1974 and numbers increased continuously up until 1983, since when they have declined slightly due to recruitment failures (Swann *et al.* 1989). Although the total Guillemot population on St Kilda (22,705 individuals in 1987) has remained rather constant since 1969, there have been changes in numbers on each of the islands (Tasker *et al.* 1988).

References Barrett 1985, Birkhead & Hudson 1977, Benn, Tasker & Reid 1987, Benn, Tasker & Webb 1987, Blake *et al.* 1980, Cramp, Bourne & Saunders 1974, Brun 1969a, Dyck & Meltofte 1975, Harris & Wanless 1984, 1989, Heubeck *et al.* in prep., Hudson 1985, Lloyd 1988, Lloyd & North 1987, Lloyd, Tasker & Partridge in press, Mudge 1988, Nettleship & Evans 1985, Da Prato 1985, Stowe 1982, Stowe & Harris 1984, Swann *et al.* 1989, Tasker *et al.* 1987, 1988, Tuck 1960, Vauk 1982, Vauk-Hentzelt, Schrey & Vauk 1986, Wanless & Kinnear 1988.

3.8.2 Estimates of North Sea wintering population

Guillemots are no long-distance migrants but are dispersive (Cramp 1985, Mead 1974). The majority of the North Sea breeding population will remain in the North Sea area in winter, although some of the immatures may move further away (Mead 1974, de Wijs 1985). Immigration from more northerly colonies occurs, but the scale is toally unknown because so few birds are ringed in arctic and subarctic regions (Camphuysen in prep., Mead 1974, de Wijs 1985). An accurate estimate of the birds wintering in the North Sea will therefore be quite difficult. Danielsen *et al.* 1986 estimated that some 5,300,000 Guillemots could occur in the North Sea (i.e. total northeast Atlantic breeding population). Tasker *et al.* (1987) estimated that just after fledging of the chicks just over 2,000,000 Guillemots were expected at sea from North Sea colonies, excluding an unknown number of immatures which had not returned to the colonies in summer. Since it is unlikely that the entire northeast Atlantic population will at any time arrive in the North Sea an estimate of the North Sea wintering population should arrive somewhere inbetween 2,000,000 and 5,000,000 Guillemots. Further ringing of northerly breeding birds may provide more accurate data.

References Camphuysen (in prep.), Cramp 1985, Heubeck, Harvey & Okill (in prep.), Mead 1974, Peterz & Olden 1987, Tasker *et al.* 1987, de Wijs 1985.

3.8.3 Distribution at sea outside the breeding season

Post-breeding movements (Jul-Oct) The three main features in the post-breeding period in the North Sea were described as (a) movement of birds away from Shetland, (b) aggregation of birds off eastern Scotland and north-eastern England, and (c) the migration of birds to the eastern North Sea (Tasker *et al.* 1987). Brown (1985) concluded that the movements of Guillemots from north British colonies, having sandeels and small clupeids as principal foods, coincide quite closely with the movements of suitable prey in that area. The fishery for Sprat off southwest Norway (examplified by Brown for 1976) takes place mainly

during August through November, the season in which Guillemots from Scottish colonies move to that coast. Brown describes the Guillemot movements entirely as "journeys to food resources'. The "Sprat-scenario" fits less well for Irish Guillemots and birds from the Irish Sea.

Winter distribution (Nov-Feb) Densities in the southern North Sea reach their maxima in this period, and the majority of the North Sea wintering population is widely dispersed in the south-western quadrant of the North Sea, with evenly low densities in most other areas (Tasker *et al.* 1987). Important areas are the north-western Dogger Bank, the Silver Pit and waters off the English east coast. Data of Dutch surveys, concentrating more in the Dutch sector of the Continental Shelf, are not yet available and therefore not mapped. Systematic surveys on board MV Holland in waters revealed that Guillemots are most abundant from late Oct to late Mar (Camphuysen & Platteeuw 1988). High densities were frequently seen off the Wadden Sea islands, but fair numbers were also found to occur off the Delta area. NIOZ-organized surveys showed that aggregations of Guillemots often occurred in a tidal front zone north of Texel (the Frisian Front), just as in the post-breeding season, around the Brown Bank and around the Dogger Bank (Anonymous 1988-89).

The Sprat fishery off the east coast of Scotland is mainly in December through March (Brown 1985, using ICES *Bulletin Statistique* 1976 data). Adult Guillemots are then moving back to Scotland to return to their colonies. At the same time they take advantage of the abundance of Sprat in the western North Sea in spring (Brown 1985). However, this conclusion is not completely in line with Tasker *et al.* (1987). Moreover, stomach contents were generally more diverse than Brown's account would suggest (see below), and breeding birds in the Moray Firth, from Orkney and Shetland area returned considerably later (Mar-Apr). It is, however, important to keep the "Sprat-scenario" in mind.

Pre-breeding period (Mar-Apr) Breeding birds return to their colonies, while non-breeding adults and immatures can still be found all over the North Sea. A mass-stranding in late April 1985 on the Dutch coast showed that considerable numbers are still present in the southern North Sea. High densities are only found off the English east coast, off the Scottish coast and around Shetland and Orkney (Tasker *et al.* 1987).

References Baillie & Mead 1982, Bourne 1981, Brown 1985, Camphuysen 1989a, 1990bc, in prep., Camphuysen & Platteeuw 1988, Hope Jones *et al.* 1984, 1985, Heubeck, Harvey & Okill in prep., Hudson & Mead 1984, Leopold 1988, Mead 1974, Peterz 1987, Peterz & Olden 1987, Tasker *et al.* 1985c, 1986, 1987, Taylor & Reid 1981, Webb 1988, Webb, Tasker & Greenstreet 1985.

3.8.4 Evidence for a changing wintering distribution

Beached Bird surveys in the Netherlands and in West Germany demonstrated an increase in numbers of Guillemots stranding since 1980 (Camphuysen 1989a, Vauk *et al.* 1987). The increase could not be explained by an increase in (chronic) oil pollution at sea and it was suggested that more Guillemots were wintering in the southeastern North Sea than previously. This suggestion was supported by seawatching data (Club van Zeetrekwaarnemers" files, Camphuysen 1989a). Mudge *et al.* (1987) suggested that adult Guillemots returned later in the

Moray Firth colonies (compared with other breeding places), and wintered only in small numbers in the immediate vicinity of the colonies, because of unfavourable feeding conditions (collapsed Sprat fishery). This could support the idea that birds usually wintering in the northwestern North Sea moved into other parts of the North Sea.

Peterz & Olden (1987) reported an increase in ringing recoveries of Guillemots in Sweden and were unable to explain this other than by an increase in wintering birds in the Skagerrak/Kattegat region. This was supported by field observations (Gärdenfors *et al.* 1984, Peterz 1987). Similar to Dutch/German data, the increase started in winter 1980/81. The sudden increase in numbers of ringed Guillemots, especially of auks entangled in gill-nets, could not be explained by changes in fishing effort or ringing effort.

References Camphuysen 1989a, (in prep.), Gärdenfors *et al.* 1984, Heubeck, Harvey & Okill (in prep.), Mudge, Aspinall & Crooke 1987, Peterz 1987, Peterz & Olden 1987, Swann *et al.* 1989, Vauk *et al.* 1987.

3.8.5 Feeding methods and diet

Guillemots dive from the surface, seeking or pursuing prey for prolonged periods under water, swimming with open wings. Piatt & Nettleship (1985) reported on incidental catches of 12,243 Guillemots in gill-nets off Newfoundland and the great majority were found entangled at 0-60 m depth. However, Guillemots were also caught in deeper waters and as many as 16 birds were found in nets set at 180 m. The diet of adult Guillemots, at all seasons of the year, is principally fish, but molluscs, crustaceans, polychaetes and fish eggs are also taken (Bradstreet & Brown 1985). There is considerable variation both with location and season in their diet. Sandeel predominates particularly in spring and summer, in late summer the diet becomes more diverse (Sprat and Herring are added) and in winter a wide variety of prey is utilized (Tasker *et al.* 1987).Recorded prey species are:

Herring *Clupea harengus*, Sprat *Sprattus sprattus*, Capelin *Mallotus villosus*, Pearlsides *Maurolicus muelleri*, Crucian Carp *Carassius carassius*, Cod *Gadus morhua*, Arctic Cod *Boreogadus saida*, Haddock *Melanogrammus aeglefinus*, Whiting *Merlangius merlangus*, Blue Whiting *Micromesistius poutassou*, Poor Cod *Trisopterus minutus*, Norway Pout *Trisopterus esmarkii*, Bib *Trisopterus luscus*, Pollack *Pollachius pollachius*, Saithe *Pollachius virens*, Five-bearded Rockling *Ciliata mustela*, Viviparous blenny *Zoarces viviparus*, Stickleback *Gasterosteus aculeatus*, sculpins *Cottidae*, Scad *Trachurus trachurus*, blennies *Blennius spp.*, Butterfish *Pholis gunnellus*, Sandeel *Ammodytes tobianus*, Raitt's Sandeel *Ammodytes marinus*, Greater sandeel *Hyperoplus lanceolatus*, gobies *Gobius spp.*, Two-spotted Goby *Gobiusculus flavescens*, Crystal Goby *Crystallogobius linearis*, Mackerel *Scomber scombrus*

and occasionally even flatfish (Anker-Nilssen & Nygård 1987, Belopol'skii 1961, Benn 1985, Beveridge 1986, Birkhead & Nettleship 1987, Blake 1983, 1984, Blake *et al.* 1985, Bradstreet 1977, Bradstreet & Brown 1985, Camphuysen in press, Cramp 1985, Erikstad & Vader in prep., Folkestad 1984, Griffiths 1984, Harris 1970, Harris & Wanless 1985, Hedgren 1976, M. Leopold , Madsen 1957, Pearson 1968, Tasker 1983, Tasker *et al.* 1985, 1986, Thomas 1988, Tuck 1960, Wanless, Reynolds & Langslow 1983, Ward 1987). Changes in the diet through the year are roughly described below.

Breeding season The chick (at the colony) is fed mostly with fish, in general species with high fat contents and calorific value (Capelin, Herring, Sprat, sandeels; Harris & Hislop 1978), with an average length of 120 mm (max 150-180 mm; Bradstreet & Brown 1985). Furness (1989) described Guillemots on Foula, Shetlands, as totally sandeel reliant during 1971-80 (diets comprised 100% sandeels), and still in 1988 (97%), while maintaining high breeding success when surface feeding sandeel specialists failed to raise chicks. There was little evidence that Guillemots utilized small 0-group gadoids in summer, when these fish are in their pelagic phase, perhaps because of the abundance of sandeels close to the colonies (Blake *et al.* 1985). Guillemots in northern Norway fed their chicks mainly on large Capelin and sandeels (110-170 mm), while Runde chicks were fed a much wider variety of fish. On Røst the chicks were mainly fed on gadoids and sandeels (Folkestad 1984). A variety of species (not occurring within the North Sea) is listed for Labrador (Birkhead & Nettleship 1987). Arctic Cod *Boreogadus saida* and Daubed Shanny *Lumpenus maculatus* (family Stichaeidae; not listed above) were the second and third most important species in the chick diet, giving way only for Capelin (>75% by number and by weight).

Post-breeding period In the post-breeding period, 0-group clupeids and sandeels were found in stomachs of Guillemots off E Scotland (Blake *et al.* 1984). Anker-Nilssen & Nygård (1987) found gadoids predominating in male adult/fledgling groups sampled off Central Norway (Nord-Trondelag). Tasker *et al.* (1985) found clupeids predominating in Guillemot stomachs of birds shot off northeast Britain in August 1984. Only in the Firth of Forth sandeels were predominating. Gadoids occurred rather frequently but were apparently taken opportunistically. In all stomachs of Guillemots shot in August 1985 off Fraserburgh (Tasker *et al.* 1986) gadoid remains were found, while one was found to contain also clupeid remains. The gadoids appeared to be 1-group Whiting. In all 11 Guillemots shot on the Berwick Bank that same August, 1-group sandeels *Ammodytes marinus* were found and in addition 6 contained gadoid and 3 clupeid remains.

Winter Gadoids sampled in Guillemot stomachs in Jan/Feb in the North Sea comprised 1-group fish (spawned the previous year). Birds stranded in the Netherlands, 1981-86, were often in poor condition and the dietary studies were therefore biased towards "longer remaining otoliths" (gadoids rather than clupeids). However, the general impression is a varied diet, with many species of gadoids taken opportunistically but with sandeels and clupeids predominating (NSO files). A November sample of Guillemots, shot off the coast south of Aberdeen, had about equal quantities of clupeid, gadoid and sandeel remains in their stomachs (Blake *et al.* 1985). Blake (1983) examined shot, oiled, Guillemots in the Skagerrak in January 1981. Clupeids and gobies predominated in the samples, and although not all items could be precisely identified it was believed that most clupeids were Sprat and most Gobies were Two-spotted Gobies, with fewer Crystal Gobies. Gadoids, including Whiting, Poor Cod, Norway Pout, Bib, Saithe, Pollack, and Cod, were also found frequently, while sandeels and other fish were relatively scarce (table 3.3).

Table 3.3. Frequency of occurrence of fish remains of oiled Guillemots shot in the Skagerrak, January 1981 (Blake 1983). The percentages are based on those stomachs containing identifiable remains. Hvaler and Bohüslan are sectors of the Swedish west coast.

Species	Norway	Hvaler	Bohüslan
Clupeid	25%	62%	72%
Gadoid	34%	40%	35%
Sandeel	7%	21%	1%
Goby	78%	57%	79%
Other	0%	0%	1%
Total stomachs	425	153	106
Stomachs with identified fish	265	111	97
%	62%	73%	92%

Invertebrates were encountered, but in few stomachs only (11% Norway, 1% Hvaler, 0% Bohüslan), including Polychaete worms, crustaceans and squid. Madsen (1957) dissected 11 Guillemots which were also shot in winter (Nov-Feb, Kattegat area and Belt Sea). Most stomachs held Herring (82%), but gobies, Stickleback, Viviparous Blenny, Mackerel and a gadoid fish were also found. Invertebrates were encountered only once.

Pre-breeding period Adults and older immatures are all in the immediate vicinity of the breeding colonies. Younger immatures or non-breeders remain elsewhere in the North Sea. Immature Guillemots in April in the southern North Sea fed mainly on sandeels, with smaller numbers of Whiting and clupeids being taken as well (Camphuysen in press). A large flock of Guillemots around 100 km off Flamborough Head was found to be feeding on sandeels, but these birds were caught and killed in trawl nets fishing for sandeels (Tasker *et al.* 1987). All fish brought in for display at colonies in May at Fair Isle and Isle of May were sandeels (Harris & Wanless 1985, Tasker *et al.* 1987). Dietary studies of beached birds (except Camphuysen in press) are scarce in this period. Erikstad & Vader (in press) described differences in Capelin selection for Brunnich's and Common Guillemots shot off northern Norway in the prelaying season. Common Guillemots were feeding mainly on maturing female Capelin in the upper water masses, while Brunnich's Guillemots were diving deeper and caught Capelin (mature and spent male and female) near the bottom.

Size of fish Body depth is used rather than body length in selecting fish of suitable size (Swennen & Duiven 1977). Experiments have shown a preferred body depth of Atlantic Herring of 23 mm (estimated 14 g or *c.* 100 mm long) and a maximum of 44 mm (estimated 96 g or *c.* 200 mm long). The preferred size of Norway Pout was also 23 mm (16 g, or *c.* 100 mm) and the maximum 41 mm (96 g or *c.* 180 mm). However, the birds readily accepted larger, but thinner, sandeels up to 220 mm long (i.e. longest Smelt at disposal during the experiments). Camphuysen (*in press.*) calculated 44.5 mm as maximum depth of Whitings eaten by free foraging Guillemots in the southern North Sea, and an average depth of 36.9 mm, well exceeding the preferred 23 mm for Norway Pout found in experiments. Although body depth is selective, most reports on Guillemot diets deal with fish-length only (whether or not calculated from otolith

length). A summary of recorded prey length per species of fish:

Capelin mean 148 ± 11.8 mm (Labrador 1983, brought to chick, Birkhead & Nettleship 1987), range 110-170 mm, most 130-170 mm (Hornoy, Norway, brought to chick; Folkestad 1984);
Herring preferred 100 mm, max 200 mm (experiments; Swennen & Duiven 1977), range 90-190 mm, most 90-130 mm (Blake *et al.* 1985);
Sprat range 20-120 mm, most 1-group (Jan/Feb, Blake *et al.* 1985), mean 104 mm (Skomer, brought to chicks; Birkhead 1976), mean 122 mm, most 120-130 mm (sampled at colony, Isle of May; Harris & Wanless 1985), mean 132 mm, most 115-154 mm (n= 32; Stora Karlsö, Sweden, brought to chicks; Hedgren 1976);
Cod range 110-137 mm (Norway, post-breeding;Anker-Nilssen & Nygård 1987), mean 117.5 ± 5.0 mm (Labrador 1983, brought to chick, Birkhead & Nettleship 1987), max 210 mm (still 1-group) (Blake *et al.* 1985);
Arctic Cod mean 118.5 ± 16.5 mm (Labrador 1983, brought to chick, Birkhead & Nettleship 1987);
Whiting range 133-224 mm, mean 191.9 (Netherlands, April; Camphuysen in press);
Blue Whiting range 38-90 mm (Norway, post-breeding;Anker-Nilssen & Nygård 1987);
Norway Pout preferred 100 mm, max 180 mm (experiments; Swennen & Duiven 1977), range 50-120 mm (Jan/Feb, 1-group fish; Blake *et al.* 1985);
Poor Cod range 40-110 mm, most 60-90 mm (Jan/Feb, 1-group fish; Blake *et al.* 1985);
Saithe range 70-160 mm (Jan/Feb, 1-group fish; Blake *et al.* 1985);
sandeels max 220 mm (experiments; Swennen & Duiven 1977), range 80-160 mm (Shetlands, Jan; Blake *et al.* 1985), range 50-120 mm, most 70-90 mm (Shetlands, Feb; Blake *et al.* 1985), range 50-140 mm, most 70-90 mm (NE Scotland, Mar; Blake *et al.* 1985), range 60-180 mm, most 70-100 mm (Firth of Forth, Mar; Blake *et al.* 1985), range 55-188 mm, mean 132.7 mm (Netherlands, Apr; Camphuysen in press), range 70-200 mm (Aberdeen, Apr; Blake *et al.* 1985), range 130-160 mm (sampled at colony, Isle of May; Harris & Wanless 1985), mean 125 ± 18.2 mm (Labrador 1983, brought to chick, Birkhead & Nettleship 1987), range 110-170 mm, most 130-150 mm (Hornoy, Norway, brought to chick; Folkestad 1984), range 30-100 mm (NE Scotland, Oct; Blake *et al.* 1985).

Preferred fish: species and size The maximum length of Herring Clupeidae taken by Guillemots is *c.* 200 mm, and therefore 0- and 1-group Herrings can be selected for further study alone. Sprat can be taken from all age-groups. Gadidae: The rapid growth of most gadoids probably precludes their consumption by Guillemots beyond the first year of life (Blake 1983, Blake *et al.* 1985). The exceptionally large Whitings found in stomachs of Guillemots in the Netherlands (Camphuysen in press) were perhaps discarded fish. 0- and 1-group Cod, Whiting and Haddock may be studied as important prey for Guillemots, together with all age-groups for Norway Pout. Ammodytidae: Swennen & Duiven (1977) indicated that Guillemots are quite capable of swallowing rather large sandeels (maximum was a 220 mm Greater Sandeel). Sandeels are not particularly long-lived and therefore it seems logic to include all age-groups in future study, but focussing on 0- and 1-group which form the bulk of total biomass.

References Anker-Nilssen & Nygård 1987, Belopol'skii 1961, Benn 1985, Beveridge 1986, Birkhead 1976, Birkhead & Nettleship 1987, Blake 1983, 1984, Blake *et al.* 1985, Bradstreet 1977, Bradstreet & Brown 1985, Briggs *et al.* 1988, Camphuysen in press, Cramp 1985, Erikstad & Vader in prep., Folkestad 1984, Griffiths 1984, Harris 1970, 1988, Harris & Hislop 1978, Harris & Wanless 1985, 1986, 1988, Hedgren 1976, Heubeck 1989b, Leopold 1988, Madsen 1957, Pearson 1968, Piatt & Methven 1988, Piatt & Nettleship 1985, Prince & Harris 1988, Spring 1971, Swennen & Duiven 1977, Tasker 1983, Tasker *et al.* 1985, 1986, Thomas 1988, Tuck 1960, Wanless, Reynolds & Langslow 1983, Ward 1987, Vader *et al.* 1988, Wanless, Harris & Morris 1985, Webb, Tasker & Greenstreet 1985.

4. TRENDS IN FISHERIES AND FISH STOCKS IN THE NORTH SEA

4.1 The worlds' marine fisheries

The rate of growth of marine fisheries has been enormous this century, particularly since the end of the Second World War. Since the 1950s, each year's world fish catches has set a new record (Anonymous 1968b). The expansion of the world fisheries showed a threefold increase in 1948-67. Fisheries for marine fish alone increased from 13,600,000 tons in 1948 to 46,000,000 tons in 1967. Herring, sardines and anchoveta predominated the catch in world fisheries throughout 1948-67 (33.3% in 1948, 41.7% in 1967), with gadoid fish ranked second (25% in 1948, 17.4% in 1967).

The increase of the catch meant to be sold as fresh fish doubled (10,000,000 tons in 1948, 18,000,000 tons in 1967), whilst the catch in industrial fisheries (for fish-meal and fish-oil) and for freezing grew more rapidly (industrial fisheries 1,500,000 tons in 1948, 20,000,000 tons in 1967; fish for freezing 1,000,000 in 1948, 8,000,000 tons in 1967). In 1970, the FAO projected the demand for fish meal in the world, based on consumption of 2,860,000 metric tons in 1961-63, at 5,790,000 tons in 1975 and 8,500,000 metric tons in 1985 (to convert the demand for meal from fish to the demand for fish it is assumed that 5 tons of fish make 1 ton of fish meal). Since the late 1960s, the international marine fisheries as a whole increased much less rapidly, and since 1970 even downward trends can be noted. A comparison of landings per species for 1970 and 1975 showes that clupeid- and flatfish catches declined significantly, but that most others still increased or stabilized. The largest share of the marine catch (60%) in 1975 came from the temperate waters of the northern Pacific and Atlantic Oceans. In this report attention has been focussed on North Sea fisheries.

References Anonymous 1968b, Barney 1981, Couper 1983, Russel-Hunter 1970, Schumacher 1980.

4.2 Fisheries in the North Sea

North Sea fisheries are mainly directed to a rather small number of species, which can be aggregated in four groups, partly because of their ecological affinities and partly because they are landed by fishing fleets directing their effort to such a species mix (Daan *et al.* 1990):
- four gadoid species (Cod, Haddock, Whiting, and Saithe), largely demersal roundfish which are often taken by bottom trawl fisheries,
- truly pelagic species (Herring, Mackerel),
- small and short-lived species (sandeels, Norway Pout, Sprat) which are exclusively taken in industrial fisheries, and
- flatfish (Sole, Plaice), truly demersal and exploited particularly by the beam trawl fleet.

Many more North Sea species are exploited but the list has been amended over the years (Holden 1978). Landings data are available from 1909 (see 4.6) and the most important species are (after Holden 1978):

Spurdog *Squalus acanthias*, skates and rays *Raja spp.*, Conger Eel *Conger conger*, Herring *Clupea harengus*, Sprat *Sprattus sprattus*, Pilchard *Clupea pilcharda*, Smelt *Osmerus eperlanus*, Angler *Lophius piscatorius*, Cod *Gadus morhua*, Haddock *Melanogrammus aeglefinus*, Whiting *Merlangius merlangus*, Norway Pout *Trisopterus esmarkii*, Pollack *Pollachius pollachius*, Saithe *Pollachius virens*, Torsk *Brosme brosme*, Ling *Molva molva*, Hake *Merluccius merluccius*, Garfish *Belone belone*, gurnards, mainly Grey Gurnard *Eutrigla gurnardus*, Scad *Trachurus trachurus*, Catfish *Anarhichas lupus*, sandeel *Ammodytidae*, Mackerel *Scomber scombrus*, Brill *Scophthalmus rhombus*, Turbot *Scophthalmus maximums*, Megrim *Lepidorhombus whiffiagonis*, Plaice *Pleuronectus platessa*, Flounder *Platichthys flesus*, Dab *Limanda limanda*, Lemon Sole *Microstomus kitt*, Witch *Glyptocephalus cynoglossus*, Halibut *Hippoglossoides hippoglossoides*, Sole *Solea solea*.

The major fisheries are exploited by four gears: the hook and line, the drift net (gill nets), the trawl and the purse seine (Cushing 1982). Other types can be found in minor or specialized fisheries. The now following descriptions of fishing gear are taken mainly from Cushing (1982).

Hook and line gear in its most simple form is known from sports anglers from small boats or from the shore. Other examples, more important in commercial fisheries, are floating long-lines and demersal long-lines. Demersal long-lines are up to 5 km in length and baited hooks are used every two metres or so. The line is left for a tide while demersal or bottom living fish can take the bait. Unbaited hooks are used for pelagic fishes in floating long-lines. In subtropical oceans tuna is fished with pelagic long-lines, with hooks of different shapes and sizes hung at variable depths from a main line of some 80 km length. Long-line fisheries require many crew to haul and shoot the lines.

Also *gill-nets* are either set on the bottom or kept floated up by buoys. North Sea Herring was taken by drift nets, until the drifters were displaced by trawlers or purse seiners. A drifter shoots a great number of nets, each floated up by boys from a heavy rope which remains attached to the vessel. The whole system, like a long curtain hung from the surface, drifts with the tide and the fish migrating with the tide swim into it.

The *trawl*, a net towed behind a fishing vessel, is today used widely throughout the world and trawl net fishing became very important when the steam trawler was introduced, at the end of last century (Lundbeck 1962). After the Second World War, a variety of tralwing gears was developed for many purposes. The trawl was one of the essential gears for the industrial fisheries, adapted to mechanization and able to be handled by a small crew.

The last major gear is the *purse seine* net, which is a curtain of net shot in a ring from a fishing vessel till the circle is complete and the hemisphere is than closed below, or pursed, and the shoal of pelagic fish is contained to be taken onboard the ship. Today the purse seine is the most powerful fishing instrument and because small and adult fish are taken indiscriminately it should be treated with care and caution.

Echosounder with trawl and *sonar* with purse seine made enormous change in fishing. Spawning and assembly grounds of Herring were easily detected by echosounding. For herring- or spratlike fish purse seine nets and sonar combination is the most efficient equipment yet devised (Cushing 1974, 1982).

Fisheries can be classified in many ways. Biological categories, for example, could be fisheries on (a) spawning grounds, (b) on feeding grounds, (c) at hydrographic boundaries, and (d) in upwelling areas (Cushing 1982). They can be classified as (a) inshore, (b) continental shelf and (c) oceanic, or (a) demersal and (b) pelagic. The classification of fisheries into (a) commercial fisheries and (b) industrial fisheries, as used in this report (4.3, 4.4), is used to indicate fisheries of which the landed fish is used for human consumption, or of which the landed fish is processed into fish meal or -oil and is thus not intended for human consumption in the form of fish protein (Goodlad 1989, Madsen 1978). "Mixed" fisheries are directed towards species for human consumption (e.g. shrimp or lobster) but from which the by-catch is landed for industrial use (Lahn-Johannessen *et al.* 1978, Madsen 1978) are not discussed as a separate fishery in this report.

Fisheries data are collected by ICES for certain standard statistical divisions. The North Sea is division IV, subdivided into IVa (northern part), IVb (central part) and IVc (southern part) as illustrated in figure 4.1 or into more particular subsectors.

References Cushing 1974, 1982, Daan *et al.* *(in press)*, Goodlad (1989, Hempel 1978abc, Holden 1978, Lahn-Johannessen, Jakupsstovu & Thomassen 1978, Lundbeck 1962, Madsen 1978.

4.3 Commercial fisheries

Some of the major trends in pelagic and demersal fisheries in the North Sea are summarized below. For a long-term description of the North Sea fisheries the reader is referred to Cushing (1982), Hempel (1978abc) and Saville (1980ab). For our project, flatfish directed commercial fisheries are of limited importance and these are therefore not treated. Gadoid, Herring and Mackerel fisheries are discussed here in some detail, but it should be realized that most landed fish in these commercial fisheries are large; too large for most seabirds to feed on.

Catch statistics show that in recent years the pelagic fish stocks in the North Sea and adjacent waters (e.g. Herring and Mackerel) have changed considerably. Schumacher (1980) described the catch of pelagic fish in the North Atlantic and found that the typical trend was a rapid rise in landings followed by a collapsing fishery. The North Sea Herring fishery peaked in the mid sixties and declined to an all time low in 1977-78: the Herring catch dropped from an average of 982,000 tons per annum during 1956-60 to only 47,000 tons during 1976-80 and than slightly recovered (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). The North Sea Mackerel fishery peaked during 1966-70 at 646,000 tons per annum and subsequently declined to only 39,000 per annum during 1981-85 (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). The common feature in the development of catches of pelagic fish arises from the shoaling behaviour of pelagic species which results in high vulnerability to fishing with modern detecting and catching methods (Schumacher 1980). Corten (*in press*) argumented that some pronounced changes in pelagic fish stocks, e.g. the shift in Mackerel overwintering grounds from south of

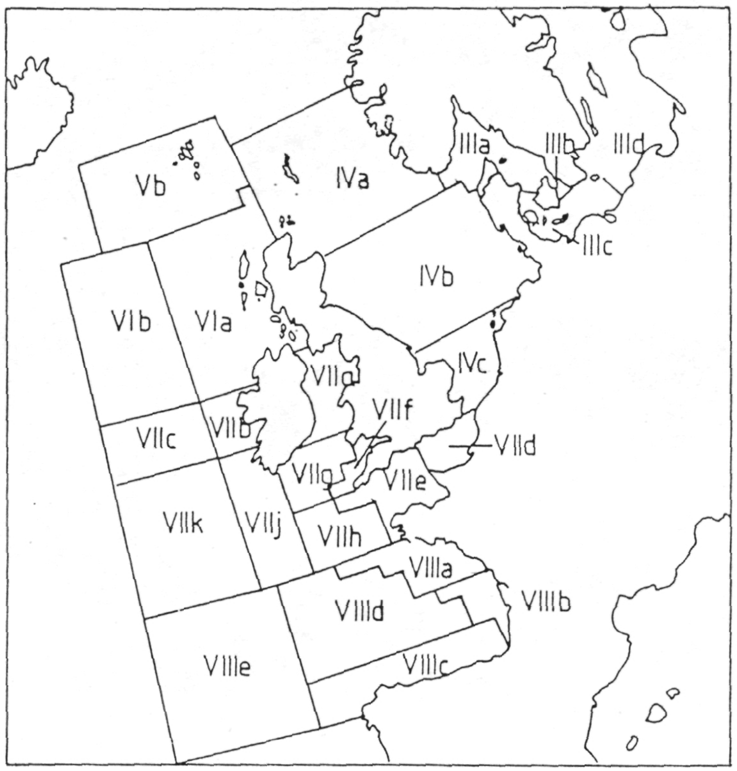


Figure 4.1. ICES statistical divisions in western Europe. The North Sea is shown as division IV (IVa, IVb, IVc).

Cornwall in 1965-80 to north of Scotland in 1982-85, are changes in the biology of these fish and cannot be explained by the effects of fishing pressure.

When the various Herring stocks in the North Sea were in the decline in the 1960s, a gadoid outburst occurred and it was assumed that the two events were related (Cushing 1980). Although the causes of the gadoid outburst remained unknown, the large increases in recruitment could be due to the release of food at an early stage in the life cycle or to relaxed predation at any stage before recruitment to the spawning stock. The trend in demersal fisheries for Cod, Haddock, Saithe and Whiting was very similar in that the catch increased during 1951-70 or 1975 and subsequently declined (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). The Cod catch peaked during 1971-75 at an average of 260,000 tons per annum, the Haddock catch during 1966-70 at 377,000 per annum (partly due to exceptionally large catches of 639,000 tons in 1969 and 672,000 tons in 1970), the Saithe catch during 1971-75 at 242,000 tons per annum and the Whiting catch during 1966-70 at 154,000 tons per annum. North Sea fisheries for Herring, Cod, Whiting, and Mackerel are discussed in this chapter in further detail (4.8, 4.10, 4.11, 4.14).

4.4 Industrial fisheries

Industrial fisheries can be defined as "any fishery whose catch is not sold directly for human consumption", i.e. the catch is usually converted to fish meal and fish oil (Madsen 1978, Goodlad 1988). The main industrial fisheries nowadays in the northeastern North Atlantic are for sandeels, Norway Pout and Sprat in the North Sea and for Capelin in the Barents Sea (Bailey & Hislop 1978). The species exploited by industrial fisheries have changed over the years and have included sandeels, Sprat, immature Herring, Norway Pout, Whiting, and immature Blue Whiting (Gauld *et al.* 1986). The importance of industrial fisheries in the North Sea has grown since it began in the early 1950s. Nowadays, industrial fisheries take almost 60% of the annual landings of fish (Gauld *et al.* 1986, Russel-Hunter 1970, Anonymous 1989d). The industrial fisheries had doubled the output in weight of the total North Sea fisheries during 1960-74 (Madsen 1978), but after reaching a peak of nearly 2,000,000 tons in the mid seventies the total landings from industrial fisheries have declined (table 4.1; Anonymous 1989d). On average some 1,460,000 tons were landed annually from 1974-87 (Anonymous 1989d). In recent years, Denmark has accounted for more than 80% of the catch, Norway for around 10% and smaller quantities were taken by the Faeroes, and the United Kingdom. In his review in 1978, Madsen (1978) indicated that industrial fisheries in the North Sea were undertaken by Denmark, the Faroes, the Federal Republic of Germany, Norway, Sweden, and the United Kingdom. While

Table 4.1. Total catch (tons) in industrial fisheries in the North Sea during 1950-88, and landings in Herring/Sprat, sandeel, and Norway Pout directed fisheries (from Madsen 1978, Anonymous 1989d).

Year	Sprat/ Herring	Sandeel	Norway Pout	Total Catch
1950	21200			28500
1951	49900			59800
1952	74400	1600		92900
1953	115900	4500		143300
1954	121700	10800		154800
1955	157000	37600		192000
1956	121000	88700		224900
1957	124900	105700	200	269100
1958	172800	100900	0	315600
1959	211500	107600	69300	430800
1960	159200	120600	26500	357000
1961	149700	177700	26300	305300
1962	161800	109300	136700	467600
1963	155700	162000	109500	606500
1964	299200	128000	44200	768600
1965	725800	130600	35500	1187500
1966	564100	142900	46800	1435000
1967	437600	188700	178300	1776500
1968	416600	193700	436800	1991600
1969	355300	113300	102600	1809800
1970	391100	191400	217200	1491000
1971	342900	382000	280100	1510400
1972	337000	349600	392400	1501300
1973	290400	294400	394800	1626100
1974	314000	525000	798000	1857000
1975	641000	428000	602000	1799000
1976	634000	488000	471000	1791000
1977	314000	786000	428000	1675000
1978	386000	787000	370000	1612000
1979	395000	578000	384000	1434000
1980	330000	729000	547000	1675000
1981	293000	569000	298000	1245000
1982	306000	611000	478000	1452000
1983	243000	537000	541000	1359000
1984	112000	669000	434000	1250000
1985	113000	622000	270000	1033000
1986	56000	848000	211000	1140000
1987	80000	825000	177000	1106000
1988	271000	893000	130000	1349000

industrial fisheries are indiscriminate in the sense that they take whatever species are available on the fishing grounds, it is possible to identify a number of main fisheries, characterized by the area and season, vessel size, and fishing gear:

Sandeel fisheries, for example, are quite distinct in that they operate from Mar to Sep in relatively shallow waters using trawls with no mesh size restrictions. The Danish sandeel catch rose from 1,600 tons in 1952 to some 700,000 tons per annum in recent years. German industrial sandeel fisheries were in operation only from the early 1950s to 1972 (peak 25,500 tons in 1957), the Faeroese sandeel fishery commenced in 1973 (1,400 tons) and the annual catch ranged from 1,200-

18,600 tons since that year, Dutch and Swedish sandeel fisheries were insignificant (Holland: 1956-61, maximum landing 5,100 tons 1959, Sweden: 1972-83, maximum 8,800 tons). Norwegian sandeel fisheries are growing (193,400 and 185,100 tons in 1987 and 1988 respectively) and formed a significant contribution to the total North Sea catch for sandeels since the early 1970s. UK sandeel fisheries started in 1969 and peaked in the late 1970s and early 1980s (maximum 52,200 tons 1982). The total North Sea sandeel catch rose steadily to a peak of some 900,000 tons in 1988 (Anonymous 1989d). The decline of the UK sandeel fisheries, mainly in operation around Shetland, was caused by a decrease in the relative economic viability of sandeels, compared to white fish, and because the sandeel stock had declined (Goodlad 1988). Tiews (1978c) reported on by-catches in the German industrial sandeel fishery in the southern North Sea between 1951 and 1973 and found that the amount of sandeel (in percent of total weight) in the catch was usually over 85%. Legal sized (over 20cm) Whiting was the most important by-catch.

Fishery for Norway Pout is usually conducted by larger vessels, fishing the deeper waters of the northern North Sea, with small mesh (16mm) trawls (Gauld *et al.* 1986). The fishery for Norway Pout in the North Sea commenced in the late 1950s, and since the bulk of the catch consists of 0- and 1-group fish, the annual landings fluctuate in response to changes in year-class strength. Most Norway Pout is taken by Danish fishermen (although the Norwegian fleet equalled the Danish catch in the mid seventies), and they landed large quantities in 1968 (410,800 tons), 1974 (464,500 tons), 1980 (366,200 tons), and 1983 (301,100 tons). The Norwegians landed some 100-200,000 tons per annum between 1972 and 1976 and so the absolute maximum amount of Norway Pout ever taken was 735,800 tons in 1974. The Faeroese fisheries for Norway Pout is rather insignificant in recent years (1985-88 less than 10,000 tons) but contributed with 50-80,000 tons per annum between 1971 and 1977 to the total North Sea catch. Small quantities of Norway Pout were taken between 1970 and 1980 by Sweden (maximum 6,800 tons in 1972), the United Kingdom (maximum 26,700 tons in 1974) and some other countries. Since 1983 there has been a significant decline in annual landings in the North Sea and the 1988 catch was the lowest since 1966. Gauld *et al.* (1986) attributed the low 1985 catch to a reduction in fishing effort compared to 1984, low stock size and poor recruitment.

There is no clear dividing line between the fisheries for Norway Pout and (immature) Blue Whiting. In general, the deeper the water fished, the higher the percentage of Blue Whiting in the catch (Gauld *et al.* 1986). The total catch of Blue Whiting, which peaked in 1982 and 1983 (both 118,000 tons) has decreased markedly, to 28,000 tons in 1988, the lowest catch since at least 1974 (Anonymous 1989d).

Further south in the North Sea, particularly outside the sandeel season, the small mesh trawl fisheries take a mixture of Sprat and immature Herrings (Gauld *et al.* 1986). In the western North Sea (ICES sector IVbW), some 55.2% of all Sprat is taken between Jan and Mar, another 39.9% between Oct and Dec (Johnson 1983). Most Sprat are landed from this area by Danish (1975-81 44.8%) and Norwegian (29.7%) fishermen. In the eastern half of the North Sea (ICES IVbE) most Sprat is taken in autumn (54.3% Jul-Sep, 29.9% Oct-Dec), again by Danish

and Norwegian fishermen (1975-81 87.7 and 12.3% respectively). Theoretically, this fishery is regulated by a "10% herring by-catch limitation". However, whereas this fishery took mainly Sprats up to 1981, the greater part of the catch is now Herring (following the collapse of the Sprat stocks and the recovery of recruit- ment to the Herring stocks). The industrial landings of Sprat peaked in 1975 and 1976 (641,000 and 622,000 tons respectively) and have declined significantly since 1982 (1986 only 16,000 tons, 1987 and 1988 slight recovery to 33,000 and 92,000 tons). Herring "contributed" in the industrial Sprat fishery with peaks of 153,000 tons in 1982, 155,000 tons in 1983 and 179,000 tons in 1988 (50, 64, and 66% of the Sprat catch in these years). Tiews (1978c) reported on bycatches in the German industrial fishery on Clupeoid fish during 1951-73 in the German Bight and found that the total amount of Herring and Sprat in the catch could be as low as 34.4%. The most abundant by-catches were Whiting and Haddock. The available data on by-catch composition are not always very accurate. In the Norwagian prawn fisheries in the Norwegian Deeps, Blue Whiting and Greater Silver Smelt tend to be the dominating species, but they are recorded as Norway Pout (Lahn-Johannessen *et al.* 1978, Thomassen 1974)!
North Sea fisheries for Sprat, Norway Pout and sandeels are discussed in this chapter in further detail (4.9, 4.12, 4.13).

References Anderson 1989, Anonymous 1984, 1989d, Avery & Green 1989, Bailey 1980, Bailey, Gauld & Kunzlik 1989, Bailey & Hislop 1978, Blake 1983, Christensen 1971, 1972, Corten 1990, Couper 1983, Cushing 1980, 1982, Duffy *et al.* 1987, Furness 1982, Furness & Ainley 1984, Gauld, McKay & Bailey 1986, Goodlad 1989, Hempel 1978abc, Heubeck 1989, Hoydal 1985, Johnson 1983, Kunzlik 1989, Lahn-Johannessen, Jakupsstovu & Thomassen 1978, Macer 1966, Madsen 1978, Nikolaev 1977, 1981, Russel-Hunter 1970, Saville 1980ab, Schumacher 1980, Thomassen 1978, Tiews 1978c.

4.5 Impact of fisheries on fish stocks and suggested interactions among fish stocks

Severe reductions of biomass of fish occurred immediately after the introduction of "modern" (steam engines) trawlers at the end of the last century in demersal fisheries (Lundbeck 1962). As far as known, these stocks have never since recovered (Furness & Monaghan 1987). The potential recovery of these stocks was demonstrated during both the First and Second World Wars, when fishing effort was low (Russel-Hunter 1970). Stock depletion due to overfishing following the introduction of some new fishery has occurred in a number of cases. Perhaps the best known example is the overfishing of major Northeast Atlantic Herring stocks in the 1960s and 1970s and the fishing ban (Jakobsson 1985). History has learnt that the development of the fisheries can be characterized by overinvest- ment in new and more powerful vessels (Daan 1980h. Overexploitation of stocks is therefore a constant risk. Generally, high exploitation rates result in (following Furness & Ainsley 1984):

- a reduction of the biomass of the stocks
- a reduction in the average and range of sizes of fish within a population
- a reduction in population distribution
- increased patchiness of distribution
- increased susceptibility to random fluctuations due to variations in recruitment

Some pelagic fish stocks have shown long-terms trends in abundance and distribution that cannot be explained by changes in fishing effort (*e.g.* Cushing 1982, Corten 1990, Furness & Monaghan 1987). The essential point is that not all the recent changes in fish stocks in the North Sea can be put down to fishing (cf. Bailey 1989). Many fishery biologists have concentrated on fishery-induced changes rather than environment-induced changes for obvious reasons. Fishing effort can be quantified, while small environmental or climatic alterations are very difficult to detect. However, several factors may act simultaneously and a proper understanding of the effect of fisheries is possible only if natural changes can be identified and quantified (Corten 1988).

Recent studies of fish stocks and fisheries more and more concentrate on interactions between fish stocks (e.g. Gislason & Helgason 1985). The effect of fisheries as described above on fish stocks may be true but side-effects should not be ignored. Measures taken on the exploitation of one fish may have unexpected effects on other fish stocks. In the North Sea yields of demersal fish increased in the 1960s, coincident with a massive decrease in stocks of Herring and Mackerel (pelagic species), as a result of a substantial increase of fishing effort directed at these two species (Cushing 1980). The increase of demersal stocks resulted from several years of exceptionally good recruitment, which may have been the result of reduced predation on larvae by the pelagic fish species. Similarly, a major increase in sandeel stocks appears to have occurred in the North Sea as a response to reduced competition with Herring and Mackerel (Andersen & Ursin 1978, Sherman *et al.* 1981). More recently, now that the Herring stocks are recovering from severe overfishing, increased predation of sandeels by Herring may have caused the recruitment failures in sandeels and, hence, the reproductive failures in seabirds in Shetland in the 1980s (Heubeck 1989a). Measures to "protect" the current size of seabird populations could thus be an increase of fishing effort on predatory fish rather than the closure of sandeel fisheries. The interactions between fish stocks are not at all fully under- stood and thus measures to ban, develop, increase or reduce fisheries may have all sorts of (unwanted) side-effects.

References Andersen & Ursin 1978, Bailey 1989, Corten 1990, Cushing 1980, 1982, Daan 1980h, Furness & Ainley 1984, Furness & Monaghan 1987, Gislason & Helgason 1985, Heubeck 1989a, Jakobsson 1985, Lundbeck 1962, Russel-Hunter 1970, Sherman *et al.* 1981

4.6 Databases, stock assessments and fish stock management

4.6.1 Databases on North Sea fish stocks, an introduction

The research on fish stocks and distribution of fish by fishery institutions is directed in the first place towards commercially interesting species. Stocks of unexploited fish in the North Sea are therefore relatively unknown. Landings data in the eastern North Atlantic are submitted to the International Council for the Exploration of the Seas (ICES), København. ICES was founded at the end of last century. Statistics derived from landings data and from sytematic surveys by fisheries institutes are treated separately in the following accounts.

4.6.2 Landing statistics and their use for total fish stock analysis

Commercial fisheries statistics are the main source of data currently used for stock assessments. Landings of fish from the North Sea, defined as ICES subarea IVa, IVb, and IVc (i.e. excluding the Skagerrak) have been published since 1909 in *Bulletin Statistique des Pêches Maritimes*. Catch statistics are quite useful since they are directly related to the problem of estimating fishing mortality (i.e. the amount of fish removed from a stock through fishing. However, several questions cannot be answered using these data alone and systematic surveys with research vessels are needed in addition. Landing statistics offer data on amount of fish landed (per fleet, age composition of the stock and length per age-group, and the amount of time spent fishing. Periods during which member nations of ICES contributed landings data for the North Sea to ICES are listed in table 4.2. The number of countries submitting data has increased steadily, partly as some nations extended their fishing activities into the North Sea and partly because more and more countries became members of ICES. The record is therefore incomplete, although from 1931 onwards it probably includes most of the landings (Holden 1978). Catch statistics for certain local fisheries may exist over considerably longer periods. Lindquist (1978), for example, describes developments in Sprat fisheries off the Swedish coast since 1859.

4.6.3 Methods in assessing total fish stocks (biomass)

Virtual Population analysis (VPA) Fish stock assessment within ICES is mostly based on the models of Beverton & Holt (1957), in particular through one of its derivatives, the Virtual Population Analysis (VPA; Gislason & Helgason 1985). VPAs are based on an analysis of catch data of the commercial fishing fleet, supported by special surveys carried out by fishery research institutes. VPAs are used for the assessment of the fish stocks and work more accurately for long-lived species than for short-lived species. VPAs are also used for predictions and management recommendations. A detailed description of the VPA using estimates of fishing mortality in the West Greenland Cod stock is published by Schumacher (1970). An investigation of the accuracy of the VPA using cohort analysis (each year-class of a fish is called a cohort) is published by Pope (1972). The VPA model is a single species model, i.e. each fish species is treated independently of the others and there is nothing in the calculations which allows for species interaction (Gislason & Helgason 1985). Recommendations on stock managements derived from VPAs can call for measures which lead to changes in certain fish stock sizes by an order of magnitude. Everybody knowns that such drastic changes may influence other species also, but nevertheless conclusions were drawn from these single-species models.

Table 4.2. Periods during which member nations of ICES contributed landings data for the North Sea fisheries to ICES *Bulletins Statistique* (after Holden 1978).

Belgium	1909-12	1920-38	1941-
Denmark	1909-38	1940-	
Faroe Islands	1932-34	1936-38	1955-
France	1925-38	1947-	
Germany	1909-38	1940-45	
DDR	1961-		
FRG	1946-		
Iceland	1933-34	1936	1954-
Netherlands	1909-38	1940-44	1946-
Norway	1909-38	1940-	
Poland	1931-38	1955-	
Sweden	1914-38	1940	1945-
U.K. (England	1909-38	1946-	
U.K. (Scotland	1909-38	1940-	
USSR	1955-		

Multi-species Virtual Population Analysis (MSVPA) is the present answer on the problems resulting from the single-species treatment in the VPA. Models of species interactions are numerous (e.g. Ursin 1982). Gislason & Helgason (1985 point out that predation, calculated within the model from the food selection of the predators, their yearly food intake and the average stock sizes, is very important. On average the total biomass of fish estimated to be predated by other fish amounts 1.6 times that removed by the fishery. The introduction of predation mortality changes the exploitation pattern calculated by traditional VPA. The most salient effect of introducing predatory interactions in the VPA for the North Sea is the increased mortalities for the younger age groups. Sparholt (1987) suggests values for residual natural mortality (i.e. predation mortality caused by "other" fish predators than the MSVPA predator species, by seabirds and seals, and the mortality caused by diseases, spawning stress, physiological based mortality and so on). Multi-species VPAs, which are currently being developed rather than ready for use, will change yield per recruit, mesh-size assessments and other measures since it seems likely that much of the current advice, which is based on calculations where the same natural mortality has been applied to all ages, is wrong (Gislason & Helgason 1985).

References Anderson 1989, Beverton & Holt 1957, Christensen 1971, 1972, Daan 1980h, Gislason & Helgason 1985, Holden 1978, Høydal 1985, Lindquist 1978, Nikolaev 1977, 1981. Pope 1972, Schumacher 1970, Sparholt 1987, Ursin 1982.

4.6.4 Management of fish stocks

The catches from fish stocks obey the law of diminishing returns (Pope 1982). Thus, if fishing effort is doubled on a fish stock the catch in the long term will not necessarily be twice as big. The typical production function for a fish stock is a curve running from A (no fishing, no catch) up (more fishing effort, more catch) to a point B. Any further increase in fishing activity, beyond point B, will lead to a decreasing long-term catch. The catch at the peak of the yield curve (point B) is called *Maximum sustainable yield* (MSY). Levels of fishing beyond B are regarded as over-fishing.

The basic ideas behind a *Total allowable catch* (TAC are very simple. The objectives of fisheries management are generally expressed as "desired level of fishing mortality", or the proportion of the available fish which is intended to be caught in a year. The TAC is thus simply an estimate of the exploitable biomass of fish in that year (Pope 1982).

4.6.5 Methods in assessing the distribution of fish

International Young Fish Survey (IYFS) What was initially set up as the International Young Herring Survey (IYHS) has changed in the course of some 30 years into the "International Young Fish Survey (IYFS)". The distribution and relative abundance of fish is studied in the IYFS and this is mainly based upon catch per unit effort. These surveys are carried out in February, were first conducted in the 1960s, and are repeated annually since that time. Participants in 1989 in the IYFS were Denmark (MV Dana), France (MV Thalassa), West Germany (MV W.Herwig), the Netherlands (MV Tridens, MV Isis), Norway (MV Eldjarn), Sweden (MV Argos), and the United Kingdom (England: MV Cirolana and Scotland: MV Scotia). For all details on (present) survey methodology, the reader is referred to the IYFS Manual (ICES, Doc. C.M. 1986/ H:2). Details on the standard analysis of data are described by Pedersen (1989). Annual and special reports on these surveys have been published through ICES and these reports are all available in the library of RIVO IJmuiden. From the IYFS, information on the distribution, relative abundance, age (group) and length of a number of fish species can be obtained. Rectangles on maps used for the IYFS measure 0.5° latitude x 1.0° longitude, and thus each equal 4 rectangles which are used to present seabird distribution data. Fish is sampled with a Gov-trawl (multi-species; 1-4 hauls per 0.5*1° square). More recently, Herring and Sprat larvae are sampled with an Isaacs-Kidd Midwater Trawl (IKMT; 293 hauls in 1989). The IYFS offers also information on hydrographic conditions (567 hydrographic stations were worked in 1989; Anonymous 1989c). Examples of the distribution of fish in the (southern) North Sea are presented in the species accounts. Number of fish per hour per haul in each age group for each rectangle, mean length per age group per rectangle, and number of hauls per rectangle are standard maps given in the annual reports. Species included in the analysis in the 1989 report are Herring, Sprat, Mackerel, Cod, Haddock, Whiting, and Norway Pout. Bottom temperature and -salinity and anomalies of surface temperature and -salinity (relative to the 1905-54 mean) are mapped. The IYFS does not provide adequate information on the abundance of sandeel (wrong net) and also data for Mackerel are regarded as being poor. Sprat data were seriously biased towards larger and older specimens prior to 1980 (IKMT was introduced in 1980). Since the IYFS is carried out in February, this information is highly valuable for our purpose: a comparison of fish distribution/fish stocks and seabird wintering distribution.

English groundfish surveys In the summer of 1977 a series of trawl surveys for demersal fish in the North Sea began, named the English Groundfish Surveys (EGFS; Harding *et al.* 1986). Groundfish surveys were planned to run for at least ten years to establish a time series of data which could be used to study the biology and ecology of demersal fish and certain problems of the fisheries

management. Some of the objectives were: to measure trends in the abundance of demersal fish, to determine the proportions of species caught in order to describe a mixed fishery, to describe the distribution of gadoids and some industrial fish species and to estimate the abundance and the distribution of species poorly sampled by the commercial fleet. To ensure year-to-year comparability the surveys were carried out in late summer (Aug/Sep) each year by RV Cirolana, using a standard bottom trawl with a fine mesh liner in the cod-end to retain juveneniles and small fish as a survey instrument. By repeating these surveys annually, it is possible to monitor changes in the abundance of fish (at each age group) and hence to estimate mortality directly. Yang (1982) used the results from groundfish surveys to estimate total biomass of fish stocks and the relative abundance of all species (with assumptions on catchability). Daan *et al.* 1990 used both results of groundfish surveys and from IYFS to estimate total biomass of fish stocks in the North Sea. From the EGFS additional age-at-length data is provided to supplement material collected from commercial landings. During the first 5 years (1977-81), 46 stations have been sampled. These stations were chosen at random within five depth bands for 9 groundfish areas in the North Sea. During the next 5 years (1982-86) up to 35 more stations were added to the sampling grid to give better spatial coverage of the North Sea (Harding *et al.* 1986).

Scottish research vessels Richards *et al.* (1978) discuss trends in Scottish Research-vessel catches of various fish species in the North Sea during 1922-71. In their analysis data were included from hauls with otter trawls or wing trawl from RV Explorer I, RV Explorer II, and RV Scotia I, with a small mesh cover over the cod-end. Only hauls made at depths greater than 30 meter were included in their analysis to eliminate possible bias due to intensive, but irregular, sampling of inshore "nursery" grounds. Nine species occurred commonly in the research vessel catches: Cod, Whiting, Saithe, Norway Pout, gurnards, Dab, Plaice, Lemon Sole and Long-rough Dab.

Acoustic surveys Echo surveys are meant to estimate the population size of pelagic fish, by using echo-sounding equipment to plot the density of fish. The interpretation of these data is extremely difficult, particularly where various pelagic species are found in the same area. It is difficult to obtain accurate estimates of abundance because of the size of the area to be surveyed, logistic problems and technical problems in interpreting the echo signals (Pope 1982). However, echo surveys can be most valuable when carried out together with counts of predatory seabirds. The aggregative response of Guillemots and Puffins to their prey was demonstrated using echo-surveys and at sea counts by Piatt (1988) and Leopold (1988). Echo-surveys are useful to locate small enriched areas which may be important for seabirds such as the Frisian front, as demonstrated by Leopold (1988). However, without sampling the fish causing the echo-traces we do not know the species and therefore the presence of a trace on the sounder does not necessarily indicate a food source that is suitable or available to the birds (cf. Burton *et al.* 1987).

References Aglen & Iversen 1980, Anonymous 1963, 1968a, 1969, 1971, 1974, 1975ab, 1976, 1977ab, 1978, 1979, 1986, 1987a, 1988a, 1989c, Bakken 1972, Becker & Corten 1974, Burton *et al.* 1987, Corten 1975ab, 1976ab, 1977ab, 1978abc, 1979ab, 1980ab, Corten & Kuiter 1973, 1974, Daan 1969, 1972, 1973, 1974, 1976, 1977, 1978, 1979abcdefgh, 1980abcdefgh, Daan *et al.* 1990, Edwards

& MacKay 1984, Edwards, Wilson & Bailey 1979, Forbes & Hutcheon 1984, Gambell & Sahrhage 1961, Gambell *et al.* 1961, 1962, Harding, Woolner & Dann 1986, Johnson 1974, 1978, 1979, 1980, 1984, Leopold 1988, McKay & Edwards 1985, Piatt 1988, Pope 1982, Postuma 1968, 1969, Postuma & Kuiter 1971, 1972, 1973, Postuma & Zijlstra 1969, 1970, Richards *et al.* 1978, Richardson *et al.* 1959, Rogalla 1966, Saville 1967, Schubert 1970, 1972, Smed 1970, 1971, 1973ab, 1974, 1975, 1976, 1977, 1978, 1979, 1980, Walsh 1974, 1977, 1979, Yang 1982, Zijlstra 1964, 1966.

4.7 Relative abundance of fish species in the North Sea and estimates of total biomass

The total North Sea fish stocks were estimated to fluctuate from 8 to 9 million tons between 1960 and 1976. In 1977 and 1978, Yang (1982a) estimated the total fish stock at 1 January 1977 and 1 January 1978 in the North Sea and presented 9,700,000 tons biomass as a mean of these years. The biomass of each species was calculated from abundance indices, derived from catches made during the English groundfish surveys in 1977 and 1978 and biomass estimates of standard commercial species (Yang 1982b). Only 18 species/groups of fish, out of a total of some 224 species, represent 90% of the estimated total biomass (table 4.3).

Table 4.3. Estimates of total fish stocks biomass (tons) in the North Sea. Mean for 1977 and 1978, measured at 1 January (from EGFS; Yang 1982)

Species	Biomass	%
Starry Ray *Raja radiata*	453,100	4.7
Herring *Clupea harengus*	250,600	2.6
Sprat *Sprattus sprattus*	755,300	7.8
argentines *Argentina spp.*	401,600	4.1
Cod *Gadus morhua*	386,800	4.0
Haddock *Melanogrammus aeglefinus*	246,400	2.5
Norway Pout *Trisopterus esmarkii*	591,600	6.1
Saithe *Pollachius virens*	595,300	6.1
Silvery Pout *Gadiculus argenteus*	251,400	2.6
Whiting *Merlangius merlangus*	355,600	3.7
Blue Whiting *Micromesistus poutassou*	154,200	1.6
Grey Gurnard *Eutrigla gurnardus*	639,200	6.6
Scad *Trachurus trachurus*	223,200	2.3
sandeels *Ammodytidae*	1,312,100	13.5
Dab *Limanda limanda*	744,200	7.6
Mackerel *Scomber scombrus*	637,600	6.5
Plaice *Pleuronectus platessa*	530,200	5.4
Long Rough Dab *Hippoglossoides platessoides*	227,200	2.3
Total biomass (tons) estimate	9,735,200	

The Herring stock had just collapsed and reached an all-time low in 1977-78 (Anonymous 1989b), so the proportions in table 4.3 were probably atypical. Another problem in Yang's data is that the trawl used on the surveys only effectively samples demersal fish on offshore grounds, and only 90 species have been taken since the surveys commenced in 1977 (Daan *et al.* 1990). Harding *et al.* 1986). Better estimates of total biomass in the North Sea are made by Sparholt (1987), from English Groundfish Surveys (EGFS) in summer and the International Young Fish Survey (IYFS) in winter. Sparholt noted the

tremendous difference in biomass comparing the first and third quarters of a year, mainly caused by the immigration of 500,000 tons of Mackerel and 1,500,000 tons of Scad into the North Sea during the third quarter. Although there are discrepancies in the reliability of the various biomass estimates, Sparholt's method is at present the best way of dealing with a wide variety of species, including fish of little or no economic value (Daan *et al.* 1990). Estimates of total biomass of fish in the North Sea following Sparholt's methods ranged from 10,868,000 tons (1985) to 14,719,000 tons (1982) (Daan *et al.* 1990). The estimated mean over 1977-86 was a total biomass of 12,257,000 tons, with Herring (11.7%), sandeels (14.6%) and Dab (17.2%) representing 43.5% (table 4.4). Trends, calculated from these biomass estimates, for fish species studied in this report, showed that Herring and Haddock increased, while Sprat, Cod, Whiting and Mackerel decreased significantly (Spearman Rank Correlation test, 1977-86, $p < 0.10$ (2-tailed), $n = 10$; see species accounts). No (significant) trends were found for Saithe (stable or slight increase), Norway Pout (fluctuating) and sandeels (fluctuating).

4.8 Herring *Clupea harengus*

The Herring is an extremely abundant fish in northwestern Europe, but it has widely been overfished so that it became less economically valuable in the late 1970s (e.g. Burd 1978, Jakobsen 1985). Herring was estimated to represent on average 11.7% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al.* 1990), with an all-time low of 1.8% in 1977, and a significant increase since that year (r_s 0.99, $n = 10$, $p < 0.02$, two-tailed). The Herring usually swims in schools near the surface or in coastal waters. At all stages of its life the Herring is preyed upon by numerous predators, including other fishes, seabirds and marine mammals. Herring is capable to grow to a maximum length of over 40 cm (680 g; Wheeler 1978), but fish of this size are extremely rare nowadays (A. Corten).

4.8.1 Calorific value, biomass and utilization by seabirds

The weight-length relationship of (young) Herring, where W = total body weight (g) and L = total body length (cm) is given by Harris & Hislop (1978) as $W = 0.00254\ L^{3.289}$. The calorific value of Herring is probably similar or slightly less than that of Sprat (Harris & Hislop 1978, M.L. Tasker). Adult Herring (over 200 mm total length) are probably too large to be swallowed by Alcidae and Kittiwakes. Gannets are probably capable to cope with all age classes and Fulmars may tear large Herrings discarded from trawlers apart (C.J. Camphuysen). From the IYFS 1989 it can be shown that the mean length of 1-group Herrings in the Central North Sea already exceed 200 mm in length (Anonymous 1989c) and, hence, 2-group Herring are clearly too large for most seabirds. Future studies should thus mainly focus on small (0-group, 1-group) Herring.

Table 4.4. Estimate of total biomass of fish in the North Sea, mean for 1977-86, following Sparholt's (1987) method from IYFS in winter and EGFS in summer by Daan *et al.* (1990), and proportion of species estimated at >10,000 tons.

	1977-86	%
Total biomass (tons) estimate	12257000	
Sturdog *Squalus acanthias* A	175400	1.4
Starry Ray *Raja radiata* F	308400	2.5
Spotted Ray *Raja montagui* F	16100	0.1
Cockoo Ray *Raja naevus* F	45500	0.4
Thornback Ray *Raja clavata* F	11600	0.1
Herring *Clupea harengus* C	1438700	11.7
Sprat *Sprattus sprattus* C	474400	3.9
Lesser Silver Smelt *Argentina sphyraena* B	18100	0.1
Greater Silver Smelt *Argentina silus* B	24200	0.2
Anglerfish *Lophius piscatorius* A	39900	0.3
Cod *Gadus morhua* A	669700	5.5
Haddock *Melanogrammus aeglefinus* A	826400	6.7
Whiting *Merlangius merlangus* A	643000	5.2
Blue Whiting *Micromesistus poutassou* B	84400	0.7
Poor Cod *Trisopterus minutus* B	91600	0.7
Norway Pout *Trisopterus esmarkii* B	751500	6.1
Bib *Trisopterus luscus* B	10500	0.1
Pollack *Pollachius pollachius* A	18800	0.2
Saithe *Pollachius virens* A	585100	4.8
Ling *Molva molva* A	29100	0.2
Hake *Merluccius merluccius* A	10600	0.1
Norway Haddock *Sebastes viviparus* B	23500	0.2
Grey Gurnard *Eutrigla gurnardus* A	205800	1.7
Scad *Trachurus trachurus* E	426700	3.5
Lesser Weever *Trachinus vipera* F	36800	0.3
Catfish *Anarhichas lupus* A	19100	0.2
sandeels *Ammodytidae* D	1788600	14.6
Dragonets *Callionymiidae* F	17400	0.1
gobies *Gobiidae* D	45000	0.4
Mackerel *Scomber scombrus* E	348600	2.8
Megrim *Lepidorhombus whiffiagonis* F	22500	0.2
Turbot *Scophthalmus maximus* F	13600	0.1
Plaice *Pleuronectus platessa* F	485100	4.0
Dab *Limanda limanda* F	2110000	17.2
Lemon Sole *Microstomus kitt* F	177800	1.5
Witch *Glyptocephalus cynoglossus* F	14500	0.1
Long Rough Dab *Hippoglossoides platessoides* F	226300	1.8
Sole *Solea solea* F	54100	0.4
group A (demersal gadoids)	3244000	26.5
group B (pelagic gadoids)	1010000	8.2
group C (clupeid)	1916000	15.6
group D (sandeels)	1750000	14.3
group E (Mackerel)	775000	6.3
group F (flatfish and soles)	3559000	29.0

4.8.2 Herring fisheries in the North Sea and total stock size

North Sea Herring is usually grouped into three "management units", including northern, central and southern North Sea stocks (Corten 1986). Burd (1985), evaluating the recent changes in the central and southern Herring stocks, concluded that management of the North Sea Herring stock as a single unit is not a viable procedure. Jakobsson (1985) described the collapse of all the major Herring stocks in the Northeast Atlantic in the late 1960s and early 1970s as the most striking phenomenon in the history of the European fisheries. The events leading to the collapse showed similar features for all the Herring stocks: a sharp increase in catches over a few years, followed by a rapid decline and a fishing ban. The southern North Sea stock declined in the 1950s, probably as a result of overfishing, and it remained at a very low level until the late 1970s (Corten 1986). The central and northern stocks gradually declined throughout the 1960s and early 1970s, as a result of overfishing of the adult component and the removal of a large number of juveniles by an industrial fishery (Corten 1986, Burd 1982). The advice was given to close the entire North Sea Herring fishery and this advice was put in effect in March 1977, but a variable amount of juvenile Herring continued to be taken as by-catch in the Sprat fisheries. Only the southern stock responded promptly to the protection measures and a series of strong year classes was produced from 1978 onwards (Corten 1986). The fishery in the southern North Sea could be opened in 1981. There was no sign of recovery of the central and northern stocks until 1982 and in fact, the spawning stock of the northern unit further declined since 1979 (Burd 1985, Corten 1986). The Herring fishery was finally re-opened in 1983. In estimates of total biomass of fish in the North Sea, Herring represented only *c.* 2% in 1977 and 1978 (Yang 1982, Daan *et al.in press*). Following a steady and significant increase (1977-86, r_s 0.99, $n = 10$, $p < 0.02$), this species was estimated to represent about 20% of the total biomass of fish in the North Sea in 1983-86 (Daan *et al. 1990*). The overall trend in the North Sea Herring stocks was a total biomass of 4,000,000-5,000,000 tons in the early 1960s, a steady decline to an all time low of some 230,000 tons in 1977 and a recovery to just over 3,000,000 tons in the late 1980s (VPA, Anonymous 1989b; see figure 4.2). Gislason & Helgason (1985) estimated the stock biomass of Herring from MSVPA to decline from some 3,400,000 tons in 1965 to an all time low of 350,000 tons in 1977. The catch, using average landings in 5-year periods from *Bulletin Statistique* dropped from nearly 1,000,000 tons during 1956-60 and 925,000 tons during 1961-65 to 843,000 tons in 1966-70, 494,000 tons in 1971-75 and an all time low of 47,000 tons during 1976-80. In the early 1980s, the landings averaged 195,000 tons (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). Long-term changes in North Atlantic and North Sea Herring stocks and fisheries are described by Burd (1978) and Schumacher (1980).

The Herring spawning grounds are situated around Scotland, off northeast England and in the English Channel and the larval drift transports the larvae into the nursery areas in the German Bight, the Skagerrak and the Kattegat (Corten 1986). Recent studies of the abundance and distribution of 6 month old Herring during IKMT sampling in February have shown that the mean numbers of larvae per standard haul were highest in the southeastern North Sea in 1979-83, where they were virtually absent between 1976 and 1978. This method of

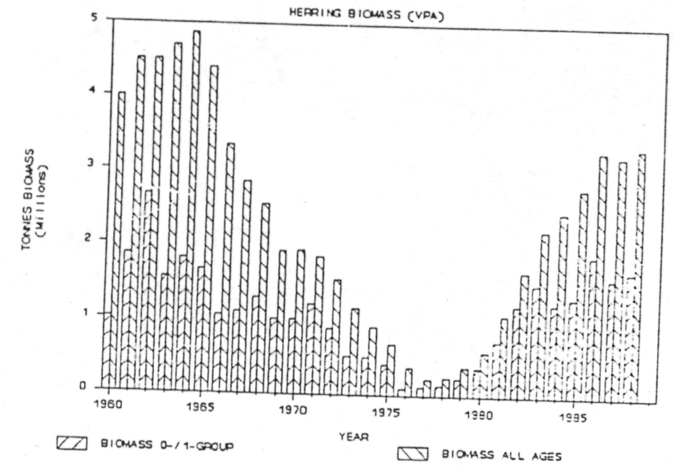


Figure 4.2. North Sea Herring stock (VPA), 1960-88 (after Anonymous 1989b.)

sampling commenced in 1977, i.e. in the middle of the low recruitment period, but the present situation with high densities in the eastern North Sea is considered "normal" (Corten 1986). In the IYFS of February 1989, 1-group Herring was mainly found in the southeastern and eastern North Sea (north to *c.* 57° N) and in the Kattegatt (figure 4.3; Anonymous 1989c), 2-group Herring was particularly abundant in the central North Sea and in the Kattegatt, while 3-group and older Herrings were found in high densities in the central and northwestern North Sea and in the Skagerrak and Kattegatt. Gislason & Helgason (1985), in their compilation of IYFS data, indicated that "young" Herring was mainly distributed in inshore waters off the Danish, German, Dutch coast, while older Herrings mainly occurred in offshore waters in the northwestern North Sea.

4.8.3 Herring data sets and their use in future studies

Herring were sampled in the IYHS and IYFS in the 1960s, 1970s and 1980s using a Gov-trawl, while IKMT sampling for immature fish commenced in 1977 (Anonymous 1989c, Corten 1986, Daan 1981a). From the IKMT sampling, a mean of index values and of larval mean lengths is calculated for each standard rectangle and mean abundances have been calculated for larger areas (see for these areas ICES C.M. 1989/Assess.: 17). From the Gov-trawl sampling, the

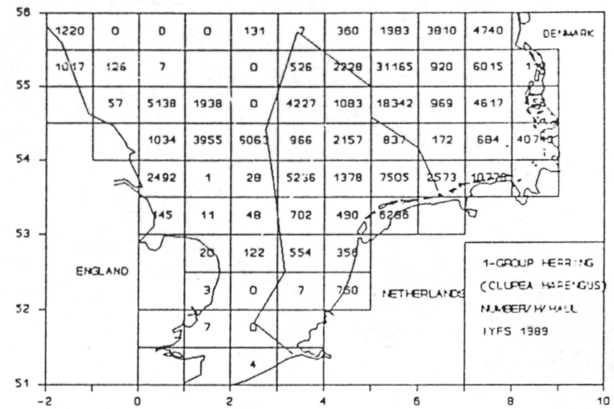


Figure 4.3. Distribution of 1-group Herring in February 1989 from IYFS in the southern North Sea (after Anonymous 1989c).

number of hauls per standard rectangle and the number of 1-group, 2-group, and 3-group and older and the mean length of 1-group fish are usually given (Anonymous 1989c). Burd (1982) described the relationships between the different independent estimates and that derived from VPA. He concluded that the IYFS 1-group index provides a valuable assessment of the 1-group stock in the North Sea but does not, however, fully reflect the state of the recruitment of North Sea spawners.

Data from the IYFS Gov-trawl in February 1989 showed that 2- and 3-group Herring occurred abundantly in the northwestern North Sea and in the Skagerrak/Kattegat area. These fish are probably too large for consumption for Alcidae. 1-group Herring, average length 130-160 mm, occurred most abundantly in the southeastern North Sea, the eastern North Sea and in the Skagerrak/Kattegat area (Anonymous 1989c). It can be valuable to study the shifts in abundance through the years in this area by means of analysis of IYFS data. Trends per grid square or per larger unit can be calculated easily. These 1-group fish were virtually absent in the northern and northwestern North Sea in 1989.

References Anderson 1989, Anonymous 1963, 1968a, 1969, 1971, 1974, 1975a, 1977a, 1978, 1985a, 1989bc, 1989f, Bakken 1972, Becker & Corten 1974, Burd 1969, 1978, 1982, 1984, 1985, Christen-

sen 1971, 1972, Cohen *et al.* 1989, Corten & Kuiter 1973, 1974, Corten 1973, 1974, 1975ab, 1976ab, 1977ab, 1978abc, 1979ab, 1980ab, 1986, 1990, Cushing 1980, Daan 1980a, 1981a, Daan *et al.* 1990, Hamre 1988, Harris & Hislop 1978, Hoydal 1985, Jakobsson 1985, Jones 1983, Nikolaev 1977, 1981, Postuma & Kuiter 1971ab, 1972, 1974, Postuma & Zijlstra 1969ab, Postuma 1968, 1969, Saville 1967, 1971, 1980ab, Saville & Bailey 1980, Schubert 1970ab, Schumacher 1980, Tiews 1978a, Wheeler 1978, Yang 1982, Zijlstra 1964, 1966, 1973.

4.9 Sprat *Sprattus sprattus*

Sprat is a small herring-like fish attaining a maximum length of *c.* 16 cm. Also this is an extremely abundant pelagic fish in northerwestern European waters which is extensively exploited in commercial and industrial fisheries (Wheeler 1978). In summer, Sprats are found in depths of 10-50 m, but they go deeper in winter. At all seasons they perform vertical movements towards the surface at night. Sprat spawns in spring and summer. Sprat was estimated to represent on average 3.9% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al.* 1990). Since 1977 (estimated at 8.2% of total biomass) the Sprat stock declined significantly (rs -0.92, n= 10, p< 0.02, two-tailed). A strong year-class in 1986, and probably also in 1988, led to a significant increase in the Sprat stock in the late 1980s (Anonymous 1989d).

4.9.1 Calorific value, biomass and utilization by seabirds

The weight-length relationship of (young) Sprat, where W = total body weight (g) and L = total body length (cm) is given by Harris & Hislop (1978) as $W = 0.009708\ L^{7.855}$. Large Sprats had significantly higher calorific value (10.9 kJ/g wet weight) than any other prey species studied by Harris & Hislop (1978) and were twice the value of Saithe and Whiting (5.1 $kJ.g^{-1}$ and 4.05 $kJ.g^{-1}$ wet weight respectively). The relationship between calorific value ($kJ.g^{-1}$ wet weight) and length (mm) for Sprats was CV = 3.215+0.063L (n= 6, r= 0.951, p< 0.001). The high value for large Sprats was due to these fish having a higher percentage of dry matter and to the fact that the percentage of fat increased with the length of the fish. Elwertowski *et al.* (1974) indicated that under extremely favourable feeding conditions the quantity of accumulated fat reached a level of 22-23% in Baltic Sprat in the late 1960s and early 1970s, compared with less than 20% under favourable conditions in the 1950s. Sprat are small fish and all age-groups are probably utilized by the larger Alcidae, Gannets and Fulmars. All age groups should therefore be incorporated in a study of this fish as prey for seabirds.

4.9.2 Sprat fisheries in the North Sea and total stock size

The North Sea Sprat appears to have first shown a general increase in abundance from about the mid sixties (Johnson 1984). The Sprat fisheries developed rather rapidly and peaked in the mid seventies (652,000 tons in 1975, 610,000 tons in 1976; Nikolaev 1981; see also chapter 4.1.4). The spectacular increase of catch in the 1970s was maninly due to a succession of outstanding year-classes, the first being that of 1972 which was at least twice as great as any generated in the previous five years. According to the Industrial Fisheries Working Group

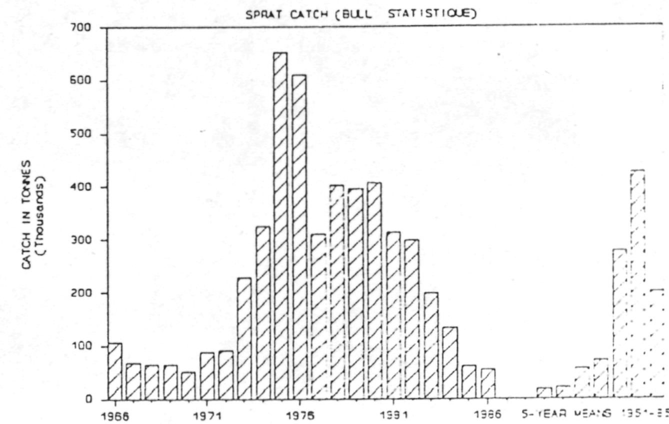


Figure 4.4. Sprat landings in the North Sea during 1966-1986, and mean catch per autumn for 1951-55 to 1981-85 from *Bulletin Statistique* (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981).

(Anonymous 1989d) the North Sea catch rose to 641,000 and 622,000 tons in 1975 and 1976 respectively, and than dropped again. The Sprat fisheries in fact collapsed to some 16,000 tons in 1986 and recovered slightly in later years. This development can be further illustrated by the nominal sprat catch in the North Sea over 5-year periods as published in *Bulletin Statistique*, although figures published in here are slightly different from those published by the Industrial Fisheries Working Group (Anonymous 1989d): 1951-55 a mean catch of 18,000 tons per annum, 1956-60 22,000 tons, 1961-65 56,000 tons, 1966-70 71,000 tons, 1971-75 277,000 tons, 1976-80 425,000 tons and 1981-85 201,000 tons (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). The Sprat catch from 1966-88 is illustrated in figure 4.4. Sprat accounted for over 95% of the Industrial fisheries clupeoid directed catch during 1974-80, but Herring gained importance since 1980 (1981 28.7% Herring, 1982 50.0%, 1983 63.8%, 1984-88 31.2-71.4%; Anonymous 1989d).

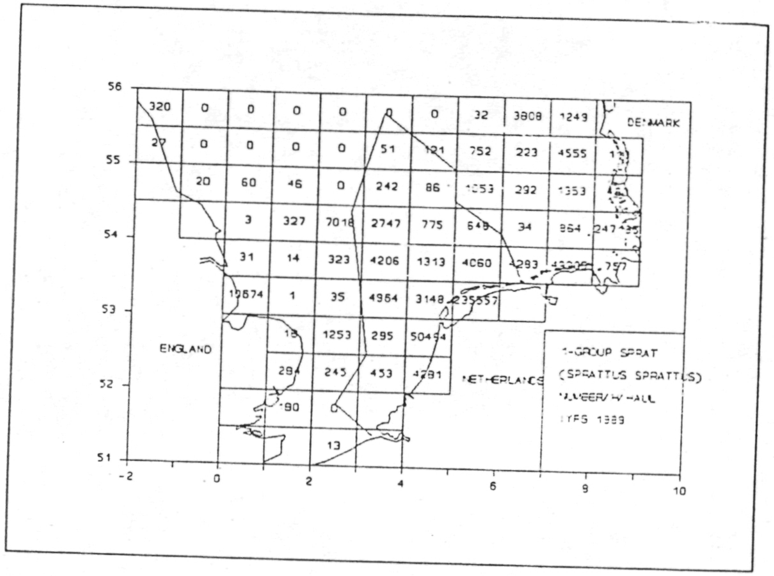


Figure 4.5. Distribution of 1-group Sprat in February 1989 from IYFS in the southern North Sea (after Anonymous 1989c).

4.9.3 Sprat data sets and their use in future studies

Sprat were sampled in the IYHS and IYFS in the 1970s and 1980s, and analysis were carried out at Lowestoft Fisheries Laboratory (Johnson 1974-85, various papers). In the 1970s, only samples from the Gov-trawl were available which were biased towards larger, older Sprat (Johnson 1974, 1978). Since 1980 supplementary data on the distribution and abundance of smaller 1-group Sprat were provided by Isaacs-Kidd trawl hauls (Johnson 1984). Data from the IYFS Gov-trawl in February 1989 showed that all age-groups were most abundant in the southern and southeastern North Sea (examplified for 1-group Sprat in figure 4.5; Anonymous 1989c). A major problem in the interpretation of IYFS data formed the distribution of certain high densities of Sprat in shallow, coastal waters which were not adequately sampled during the surveys. This fact was well demonstrated in 1974, when the 1973 year-class was extremely abundant in English and Scottish east coast fisheries, whilst the survey did not reflect its strength at all (Johnson 1974). Fisheries data, more particularly the development and collapse of certain fisheries in the North Sea since 1970, therefore provide very important supplementary data on (local) abundance of Sprat. At the 1979 meeting an ICES Council resolution was adopted deciding that "acoustic surveys

of the sprat stocks in the North Sea should be carried out in January so that the main fishing area in the North Sea at that time should be covered" (Johnson 1980, ICES Counc.Res. 4:26/1979). Several reports on echo-integrator surveys for Sprat are published since (e.g. Aglen & Iversen 1980, Edwards *et al.* 1979, Edwards & McKay 1984, Johnson 1979, 1980).

References Aglen & Iversen 1980, Anderson 1989, Anonymous 1989cd, Bailey 1980, Burd & Johnson 1983, Christensen 1971, 1972, Edwards, Wilson & Bailey 1979, Edwards & McKay 1984, Elwertowski, Giedz & Maciejczyk 1974, Hoydal 1985, Johnson 1974, 1978, 1979, 1980, 1982, 1983, 1984, 1985, ICES IYFS and IYHS reports see 4.6, ICES Reports of the Industrial Fisheries Working Group, Lindquist 1978, MacKay & Edwards 1985, Nikolaev 1977, 1981.

4.10 Cod *Gadus morhua*

Cod are stout-bodied fishes attaining a length of well over 1 metre. Average cod measure nowadays 120 cm (*c.* 11.5 kg) and the maximum weight is around 45 kg, although historical records of 90 kg exist. This fish has been exploited ever since man began to fish in the seas of Europe (Wheeler 1978). Cod spawns in Feb-Apr in 200 meter deep water, towards which considerable migrations are performed. Cod was estimated to represent on average 5.5% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al.* *1990)*. The Cod stock declined significantly in these years (rs -0.60, n= 10, p< 0.10, two-tailed).

4.10.1. Calorific value, biomass and utilization by seabirds

The weight-length relationship of (young) Cod, where W = total body weight (g) and L = total body length (cm) is given by Harris & Hislop (1978) as $W = 0.00626\ L^{3.109}$. The calorific value of Cod is not known, but it is probably in the same (rather low) range as Saithe and Whiting. The calorific value of Saithe is at 37-43 mm 5.1 $kJ.g^{-1}$ wet weight, the calorific value of Whiting is given in chapter 4.11.1 (after Harris & Hislop 1978 and Furness *et al.* 1988). Cod are large fish and only immatures are preyed upon by Alcidae. Even the largest Cod recorded from otoliths in Guillemots' stomach studied off Scotland was 1-group fish (210 mm; Blake *et al.* 1985). Future studies of Cod as possible seabird prey should therefore concentrate on 0- and 1-group fish. Discards are often torn apart by Fulmars (a special interest was recorded for the guts and liver) or swallowed whole by Gannets.

4.10.2 Cod fisheries in the North Sea and total stock size

The Cod catch increased from the early 1950s to the mid seventies and than stabilized (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). The nominal Cod catch in the North Sea over 5-year periods was during 1951-55 on average 78,000 tons per annum, 1956-60 98,000 tons, 1961-65 122,000 tons, 1966-70 236,000 tons, 1971-75 260,000 tons, 1976-80 228,000 tons and 1981-85 233,000 tons (figure 4.6). The largest amounts were taken in 1971 (320,000 tons) and 1972 (347,000 tons). From Scottish research vessels trends in abundance are studied for Cod (Richards *et al.* 1978). Prior to the 1970s there were no

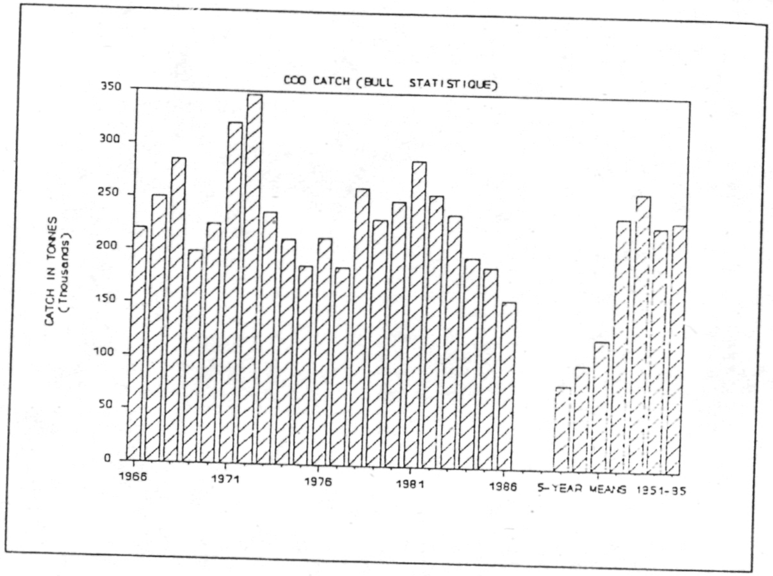


Figure 4.6. Cod landings in the North Sea during 1966-1986, and mean catch per annum for 1951-55 to 1981-85 from *Bulletin Statistique* (Anderson 1989, 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981).

consistent trends in the abundance of Cod, but during the prewar period the abundance of Cod decreased overall in the North Sea. During 1946-71 Cod increased in the northern North Sea and to a lesser extent in the central North Sea. In the northwestern North Sea abundance increased until the mid fifties and remained high until 1960 since when it has tended to decrease.

4.10.3 Cod data sets and their use in future studies

The IYFS provides the most valuable data on immature Cod distribution in winter. Landing statistics from ICES are of limited importance, but readily available. The EGFS may prove to be valuable to study trends according to summer surveys, compared to IYFS data and to assess the total North Sea stock (cf. Daan *et al. 1990*). From the February 1989 IYFS it can be demonstrated that 1-group Cod occurred widely scattered in the entire North Sea, with as maxima per hour per haul only 116 and 109 individuals in rectangles off the English east coast only very small numbers in the northern North Sea (Anonymous 1989c). The older Cod (2- and 3-group) were found in higher numbers in the northern North Sea. From an multi-year analysis of IYHS data

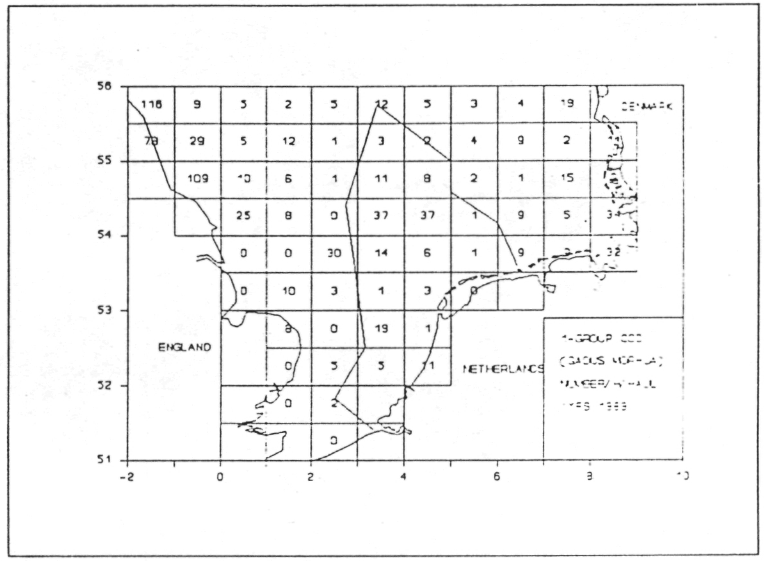


Figure 4.7. Distribution of 1-group Cod in February 1989 from IYFS in the southern North Sea (after Anonymous 1989c).

for juvenile Cod, published in 1976, it can be seen that these low numbers for 1-group Cod are typical, but also that the occasional high figures (several thousands of fish per hour per haul) were always found in the southeastern North Sea (Anonymous 1976). The 1-group Cod in February 1989 averaged between 150 and 250 mm in length and thus equalled the maximum length which smaller seabirds can handle and swallow (Anon 1989c). Besides from the EGFS. also from the Scottish research vessel catches of Cod in the North Sea long-term trends in abundance can be obtained (cf. Richards *et al.* 1978; see 4.10.2). However, Scottish research vessels focus their research on the northern North Sea (north of 54° N).

References Anderson 1989, Anonymous 1976, 1977b, 1979, 1989c, Blake *et al.* 1985, Christensen 1971, 1972, Cushing 1980, Daan 1969, 1972, 1973, 1974, 1975, 1976, 1977, 1978ab, 1979abcdefgh, 1980bcdefgh, 1981b, Furness, Hudson & Ensor 1988, Hamre 1988, Houghton & Flatman 1981, Hoydal 1985, Nikolaev 1977, 1981, Richards *et al.* 1978, Tjelmeland 1989, Werner 1963.

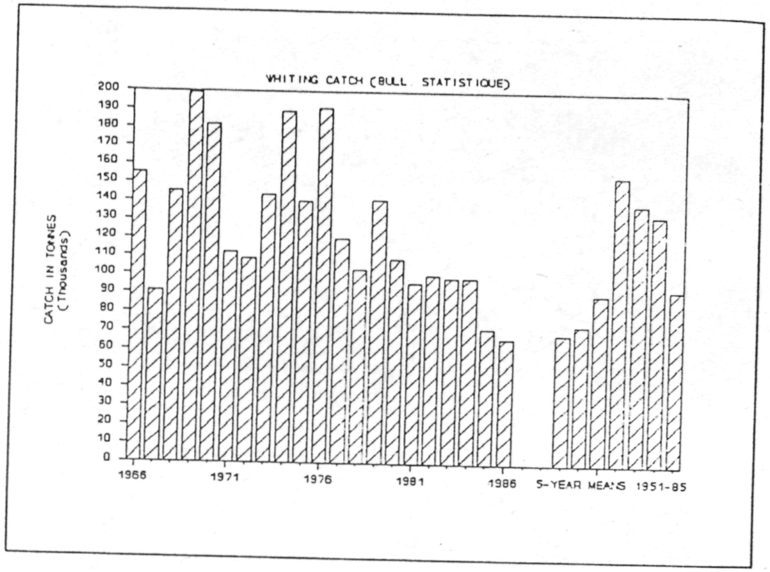


Figure 4.8. White Landings in the North Sea during 1966-1986, and mean catch per annum for 1951-55 to 1981-85 from *Bulletin Statistique* (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981).

4.11 Whiting *Merlangius merlangus*

Whiting is a well-known member of the Cod-family, a slender-bodied fish with a narrow, rather pointed head. It is very common in shallow inshore waters, occurring most abundantly between 30 and 100 meter (Wheeler 1978). The smallest fish are found close inshore. The Whiting is a valuable food-fish which is extensively fished in European seas. Whiting spawns between Jan and Jul (mainly in spring) without making extensive migrations. Whiting was estimated to represent on average 5.2% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al. 1990*). The Whiting stock declined significantly in these years (rs -0.78, n= 10, p< 0.02, two-tailed).

4.11.1 Calorific value, biomass and utilization by seabirds

The weight-length relationship of (young) Whiting, where W = total body weight (g) and L = total body length (cm) is given by Harris & Hislop (1978) as $W = 0.00854\ L^{2.978}$. The calorific value is not particularly high. Harris & Hislop (1978) estimated it for small Whitings (at 40-64 length) to be 4.05 $kJ.g^{-1}$ wet weight.

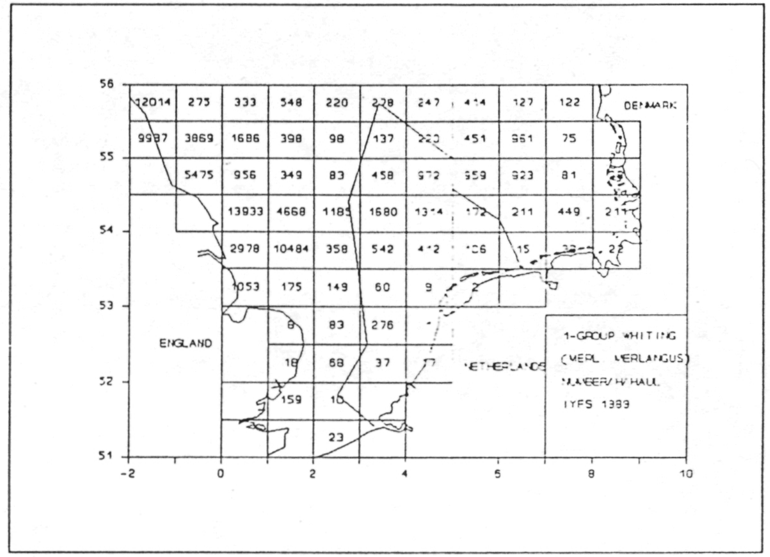


Figure 4.9. Distribution of 1-group Whiting in February 1989 from IYFS in the southern North Sea (after Anonymous 1989c).

Larger Whitings (180-280 mm) were slightly better and estimated at 5.2 $kJ.g^{-1}$ wet weight (Furness *et al.* 1988). However, Whiting offal (11.0% of the mass of gadoid fish is thrown overboard as offal (Furness *et al.* 1988) is considered being rather rich. Whiting offal from 180-280 mm fish has an calorific value of 12.6 $kJ.g^{-1}$ wet weight. Similar to Cod, Whiting are rather large fish and only immatures are possibly preyed upon by Alcidae. Future studies of Whiting as possible seabird prey should therefore concentrate on 0- and 1-group fish. Discarded larger Whitings are often torn apart by Fulmars to reach liver or guts or they are swallowed whole by Gannets.

4.11.2 Whiting fisheries in the North Sea and total stock size

The Whiting catch increased during the 1950s and 1960s, peaked in 1969 and 1970 at *c.* 200,000 tons per annum and again in the mid seventies at 189,000 tons in 1974 and 191,000 tons in 1976 and subsequently declined (figure 4.8; Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). Since 1980 the North Sea catch did not exceed 100,000 tons.

4.11.3 Whiting data sets and their use in future studies

The IYFS provides the most valuable data on immature Whiting distribution in winter. Landing statistics from ICES are of limited importance, but readily available. The EGFS may prove to be valuable to study trends according to summer surveys, compared to IYFS data and to assess the total North Sea stock (cf. Daan *et al. 1990*). From the February 1989 IYFS we learn that most 1-group Whiting can be found in the western North Sea (off the English and Scottish east coast) and that relatively few are captured in rectangles in the German and southern Bights (Anonymous 1989c). The occurrence of 1-group Whiting in the southern North Sea in 1989 is illustrated in figure 4.9. From an analysis of earlier IYHS data (1965-75) and from other compilations we can see that the western North Sea is not always so important (Anonymous 1976, Gislason & Helgason 1985). Large quantities are sometimes caught in the eastern and southeastern North Sea. Older Whiting (2- and >3-group) have a more northerly and westerly distribution (Anonymous 1989c, Gislason & Helgason 1985). Scottish research vessel data and long-term analysis of Whiting abundance derived from these surveys can also be useful, but these surveys concentrate on the northern North Sea only (Richards *et al.* 1978, see 4.10.3).

References Anderson 1989, Anonymous 1976, 1977b, 1979, 1989c, Christensen 1971, 1972, Cushing 1980, Daan 1972, 1973, 1974, 1976, 1977, 1978b, 1979abcdefgh, 1980bcdef, 1981b, Furness, Hudson & Ensor 1988, Gambell & Sahrhage 1961, Gambell, Hoydal 1985, Nikolaev 1977, 1981, Roessingh & Sahrhage 1961, Gambell *et al.* 1962, Harris & Hislop 1978, Jones & Hislop 1978, Richards *et al.* 1978, Werner 1963.

4.12 Norway Pout *Trisopterus esmarkii*

A small member of the Cod-family, and an extremely common small gadoid in northern European waters. It is found most commonly offshore in depths of 80-200 meter and Norway Pout spawns over the edge of the continental shelf in Mar-May. Norway Pout is of no interest for commercial fisheries, but it is utilized extensively in industrial fisheries for fish-meal production. Norway Pout was estimated to represent on average 6.1% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al. 1990)*. According to these estimates the Norway Pout stock remained rather stable in recent years (rs 0.04, n= 10, n.s.).

4.12.1 Calorific value, biomass and utilization by seabirds

The weight-length relationship of (young) Norway Pout, where W = total body weight (g) and L = total body length (cm) is given by Harris & Hislop (1978) as $W = 0.0101\ L^{2.730}$. The calorific value of Norway Pout is unknown, but probably similarly low as that of Saithe and Whiting (4.10.1, 4.11.1). The maximum age recorded from the North Sea is Norway Pout of 4 years old, however, the majority of this population are usually 1 year old (Raitt 1968). Norway Pout are small fish and although the maximum length for Icelandic fish was 25cm and of some specimens from the Barents Sea it was 35cm, the maximum length for North Sea fish appears to be nearer 20-21cm. All age-groups may be utilized by

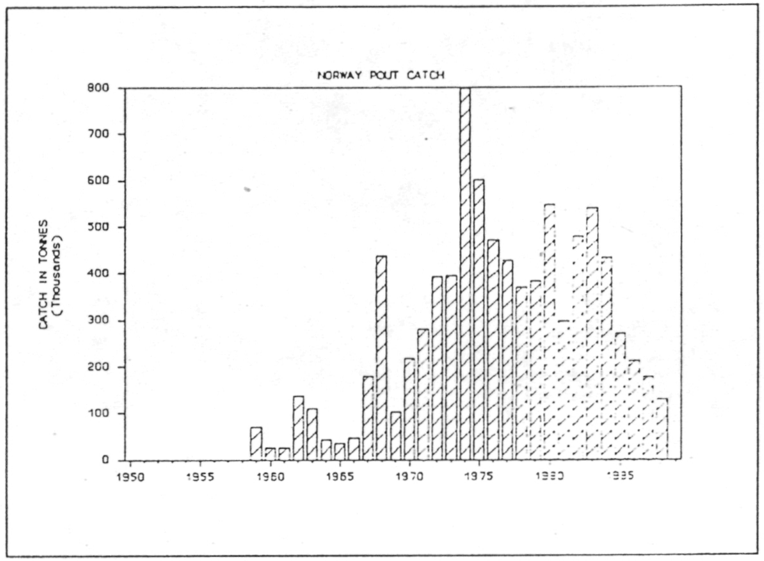


Figure 4.10. North Sea industrial fisheries catch of Norway Pout, 1950-1988 (after Anonymous 1989d).

the larger Alcidae, Gannets and Fulmars and all age groups should therefore be incorporated in a study of this fish as prey for seabirds.

4.12.2 Norway Pout fisheries in the North Sea and total stock size

Norway Pout fisheries commenced in the late 1950s when an industrial fishery for this species was developed by Norway and Denmark (see also chapter 4.4). Denmark took the greatest share in a fishery that peaked in the early 1970s (e.g. 465,700 tons from a total North Sea catch of 753,200 tons in 1974; Madsen 1978). The Danish catch in 1988 (79,000 tons) was the lowest since the late 1960s. Norwegian industrial fisheries for Norway Pout peaked in 1972 (120,500 tons), 1974 (154,200 tons), 1975 (218,900 tons) and 1976 (108,900 tons) and this fishery subsequently declined to some 20,000 tons per annum in the late 1980s. An industrial fishery for Norway Pout commenced in the Faeroes in 1969, peaked in 1974 at 85,000 tons and subsequently declined to an all-time low of 1,500 tons in 1988. Swedish and U.K. industrial fisheries for Norway Pout were in operation only for few years and only contributed significantly to the landings in the early 1970s (Anonymous 1989d). The development of the Norway Pout

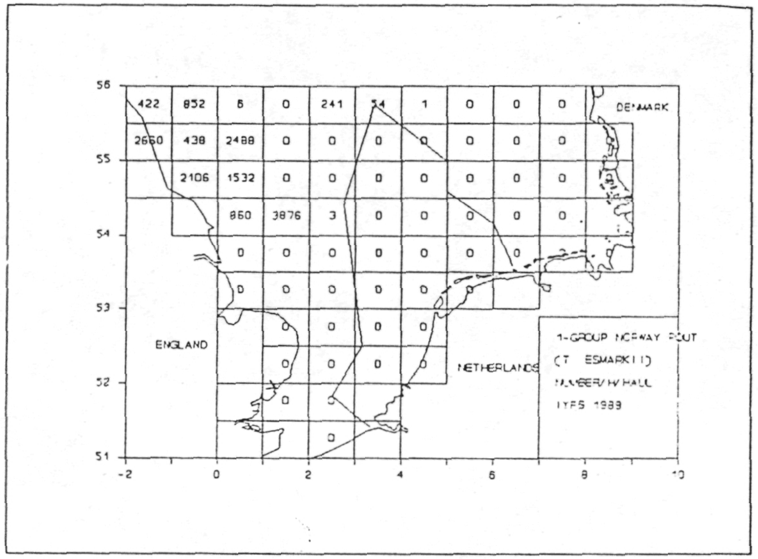


Figure 4.11. Distribution of 1-group Norway Pout in February 1989 from IYFS in the southern North Sea (after Anonymous 1989c).

fishery in the North Sea is illustrated in table 4.1 and in figure 4.10. The species composition in Norwegian Norway Pout landings in the 1980s is given in the Industrial fisheries working group report of 1989 (Anonymous 1989d). Blue Whiting was represented in the catch in equal or sometimes even greater quantities, while Cod, Haddock, Whiting, Saithe, Herring and Mackerel were rather scarce. The Danish fishery for Norway Pout is quite different from Norwegian fisheries because the first is peaking in winter (Sep-Feb), while the latter is in operation the whole year round.

4.12.3 Norway Pout data sets and their use in future studies

The IYFS provides the most valuable data on Norway Pout distribution in winter. Landing statistics from ICES can be important as well and these are readily available in Industrial fisheries working group reports. The EGFS may prove to be valuable to study trends according to summer surveys, compared to IYFS data and to assess the total North Sea stock (cf. Daan *et al. 1990*). Norway Pout is a typical northern North Sea species. In figure 4.11, the distribution of 1-group Norway Pout in the southern North Sea from the 1989 IYFS, can be seen that

the southern and southeastern North Sea are virtually clear of Norway Pout, while reasonable numbers occur off the east coast of England. Further to the north and west this fish was even more abundant. Abundance indices can be derived from IYFS (February) and from EGFS (August), but also from "English Norway Pout surveys" (November) and Scottish groundfish surveys (August; cf. Anonymous 1989d). Scottish research vessel data and long-term analysis of Norway Pout abundance derived from these surveys can be particularly useful, because these surveys concentrate on the northern North Sea (Richards *et al.* 1978, see 4.10.3).

References Anonymous 1977c, 1978b, 1984, 1989cd, Daan 1979abcdefgh, 1980bcdef, 1981b, Gauld, McKay & Bailey 1986, Madsen 1978, Raitt 1968b, Richards *et al.* 1978, Tiews 1978c.

4.13 Sandeels *Ammodytes spp.*

Sandeels are rather small marine fishes with 6 species known to occur in European waters (Wheeler 1978). The sandeels are mainly found in the northern hemisphere and most abundantly in the North Atlantic. It is an extreme important food fish to a wide variety of other fishes (e.g. Herring, Mackerel and gadoid fishes), seabirds and marine mammals. Two of the smaller species, *Ammodytes tobianus* and *A.marinus* are extremely abundant, repectively inshore and offshore in the North Sea. These species grow to a maximum length of *c.* 20-24 cm. Sandeels spend much of their time buried in the sand, but in summer they make diurnal movements into the water column to feed. From time to time vertical migrations are performed towards the surface. Sandeels were estimated to represent on average 6.1% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al. 1990*). The stocks remained rather stable in these years (rs -0.01, n= 10, n.s.).

4.13.1 Calorific value, biomass and utilization by seabirds

The weight-length relationship of (young) sandeels, where W = total body weight (g) and L = total body length (cm) is given by Harris & Hislop (1978) as $W = 0.00209\ L^{3.148}$. The relationship between calorific value (kJ.g^{-1} wet weight) and length (mm) for sandeels was $CV = 4.908 + 0.022L$ ($n= 9$, $r= 0.731$, $p< 0.02$). The calorific value for larger sandeels (60-207mm) is 6.5 kJ.g^{-1} wet weight, whilst the calorific value for larval fish is 5.8 kJ.g^{-1} wet weight. The high value for large sandeels, like that in Sprat, was due to the fact that the percentage of fat increased with the length of the fish. Sandeels are slender fish and all age-groups are probably utilized by the (larger) Alcidae, Gannets and Fulmars. All age groups should therefore be incorporated in a study of this fish as prey for seabirds.

Of great importance for feeding seabirds are so called "sandeel balls". Just below the surface large concentrations of fish move continually in on themselves (R. Tulloch in Goodlad 1989), forming a ball of fish. These sandeel balls are mainly seen in late summer and although the precize mechanism of the formation of these balls is unknown it is generally believed that predators such as Mackerel, Pollack or Herring drive these fish to the surface. The breeding seabirds in

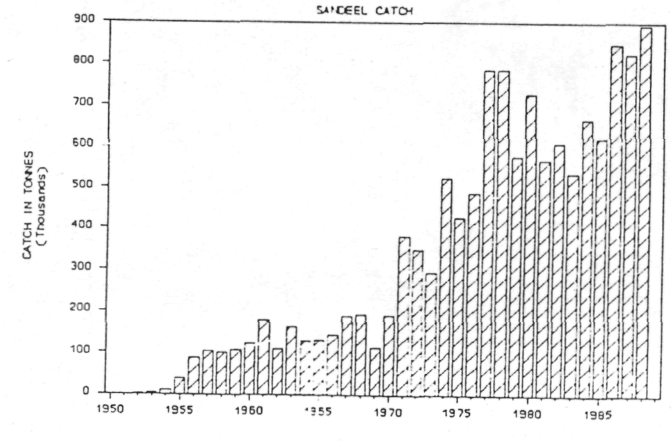


Figure 4.12. Landings of sandeel from the North Sea, 1952-1988 (Anonymous 1989d).

Shetland were mainly confronted by a lack of these balls in recent years rather than by a total lack of sandeels in their feeding areas.

4.13.2 Sandeel fisheries in the North Sea and total stock size

Landings of sandeels in the North Sea increased in 1988 to 893,000 tons, which is the highest ever recorded (figure 4.12). Most sandeels are taken in early summer (80% Apr-Jun). Most sandeels are taken by Danes and Norwegians, whilst comparatively small quantities are taken by British fishermen (max. 52,200 tons in 1982). A new fishery for sandeels, commenced in the 1970s, is now being developed in the Faeroes (15-18,000 tons in 1987 and 1988). Annual landings of sandeels in the southern North Sea ("southern assessment area") increased from 100-200,000 tons in the early 1970s to 400-500,000 tons in the 1980s. Landing peaks were reached in 1978 (577,200 tons), 1984 (532,800 tons), and 1985 (513,500 tons). Most sandeels were taken in an area defined by 54 and 56° 30' N and English east coast to 6° E (subsectors 1A and 2A). Further details on the sandeel fisheries in the North Sea are given in chapter 4.4. Total biomass estimates (VPA) for sandeels in the southern North Sea ranged from 798,962 tons in 1981 to 2,096,923 tons in 1986.
The Shetland sandeel fishery is quite distinct from the North Sea sandeel fishery

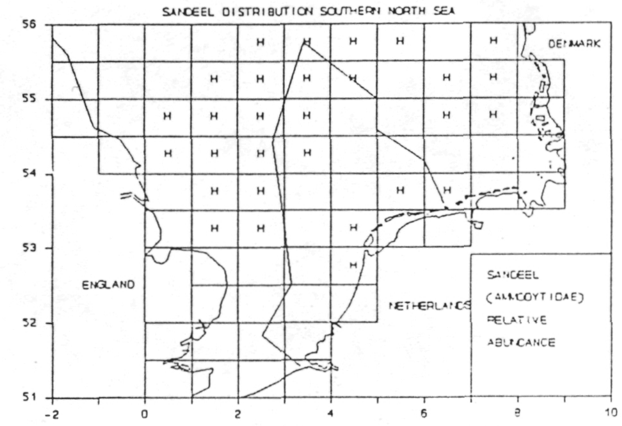


Figure 4.13. Distribution of sandeels in the southern North Sea: 95% is assumed to occur within the area marked with "H", 5% in the remaining rectangles (redrawn from Gislason & Helgason 1985).

since it is based on a separate, local stock. The fishery for sandeels in Shetland began in 1974, and rose to a peak catch of 52,600 tons in 1982. Landings are now seriously reduced and are now less than 10,000 tons per annum (Goodlad 1989). The Shetland sandeel fishery is a classic recruitment fishery: the bulk of the catch after July consists of O-group recruits to the adult stock, i.e. juvenile sandeels spawned in January. During its peak, the industrial fisheries in Shetland took over 50% of the total stock of sandeels (Goodlad 1989, Kunzlik 1989).

4.13.3 Sandeel data sets and their use in future studies

Sandeels are not sampled in the IYFS and distribution patterns or abundance indices based on scientific surveys cannot be produced easily (at any season). Landing statistics from ICES refer to certain standard areas (Danish sandeel assessment areas), including the "southern assessment area" (North Sea, south of 56° 30'N), the "northern assessment area" (north of that line) and the "Shetland assessment area" (around the Shetland archipelago). These sectors are divided into 11 subsectors (1A, 2A, 4, 5, and 6 refer to the "southern assessment area") for which catch statistics are (or can be) presented in the annual reports of the Industrial Fisheries Working Group (ICES). VPAs, although inaccurate for short-

lived fish like sandeels, are the only suitable source of information to find out any stock changes for this species in recent years. Gislason & Helgason (1985) mapped the distribution of sandeels in the North Sea from ICES working group reports (Anonymous 1977c, 1978b), as illustrated for the southern North Sea in figure 4.13. The bulk of the southern North Sea population (estimated to represent 95% of the stock) occurred in the central and eastern parts of this area. In the northern North Sea (not illustrated here) some 96% of the population occurred just west of the Skagerrak and around the Shetland islands (separate stock).

References Anonymous 1977c, 1978b, 1984, 1989d, Bailey, Cohen *et al.* 1989, Fowler & Dye 1987, Gauld & Kunzlik 1989, Fowler & Dye 1987, Gauld, McKay & Bailey 1986, Gislason & Helgason 1985, Goodlad 1989, Harris & Hislop 1978, Heubeck 1989a, Kunzlik 1989, Macer 1966, Madsen 1978, Reay 1970, Sherman *et al.* 1981, Tasker 1989, Tiews 1978.

4.14 Mackerel *Scomber scombrus*

The Mackerel is a common and highly migratory North Atlantic fish living near the surface in huge shoals above the continental shelf (Wheeler 1978). It is a slow-growing fish, attaining a maximum length of 66cm (large specimens may be as much as 20 years of age) and nowadays it is an important food fish of which large quantities are frozen, canned or smoked. Mackerels spawn in summer and enter the North Sea in large numbers for spawning (Anonymous 1988b). In winter, Mackerel shoals retire to deeper water. Mackerels are captured in different ways, including several types of nets and feathered hooks. Mackerel was estimated to represent on average 2.8% of the total biomass of fish stocks in the North Sea in 1977-86 (Daan *et al. 1990)*. Since 1977 (estimated at 6.2% of total biomass) the Mackerel stock in declined significantly (rs -0.99, n= 10, p< 0.02, two-tailed). Also the ICES Mackerel Working Group recorded a steady decline in the spawning stock biomass and the 1988 figure is the lowest on record (Anonymous 1989a).

4.14.1 Calorific value and utilization by seabirds

Adult Mackerels are only of interest for Gannets as possible prey. Alcidae and Kittiwake are probably incapable of coping with any larger Mackerel than 0-group or 1-group (if they eat this fish at all). Further studies should focus on these smaller age groups. The calorific value of Mackerel is unknown but because it is a rather fat fish this can be expected to be high.

4.14.2 Mackerel fisheries in the North Sea and total stock size

Mackerel fisheries in the northeast Atlantic peaked in the 1970s and then declined dramatically. Schumacher (1980) described the catch of pelagic fish in the North Atlantic and found that the typical trend was a rapid rise in landings followed by a collapsing fishery (see 4.3). When the Mackerel spawning stock was assessed in 1988 from an egg survey an all time low was recorded of only 37,000 tons (Anonymous 1989a). During the late 1970s the spawning stock was

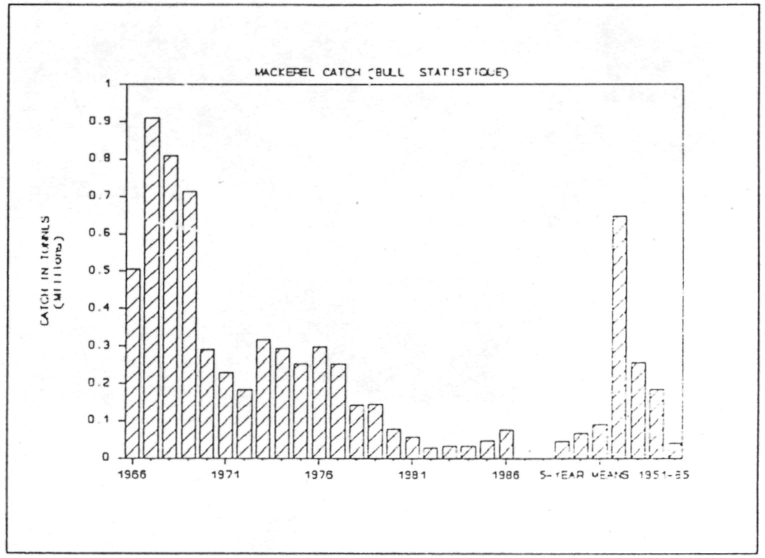


Figure 4.14. Mackerel landings in the North Sea during 1966-86, and mean catch per annum for 1951-55 to 1981-85 from *Bulletin Statistique* (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikcaev 1977, 1981).

already declining very rapidly (826,000 tons in 1975, 583,000 tons in 1977, 336,000 tons in 1979, 189,000 tons in 1981). The development of North Sea Mackerel fisheries during the last four decades is described in figure 4.14 from *Bulletin Statistique* (Anderson 1989, Christensen 1971, 1972, Hoydal 1985, Nikolaev 1977, 1981). The peak during the late 1960s can be clearly seen in the five-year means on the right (646,000 tons per annum). This peak was reached through a rather sudden increase in landings in the mid sixties. By far the greatest share in the North Sea Mackerel fisheries was taken by the Norwegians (Hamre 1980, Anonymous 1989a). Substantial amounts were landed by the Danes, fishermen from the Faeroes (since 1969), France, and in some years the USSR. The total North Sea stock of Mackerel, estimated at some 2,500,000 tons in the mid sixties, declined to less than 400,000 tons in 1971 (Hamre 1978). Since 1970 the fishery has been regu- lated and this resulted in some recovery of the stock. In the Western stock more countries contribute significantly to the total catch, including France, Ireland, the Netherlands, Norway (sometimes), Poland, Spain, UK, and the USSR. Mackerel, a pelagic shoaling fish, is especially vulnerable for modern fishing techniques with purse seine nets and sonar equipment. Overfishing is generally believed to have caused the collapse in the fishery (cf. Schumacher 1980).

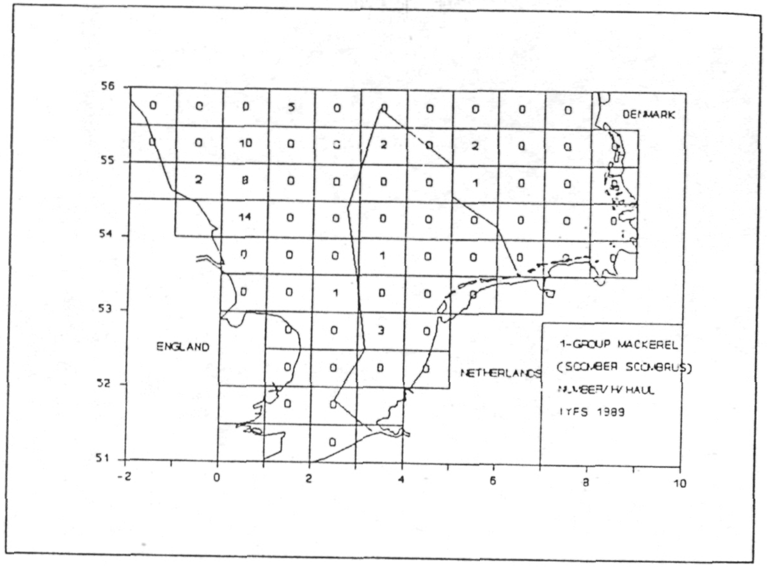


Figure 4.15. Distribution of 1-group Mackerel in February 1989 from IYFS in the southern North Sea (after Anonymous 1989c).

4.14.3 Mackerel data sets and their use in future studies

Data on the distribution of Mackerel in winter from the IYFS are not particularly good, because these powerful fish usually escape from the Gov-trawl (A. Corten). The distribution of immature (1-group) Mackerel in the southern North Sea from the IYFS in February 1989 is shown in figure 4.15. Few rectangles were found to hold Mackerel and those which have Mackerel show low densities. Mackerel data sets are usually divided into the "North Sea" stock (ICES division IV), the "Western" stock (ICES VI and VII) and the "Skagerrak/Kattegat" stock (ICES IIIa). VPA's derived from catch statistics are probably the best source of data for this fish.

References Anderson 1989, Anonymous 1988b, 1989ac, Boddington 1959, Christensen 1971, 1972, Cohen *et al.* 1989, Hamre 1978, 1980, Hovdal 1985, Jones 1983, Nikolaev 1977, 1981, Saville 1980ab, Schumacher 1980, Tiews 1978a, Walsh & Martin 1986, Walsh 1974, 1977, 1979.

5. SEABIRDS, FISH STOCKS AND FISHERIES

5.1 Population regulation, energy budgets, and food availability

Most seabirds are long-lived, show delayed maturity and a low breeding rate. Many species have annual adult survival rates of over 90%, resulting in an overall mean adult lifespan of up to 35 years (Dunnet *et al.* 1990, Furness & Monaghan 1987). Many species have clutches of only one egg and do not breed for the first time until several years old. Age at first breeding (years), clutch size (number of eggs) and the mean annual survival rate for adults (%) in some of the most common seabirds in the North Sea are: 9.2 years, 1 egg, 97% in Fulmar (Dunnet & Ollason 1978); 4-5 years, 1 egg, 94% in Gannet (Nelson 1978); 5.3 years, 2-3 eggs, 90-96% in Herring Gull (Dunnet *et al.* 1990); 3-5 years, 1-3 eggs, 81-86% in Kittiwake (Coulson & Wooller 1976); 3-7 years, 1 egg, 94% in Guillemot (Birkhead & Hudson 1977); 4-5 years, 1 egg, 91% in Razorbill (Lloyd & Perrins 1977); 4-5 years, 1 egg, 95% in Puffins (Ashcroft 1979). Seabirds are generally at the K-side of the r-K continuum of life strategies. Typical "r-selected" species live in unpredictable environments, are generally small and short-lived with good powers of dispersal, have high reproductive rates, suffer high density-independent mortalities, and are opportunistic with markedly fluctuating populations. On the contrary, typical "K-selected" species live in predictable environments, are usually larger, are long-lived and colonize new habitats slowly, have low reproductive rates and suffer low density-independent mortalities. They are ecologically restricted and normally have very stable populations maintained close to their carrying capacity (K) by density-dependent controls (Campbell & Lack 1985). Such species tend to invest in few well provided young only and to conserve resources for themselves (Furness & Monaghan 1987). In K-strategists competitive ability is favoured rather than high reproductive output.

The K-strategy assumes that the population level is stable, fluctuating around an equilibrium. Many seabird populations have changed enormously in numbers in historical times. Besides changes in the natural environment it seems likely that human interference by exploitation of seabird colonies and overfishing has played an important role. This circumstance complicates the determination how their numbers are actually regulated. Population change in an animal population is the difference between recruitment + immigration and mortality + emigration. Furness & Monaghan (1987) conclude that density-dependent competition for food during the breeding season may be an important mechanism (affecting recruitment). Ricklefs (1990: 5) concludes "the demography of seabirds more strongly suggests the prevalance of density-dependent limitation of population size". He suggests that "owing to their tremendous powers of dispersal, seabirds escape the constraints of population density during the nonbreeding season, when they may spread out thinly over the open ocean". Furness & Monaghan (1987) furthermore state that "food shortage in winter may influence the ability of an individual to compete for food during the breeding season ..." (: 52). Food shortage in winter may also affect immature survival and recruitment, as actually is presumed for the Guillemot on Isle of May (3.8.1). A good understanding of key factors and mechanisms of population regulation is essential for evaluating the impact of fisheries on seabird populations. For example, food availability in winter would be not a decisive factor if numbers are

regulated by food availability during the breeding season affecting reproductive success.

The most substantial contributions to seabird energy budgets are migration, foraging, moult, egg production and provisioning of chicks (Furness 1982, 1984b). Energy costs of certain specific activities, such as flapping or gliding flight, swimming, resting, and foraging trips, have been accurately measured or were estimated, for a number of species (e.g. Kendeigh *et al.* 1977, Pennycuick 1989, Prange & Schmidt-Nielsen 1970). Other activities, some of them widely employed by seabirds, have received relatively little attention so far (Furness 1984b). However, models have been developed in which reasonable assumptions could be made for energy costs of activities which have not been measured in detail (Furness 1978b, 1982) and estimates are now available on the role of seabirds as marine predators (Furness 1978b, Furness & Cooper 1982, Wiens & Scott 1975). Furness (1982) concluded, that in some marine ecosystems, seabird predation on fish stocks is quantitatively important and may potentially compete with fishing interests, while changes in fish stocks are likely to have a direct effect on seabird population biology. The best estimate of sandeel consumption by seabirds at Shetland in 1981-83 was 47,000 tonnes while the industrial fisheries around Shetland took 45,000 tonnes, 25,000 was consumed by predatory fish and 9,000 tonnes by seals (Furness 1990). Furness concluded that 126,000 tonnes were consumed of an estimated production of only 100,000 tonnes! North Sea seabirds are estimated to consume around 5-15% of the annual production of small fish (Furness unpubl. cited in Dunnet *et al.* 1990).

Several of the more substantial contributions to energy budgets are either typical for the breeding or for the non-breeding season. The physical impact of breeding on the adults is considerable in terms of energy expenditure and we may expect them to trade-off current against future reproductive potential when food shortages occur in the breeding period (Drent & Daan 1980, Monaghan *et al.* 1989). Declines in the availability of food in the breeding season lead to reduction of breeding success, or abandonment of the breeding attempt. In some case studies clutch size and hatching were normal while the chicks died of starvation in the first week after hatching (Lid 1981, Monaghan *et al.* 1989). Food conditions in the pre-breeding period may even affect whether or not birds attempt to breed at all (Drent & Daan 1980, Monaghan *et al.* 1989). Typical for the non-breeding period are moult and migration. Furness (1984b) suggested that lower ambient temperatures in winter and a likely reduction in foraging success add to energy requirements in the non-breeding season. Typical for the breeding season, of course, are egg production, incubation and chick maintenance.

The effects of reduced food availability on seabird's breeding performance have been demonstrated in various cases. Several seabird populations were found to rely on a single fish species and breeding failures occurred when this species became unavailable (Anker-Nilssen 1987, Barrett *et al.* 1987, Furness & Ainley 1984, Heubeck 1989a, Lid 1981). Seabird species vary in their ability to take advantage of occasional increases, or on the other hand to cope with sudden decreases in food availability (Furness & Ainley 1984). Low clutch size (petrels, auks), surface feeding habits (gulls and terns) or limited feeding ranges (cormorants) are some important factors which explain why certain seabirds have difficulty coping with reductions in the availability of fish. Piatt & Methven (1988) found a significant correlation between Capelin abundance and the

amount of Capelin taken by Puffins and Guillemots. It was indicated that alcids have minimum fish density requirements for achieving satiation. Important factors that may negatively affect the ability of seabird species to cope with fluctuations in the availability or distribution of fish stocks are (Furness & Ainley 1984):

- surface feeding habits (e.g. gulls and terns)
- specialized and inflexible feeding habits (e.g. auks)
- limiting foraging ranges (cormorants)
- limiting ability to increase time spent foraging (e.g. terns)
- energetically expensive food-searching techniques (e.g. terns)
- limited ability to respond to incidental high food availability with reproduction (e.g. petrels, auks)

The effects of reductions in food availability in winter are much less known. Delays in moult, increased susceptibility to disease or pollution, and migration may result from food shortages in that season. With delayed maturity, large numbers of seabirds are in the pre-breeding component of the population (Dunnet *et al.* 1990). Age at first breeding is usually highly variable within a species and the pre-breeders component constitutes a large and important reservoir of recruits to the breeding population. Extra-mortality in winter is therefore not necessarily visible at colonies straight away, but a series of winters with extra mortality amongst immatures and adult pre-breeders results into reduced recruitment into the breeding stock and, hence, in population declines despite good breeding success.

Seabird wrecks are a well known feature in the ornithological literature. Influxes, preceding wrecks, bring species in areas where they usually do not occur or in much smaller numbers and these events therefore receive much attention. It should be noted that wrecks are recorded as long as birdwatchers make notes on what they see, but still their cause is not fully understood. Seabird wrecks are often thought to have been caused by poor feeding conditions (adverse weather) or reductions in food, with the birds dying from starvation. Wrecks are known both from the Atlantic and the Pacific and also from the southern oceans (Crochett & Kearns 1975, Gabrielson & Jewett 1970, Murphy & Vogt 1932, Veitch 1976, Witherby 1912). Species involved in wrecks are very often surface feeding birds (Procellariiforms, phalaropes, Kittiwake) and at least in the North Atlantic birds originating from arctic (or antarctic) breeding places are very often involved (dark-phase Fulmars, arctic Kittiwake populations, skuas, Little Auks; Camphuysen & van IJzendoorn 1988, Murphy & Vogt 1933, Packard 1932, Pashby & Cudworth 1969). Mass mortality of auks, presumably due to food shortages either or not in combination with adverse weather, has been reported rather frequently (Bailey & Davenport 1972, Bateson 1961, Blake 1984, Dement'ev *et al.* 1968, Lloyd *et al.* 1974). Rough seas can make feeding very difficult, even for deep diving species such as Guillemots (Birkhead 1976).

Starvation was always the proximate cause of death in these wrecks. Most authors tried hard to find evidence that exceptionally adverse weather had been the trigger factor. In most documented cases, however, the attempts to explain the wrecks are not satisfactory. Lack of food in the wintering areas may have caused (southward) migration in many more cases than described, while severe storms have probably made influxes visible rather than that they actually have caused the wrecks.

References Anker-Nilssen 1987, Ashcroft 1979, Bailey & Davenport 1972, Barrett *et al.* 1987, Bateson 1961, Birkhead 1976, Birkhead & Hudson 1977, Blake 1984, Camphuysen & van IJzendoorn 1988, Coulson & Wooller 1976, Crochett & Kearns 1975, Dement'ev *et al.* 1968, Drent & Daan 1980, Dunnet & Ollason 1978, Dunnet *et al.* 1990, Furness 1978b, 1982, 1984, Furness & Ainley 1984, Furness & Cooper 1982, Furness & Monaghan 1987, Gabrielson & Jewett 1970, Heubeck 1989a, Kendeigh *et al.* 1977, Lid 1981, Lloyd & Perrins 1977, Lloyd *et al.* 1974, Monaghan *et al.* 1989, Murphy & Vogt 1932, Nelson 1978, Packard 1932, Pashby & Cudworth 1969, Pennycuick 1989, Piatt & Methven 1988, Prange & Schmidt-Nielsen 1970, Veitch 1976, Wiens & Scott 1975, Witherby 1912.

5.2 Interactions with fisheries: overview

During the last 20 years, competition between seabirds and fisheries became a topic of special interest to many biologists. Symposia were organized and a large number of publications appeared discussing the (possible) impact of fisheries on the availability of food and the use of seabirds as indicators of fish stocks (e.g. Anderson *et al.* 1980, Bailey 1989, Bailey & Hislop 1978, Duffy 1983, Furness 1982, 1984a, 1984b, 1987, Furness & Ainley 1984, Heubeck 1989a, Myrberget 1982, Nettleship, Sanger & Springer 1984). The interactions with fisheries are varied and complex. Furness (1982) and Furness & Ainley (1984) gave some case studies of some areas where fishery-induced changes in marine ecosystems have led to alterations in food availability to seabirds. Several species were and still are able to profit from discarded fish from trawlers: a supply of food which gained importance this century (Boswall 1960, Bourne 1983, Dändliker & Mülhauser 1988, Hudson 1988). Overfishing of whitefish since the 1880s coupled with reductions of Herring and Mackerel most probably led to increases in stocks of small fish, particularly sandeels (Andersen & Ursin 1977).

It has been suggested that the steady increase in seabird numbers, particularly in Shetland and Orkney, was caused by the increase in the sandeel stocks (Furness 1984a). Seabirds have been used as indicators of marine food supplies (Anderson *et al.* 1980, Cairns 1987, 1988, Montevecchi 1986), either directly because the presence of feeding seabirds indicates the presence of fish shoals, or indirectly because changes in their diet indicate changes in fish stocks or the availability of fish. Negative and positive effects of fisheries on seabirds (or more directly of fisheries on fish stocks) are known worldwide (Blake 1983, Duffy 1983, Furness 1987, Furness & Ainley 1984, Furness & Birkhead 1984, Heubeck 1989, de Korte 1988, Lid 1981, Monaghan *et al.* 1989, Nettleship *et al.* 1984). Negative effects are overfishing and fish stock depletion, when the food fish for seabirds is taken away, positive effects are the increase in the provision of discards and offal to seabirds and, of greater overall importance, ecosystem changes (e.g. due to overfishing of predatory fish) leading to the expansion of small fish such as sandeels (Furness 1984a). Some examples are discussed below in some detail.

5.2.1 Case studies of fishery induced changes in marine eco-systems and the effect on seabirds

The "guano birds" (Peruvian Cormorants *Phalacrocorax bougainvillii* (also called guanays), Peruvian Boobies *Sula variegata* (piqueros), and Brown Pelicans *Pelecanus occidentalis*), breeding on islands off Peru are of particular interest

because of the periodical disappearance of their principal food fish, the Peruvian Anchovy *Engraulis ringens*, due to natural factors (hydroclimatic, the El Niño; Canby 1984). The coastal ecosystem off Peru is strongly influenced by an upwelling system. Cool and nutrient rich waters of the Peru or Humboldt Current bath the Peruvian coast. Periodically abnormal conditions arise and warmer water approaches the coast and the fish stocks, fisheries and seabird populations collapse (see detailed description in Nelson 1978). The seabird populations were able to recover rapidly from these crashes thanks to the extremely rich food supplies in "normal years". Quite recently, however, the vast overexploitation of the anchovy stocks by the fishing industry has led to a serious reduction in the population of the guano birds. Stock depletion prevented seabird populations to recover from the natural crashes (Nelson 1978).

Competition with purse-seine fishery has been suggested as the main cause of the population decrease of African penguins *Spheniscus demersus* off southern Africa (Duffy *et al.* 1987). Detailed studies showed that direct competition was limited in the breeding season because penguins are constrained to nearshore waters where purse seiners cannot fish and because penguins take smaller fish than does the fishery. However, it appeared that immature penguins, spending their first year at sea in an area of intense fishery activity, had a very low survival compared with immatures spending their first year in a bay closed to commercial fishery. This study shows how important fisheries competition can be outside the breeding season.

Puffins on Røst have suffered from repeated breeding failures (Lid 1981). Anker-Nilssen (1987) demonstrated how chick growth and fledging success were affected by the quality and the quantity of food. A dramatic decline in the Herring populations dates from 1968 and was, no doubt, caused by overfishing (Hamre 1988). In 1969 was the first year when abnormally high chick mortality occurred. Data from 22 consecutive years now seem to verify the hypothesis that the breeding success of Puffins on Røst is strongly dependent on the spawning yields of the local Herring stocks (Anker-Nilssen 1987). The Herring stocks are now slowly recovering, but are still very low (Jakobsen 1985, Hamre 1988).

Guillemot populations on Bjørnøya and in northern Norway collapsed after 1985. Population reductions of 70, 80, and 90% were found in many of the most northern colonies and acute food shortage (disappearance of Capelin) appeared to have caused the crash (Anonymous 1987bc, Frikke 1988, Vader *et al.* 1988). Overfishing was perhaps not the only or ultimate cause of the disappearance of the Capelin, since stock collapses were also recorded when Capelin fishery was insignificant. It should be noted that large scale industrial fisheries for Capelin were only quite recently developed and there were no changes in the management of the Capelin stock when the first signs of a collapse could be noted in 1981 (Hamre 1988).

Since 1982, reductions in the sandeel stocks around Shetland, which are believed to be fairly isolated stocks, have been recorded (Goodlad 1989, Kunzlik 1989). Breeding failures among several species of seabirds since the early 1980s, all sandeel specialists, occurred and the rapidly increasing seabird populations stabilized or declined (Heubeck 1989a). The most affected species were Great and Arctic Skua, Kittiwake, and Arctic Tern. Puffins also showed signs of food shortage and some chicks died. Breeding success of these seabirds was clearly affected by reduced availability of sandeels. The sandeel fishery in these waters had increased from 8000 tonnes landed in 1974 to 52,600 tonnes in 1982 and

subsequently declined. One reason for this decline in sandeel fisheries, other than the decline in the sandeel stocks, was the change in the relative economic value of sandeels compared to whitefish (Goodlad 1989).

In most of these and other cases (Furness 1982, Furness & Ainley 1984, Nettleship, Sanger & Springer 1984, and further references below this paragraph), the direct link between fisheries and the fish stock collapse could not be proved. Other factors, such as climatic influences or (natural) recruitment failure, may have played their role. However, several factors may be involved, but the fishery is the only one we can control (P.Ellis in Heubeck 1989a). The sandeel fishery in Shetland, for example, is a classic recruitment fishery. The species is short-lived and sensitive to failure of recruitment over a few years. Fishing when recruitment is low could cause problems (R.W. Furness in Heubeck 1989a). The fisheries management is mainly concerned about the possibilities of good fishing next year and the total allowable catch (TAC) is thus preferably pretty near the maximum sustainable yield (MSY). The predation of fish by seabirds is usually regarded as "insignificant", and is thus ignored, while that of marine mammals (e.g. seals) is considered as a plague, and culling is often suggested to protect the fisheries (Lavigne 1990). Recently it has been shown that seabird populations may consume up to 29% of the food fish in the immediate vicinity of the breeding colonies (Furness 1978b, Furness & Cooper 1982, Wiens & Scott 1975)

5.2.2 Seabirds profit from increase in small fish

Most North Sea seabird populations have increased in numbers for at least 80 years or so, but most populations are now showing signs of reaching a population ceiling or at least of stabilization (Cramp *et al.* 1974, Fisher 1952, Furness 1982, Lloyd *et al.* in press). The population increase may be taken as evidence that food supplies have improved, but many seabird populations were heavily exploited during the eighteenth and nineteenth centuries so that these increases might as well be due to the relaxation of such exploitation (Coulson 1963, Furness 1982, Potts 1969). Coulson (1963) and Potts (1969) have argued that food supplies were superabundant.

Andersen & Ursin (1977) concluded from a complex model that the reduction of Herring and Mackerel stocks were likely to have caused increases in the populations of their ecological competitors (e.g. sandeels, Sprat, Norway Pout). Such an effect is difficult to prove, but Sherman *et al.* (1981) demonstrated that indeed, population explosions of small, fast-growing sandeel can coincide with depletions of larger predators, including Herring and Mackerel in a continental shelf ecosystem. An increase of small fish, due to overfishing of the predators or ecological competitors, was also found in the Barentz Sea (Capelin stock in the 1970s; Hamre 1988). Several authors have pointed out that the increase of seabirds may have been caused by such fishery induced, new food supplies (e.g. Furness 1984a, Wanless 1987). Furness (1982) concluded that the overfishing of Herring and Mackerel might have improved the sandeel availability to seabirds in the short term, but that the partial recovery of the whitefish stocks would now have taken up the sandeel surplus, while the ever increasing fishery for sandeels is currently removing an increasing part of the sandeel stocks. He

later stated (Furness 1984a) that current, and likely future trends to conserve whitefish and Herring stocks and to increase industrial fishing for sandeels can be seen as a threat to seabird populations.

5.2.3 Seabirds taking offal and discarded fish

Increases of seabird populations may perhaps partly be attributed to increased availability of food resulting from provision of offal and discards (Furness 1984a). Fisher (1952) concluded that the increase of spread of the Fulmar was linked with new food supplies which were made available as offal from whalers and whitefish trawlers. The Fulmar is indeed a well known species scavenging for offal behind trawlers, particularly in the northern North Sea (Hudson 1988, Hudson & Furness 1988, 1989). Other scavengers are Gannet, Great Skua, Great and Lesser Black-backed Gull, Herring Gull and Kittiwake. In the southern North Sea also Common Gull and in coastal waters Black-headed Gulls are found scavenging behind trawlers. Studies of scavenging seabirds behind whitefish trawlers in Shetland's waters showed that almost all offal was consumed by seabirds, predominantly by Fulmars which excluded other seabirds by their aggression (Hudson & Furness 1989). Discarded fish was generally ignored by Fulmars, but these were taken by gulls, Gannets and skuas. Quantities of offal and fish discards from whitefish boats and Norway lobster boats around the British Isles were estimated at 107,400 tonnes and 156,300 tonnes respectively (Furness, Hudson & Ensor 1988). Assuming that a "1000 gram seabird" could survive on 64 kg of offal per year or on 120 kg of discards per year, they estimated that if all the offal and discards were taken, then some 2,800,000 of such "1000 gram seabirds" might be supported by this food supply alone (Furness, Hudson & Ensor 1988). These calculations may be crude, however, it is clearly demonstrated that the increasing fisheries in the North Sea have supported a large number of seabirds. Clearly, scavenging seabirds cannot consume all the offal and discards. Some must sink and may be taken by fish, marine mammals and perhaps auks. However, studies in Shetland and on the west coast of Scotland showed that some 90% of the offal and 75% of the discards were indeed taken by seabirds (Furness, Hudson & Ensor 1988).

References Andersen & Ursin 1977, Anderson & Gress 1984, Anderson *et al.* 1980, Anker-Nilssen 1987, Avery & Green 1989, Bailey 1986, 1989, Bailey & Hislop 1978, Bailey, Gauld & Kunzlik 1989, Bax 1989, Blake 1983a, 1984, Boswall 1960, Bourne 1983, Burger & Cooper 1984, Cairns 1987, 1988, Coulson 1963, Cramp, Bourne & Saunders 1974, Crawford & Shelton 1978, Croxall, Ricketts & Prince 1984, Cushing 1975, 1982, Dändliker & Mülhauser 1988, Duffy 1983, Duffy *et al.* 1987, Fisher 1952, van Franeker 1990, Furness 1978b, 1982, 1984abc, 1987, 1989a, Furness & Ainley 1984, Furness & Cooper 1982, Furness & Monaghan 1987, Furness, Hudson & Ensor 1988, Goodlad 1989, Hamre 1978, 1988, Hempel 1978abc, Heubeck 1989a, Hudson 1988, Hudson & Furness 1988, 1989, Jakobsen 1985, Jones & DeGange 1988, De Korte 1988, Kunzlik 1989, Lavigne 1990, Lloyd, Tasker & Partridge in press, MacCall 1984, Monaghan, Uttley & Burns 1988, Monaghan *et al.* 1989, Montevecchi, Birt & Cairns 1988, Myrberget 1982, Nelson 1978, Nettleship, Sanger & Springer 1984, Piatt & Nettleship 1987, Piatt & Reddin 1984, Potts 1969, Richardson 1989, Rikardsen 1984, Sherman *et al.* 1981, Tasker 1989, Tasker *et al.* 1989, Turkstra 1989, Vader *et al.* 1988, Vermeer & Morgan 1989, Wanless 1987, Wiens & Scott 1975.

5.3 Wintering seabirds and North Sea fish stocks

Blake (1984) suggested that the main factor causing the 1983 wreck of auks on Britain's east coast were changes in the availability of fish. In another paper he suggested that the depletion of fish stocks in the industrial fisheries (either caused by natural fluctuations or overfishing) had caused a shortage of food in winter which might prove equally lethal to seabirds in the long run as major oil spills in combination with chronic oil pollution (Blake 1983). Camphuysen (1989a) demonstrated that the stranding in Britain in 1983 was one wreck in a series of similar wrecks in the southern and southeastern North Sea. Recent studies indicate that Scottish Guillemot populations suffer from increased mortality in winter, while more and more Guillemots are wintering in the North Sea and while the wintering birds are expanding their wintering range in these waters (Harris & Wanless 1988, Heubeck in prep., Mudge *et al.* 1987, Peterz & Olden 1987, Swann *et al.* 1989). Breeding numbers are now found to decline or at the most to stabilize in many colonies while breeding success remains high. Declines in recruitment to the breeding populations (due to an increase in winter mortality) are thought to have caused the population declines (e.g. Harris & Wanless 1988, Swann *et al.* 1989). The apparent expansion of the wintering range brought large numbers of birds into areas where they are at risk for chronic oil pollution to a considerably greater extent than before, or where the chances to drown in gill-nets are much greater.

Some of the most obvious changes in fish stocks and fisheries in the North Sea during the last 20 years were the collapse of the Herring stock in the late 1970s and its recovery during the 1980s (Corten 1986, 1990). Secondly, there was a Sprat-boom in the 1970s and a collapse in the Sprat fishery in the early 1980s. The decline in Sprat numbers in the northern North Sea appeared to have been accompanied by a contraction of their distribution away from Shetland (Kunzlik 1989), fisheries off northeast Scotland collapsed, and new fisheries developed further to the south (Johnson 1982, 1983, 1985, Anonymous 1989d). Sandeel fisheries gained importance during the 1970s and 1980s and in the North Sea an absolute maximum of nearly 900,000 tonnes were landed in 1988 (Anonymous 1989d). The Norway Pout stocks, and its typical northern North Sea fishery, were found to decline in the 1980s: general trends in biomass estimates showed that their mean total North Sea biomass has been reduced from 728,000 tonnes during 1976-84 to 244,000 tonnes since 1985 (Anonymous 1989d).

It is tempting to relate fisheries to the observed changes in fish stocks and consequently to the problems faced by seabirds during the 1980's. However, this would be a simplification that ignores the complexity of interactions. A more detailed approach will be required to assess cause-effect relationships.

References Anonymous 1989d, Blake 1983, 1984, Camphuysen 1989a, Corten 1986, *1990*, Harris & Wanless 1988, Heubeck in prep., Johnson 1982, 1983, 1985, Kunzlik 1989, Mudge *et al.* 1987, Peterz & Olden 1987, Swann *et al.* 1989.

6. CONCLUSIONS

The conclusions in this chapter have been formulated on the basis of selection of Guillemot, Razorbill and Kittiwake for future study. These three species show similar changes in breeding numbers, wintering distribution and strandings in the southern North Sea. Problems faced by them apparently are less threatening to other abundant seabirds such as the Gannet and the Fulmar. Questions that had to be answered by this feasibility study were (summarized from chapter 1.2): (1) Which fish are important as prey for seabirds in the North Sea?; (2) What sort of data are available on fish stocks and fisheries in the North Sea?; (3) What sort of data are available on breeding populations of seabirds in the North Sea?; (4) What sort of data are available on populations of seabirds wintering in the North Sea?; (5) Would it be possible to identify causal relationships between changes in fish stocks and wintering seabirds in the North Sea?; (6) Which recommendations can be made for a future study?

6.1 Important prey fishes for selected bird species

Information on the diet of seabirds is fragmented and incomplete. Details on diet composition, calorific value of prey fish, and preferred/predominating size of fish have been published in many papers. Seabird diets are not very well studied outside the breeding season. The composition of most diets is largely dependent on what is readily available in the area where they stay. Some studies indicate that seabirds have some minimum density requirements to achieve satiation and these requirements deserve more attention. Also many species seem to prefer "rich" fish as Sprat and sandeels rather than other species. Their main prey consists of small fish (less than 200 mm in length) including commercially important species as Sprat, immature Herring, immature common Gadoids (Cod, Haddock, Whiting), Norway Pout, Scad and sandeels, and species not utilized in North Sea fisheries (e.g. gobies, sticklebacks). There is considerable evidence that sandeels, Sprat and young Herring are the most important prey. To include the bulk of their diet in future studies it is suggested that the following fish should be incorporated:

Herring *Clupea harengus* 0-group and 1-group
Sprat *Sprattus sprattus*
Cod *Gadus morhua* 0-group and 1-group
Haddock *Melanogrammus aeglefinus* 0-group and 1-group
Whiting *Merlangius merlangus* 0-group and 1-group
Norway Pout *Trisopterus esmarkii*
sandeel *Ammodytes spp.*

Less important are:
Poor Cod *Trisopterus minutus*
Bib *Trisopterus luscus* 0-group and 1-group
Blue Whiting *Micromesistus poutassou* 0-group and 1-group
Pollack *Pollachius pollachius* 0-group and 1-group
Saithe *Pollachius virens* 0-group and 1-group
Scad *Trachurus trachurus* 0-group and 1-group

Data on gobies and sticklebacks in the North Sea are difficult to obtain, but these species should not be ruled out completely.

6.2 Data sets on fish stocks and fisheries

Landing statistics from commercial fisheries should be used to find out trends in fish stocks (VPA) for the species listed above. Information on landing statistics is published in *Bulletins Statistique* since 1909 and in many papers and reports. This sort of information is sufficient for our purpose. There is no need for any extra runs of the ICES computers. Information on fish distribution is very important, particularly for winter situations. From the International Young Fish Survey these data are available in many working group reports. These results are particularly useful to study regional differences in the abundance of fish and to identify "high density areas". High densities of fish (and associated auks) may occur in very small areas and the IYFS grid may prove to wide for these local "anomalies". However, general patterns are described quite well and calculations can be made as to differences among years and areas. In my view there is little reason for any extra analysis by ICES. A map is prepared in which the distribution can be plotted using a home computer from ICES reports and simple matrices can be used to compare several areas for fish. Units are fish/hour/haul/square (NHH) and effort/-square. Surveys are carried out in February or, occasionally, in March. Information from acoustic surveys is available in published form. These data are only to be used to locate any high density areas which were overlooked by other methods, or in direct comparison with seabird distribution. The results from acoustic surveys may add much of what is overlooked due to the width of the IYFS grid. The IYFS together with groundfish surveys can be used to derive abundance indices of fish and trends in time.

6.3 Data sets on breeding seabirds

Breeding populations of seabirds in the North Sea are rather accurately known and population trends can be easily described using a large number of publications. For most countries the status of seabirds is well known while frequent updates ensure that population trends can be described. Breeding success is a parameter which is not a standard monitoring programme in most colonies, but for large areas of the North Sea, particularly from British colonies, information can be obtained rather easily. Information on seabird populations (status and trends) is readily available in published form from Britain and Ireland, Norway, Denmark and FR Germany. Similar information from Iceland and the Faroes does not exist or only in a fragmented and incomplete form.

6.4 Data on populations of wintering seabirds in the North Sea

Estimates of the number of wintering seabirds in the North Sea are remarkably scarce. Few accounts correct for immigration of northerly populations and usually the North Sea breeding population plus the newly fledged birds or just the

"northeast Atlantic" breeding population are used to estimate the minimum number of birds wintering in the North Sea. Estimates can be made from the densities calculated from seabird studies at sea, but large white (unsurveyed) areas will make these estimates not particularly accurate.

Information of seabird distribution at sea is available for the years 1979-85 from the Scottish Seabirds at Sea Team. To do a trend analysis several runs from their computer are necessary. These data are available against cost (Kittiwake, Razorbill, Guillemot, Nov-Mar, 1979-85, equals to 3*5*7 runs, total costs estimated at *f* 2700). Information on seabird distribution at sea in recent years is collected by Club van Zeetrekwaarnemers (CvZ), Dienst Getijdewateren Rijkswaterstaat (DGW), Nederlands Instituut voor Onderzoek der Zee (NIOZ), and by Ornis Consult (Denmark). Little or nothing is so far being published of these data. The CvZ and DGW data are not even computerized yet. NIOZ and CvZ/DGW data are necessary to fill in the recent years. The availability or cost of CvZ/DGW data is at present not clear. The NIOZ data are not available until they are being published. Slight, but basic, differences in methods will make direct comparsion with Scottish data difficult. For a trend analysis (pattern of distribution rather than exact densities) these differences can probably be ignored. Units are birds/km /month/square and effort/month/square. Surveys at sea are conducted throughout the year.

Information on seabird migration is available in the form of a database running from 1974 to today (CvZ, since 1991 Nederlandse Zeevogelgroep). Much of these data have been published in a format which makes them readily available and analysis can be carried out with personal computers. Units are birds/hour/seven-days-period and effort/seven-days-period. Seawatching is carried out throughout the year.

Information on seabird strandings is available from Nederlands Stookolieslachtoffer-Onderzoek (NSO). Recent data have to be put in the computer, most of the older data (1969-85) have been published in an accessible format. More recent data are available free, but time to store them into the computer should be budgetted. Units are stranded birds/km/sector/month and effort/sector/month. Surveys are mainly conducted in winter (Oct-Apr; Camphuysen 1989a).

6.5 Possibilities for identifying causal relationships between changes in fisheries, fish stocks, and wintering seabirds in the North Sea

From the discussions in chapter 4 it has become clear that it is extremely difficult to link fishery pressure to changes in fish stocks. Important interactions between fishes (predator/prey; competition) and changes in recruitment (e.g following climatic change) may obscure the importance of fishery induced mortality. Many assumptions, crude estimates and uncertainties are met in discussions of fish stock changes, and few people appear to share the same view on causes and effects. Hence, it will be difficult (if at all possible) to assess the responsibility of a particular fishery for a particular reduction in the availability of fish for seabirds. The studies of the reduced availability of sandeels for seabirds in Shetland are a good example of the difficulties that can be met. The Shetland problem concerns a local sandeel stock, with well known fisheries, and well known seabird populations and diets. However, this case proved to be considerably more

complex than was expected, mainly because it was so difficult to supply firm scientific evidence on the effect of fisheries on sandeel stocks.

Similarly, considerable problems arise when looking for evidence that changes in fish stocks have caused negative effects on seabird populations wintering in the North Sea. Sizes of seabird populations during winter in the North Sea are not very well known, so it will be difficult to assess whether fish stocks can satisfy the energy requirements of seabirds. Quantitative comparisons are further hampered by the fact that presence of fish not necessarily means availability of fish to seabirds.

Considering the above, it has to be concluded that the type of investigation suggested by the questions of the Netherlands Society for the Protection of Birds (chapter 1.2) is unlikely to produce the expected results. Scientific proof that the large seabird wrecks during the 1980's (and problems in colonies) are the direct result of reduced fish stocks, will be hard to obtain. Firm evidence that such fish stock reductions are a direct consequence of overfishing is even more difficult.

Does this all mean that all we can do is sit and wait to see what happens to the birds of the North Sea? Definitely not! Research on the effects of fisheries on sizes and distributions of fish stocks has to be strongly promoted. Such work, however, is a specialized job for fishery institutes. Research by fishery biologists into fish species that are important to birds (like Sprat, sandeels, young Herring etc.) is economically sensible since the same small fishes are the major source of food for predatory fish species harvested by commercial fisheries.

The contribution of ornithologists and conservationists should be the supplying of evidence that seabirds do respond to, or suffer from, changes in sizes or distributions of fish stocks. As strictly quantitative evidence will be hard to obtain, a qualitative study is recommended. Such a study should describe in general terms the requirements of seabirds in a way that allows the inclusion of the interest of seabirds into fisheries management decisions.

6.6 Recommendations for further ornithological study

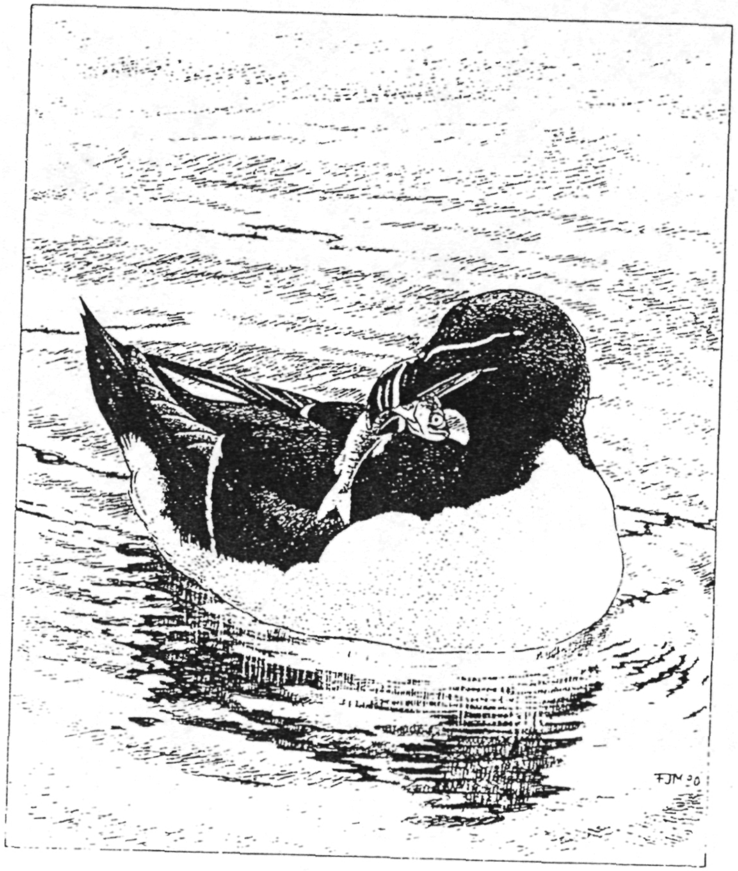
Several studies have been, or are being conducted to investigate interactions between seabirds, fish stocks and fisheries. However, all these studies focus on birds during the breeding season. From Scottish colonies, there are examples that not food shortages during summer, but apparently extra mortality of birds in wintering areas are causing decreases of breeding populations. It is extremely important that changes in wintering areas are studied.

This report suggests that certain seabird species have changed their winter distribution since ca. 1980, and that probably more seabirds have chosen the southern and eastern North Sea as their wintering area. It seems evident that this change has led to increased winter mortality. Limited food supplies may play a role in this, but higher mortality from oil pollution (southern North Sea) and drowning in fish nets (Skagerrak) are also involved.

As stated above, it will be difficult to find clear evidence that food shortage within the new wintering areas is causing extra mortality. However, it should be possible to investigate whether changes in fish stocks (and possibly fishery-pressure) have been the cause of birds moving out of their former wintering areas. With the data-sets described in this report it should be possible to perform a "trend-analysis" that links changes in seabird distribution to changes in fish

stocks over the past 20 years. If such correlations exist, it may be possible to show that fish stock depletion is the most likely factor to have caused changed wintering areas and increased mortality. A preliminary example of such analysis has been discussed for the Guillemot (chapter 3.8). Probably, such an analysis can also supply figures for minimum stock-size or density of food-fishes to allow seabirds to survive in a particular area of the North Sea.

Further study will also have to document increased mortality of seabirds in their new wintering areas. For this purpose the origin of birds wrecked in the Netherlands has to be established by means of biometrics and ringing recoveries. If it is known where "our" seabirds come from, information can be collected on status and trends, breeding success and recruitment into the breeding stock of these particular breeding areas. Such information is available at least for some important seabird colonies around the North Sea. Mortality data from the Dutch coast may thus be linked to population declines elsewhere.



7. PROPOSED RESEARCH

7.1 Project description

As recommended in chapter 6.6. it is proposed to set up a research project that makes a co-ordinated analysis of trends in populations (sizes, distributions) of some selected bird and fish species. Birds selected for such a study are the Guillemot, Razorbill and Kittiwake because these species seem to have suffered from similar problems since ca. 1980. Fish species are selected on the basis of their importance in the diet of Guillemot, Razorbill and Kittiwake. Main species are Sprat, sandeels, Norway Pout and young Herring, Cod, Haddock and Whiting. The project includes a study that compares mortality of seabirds in the southern North Sea to trends in the breeding populations to which these birds belong.

The purpose of this research project is to supply evidence that seabirds have moved their wintering areas after ca. 1980 in response to changes in fish stocks. Secondly, it has to be shown that these shifts in wintering areas have caused increased mortality of seabirds, leading to declines in some breeding populations. It is not the intention of this project to search for conclusive evidence that fishery pressure (or any other factor) has led to changes in fish stocks. However, fishery developments are part of the project, and any indications of influence on fish stocks will be documented as far as possible. Findings from this project may be of assistance in promoting particular studies by fishery biologists.

Basic topics for the proposed research are:
- trends in numbers, distribution and migration of wintering seabirds;
- trends in mortality, origin, and sex/age-composition of wintering seabirds;
- trends in breeding success and breeding numbers of selected seabird populations;
- diet and energy requirements of seabirds outside the breeding season;
- trends in distribution, stock-size en fishery-pressure for important prey fish species.

Data sets and methods that allow such research have been discussed throughout this report and will not be repeated here. An impression of the intended approach for integration of datasets is best obtained from the preliminary discussions on the Guillemot and the so-called "Sprat-scenario" (3.8). Evidently, the proposed work will be in much more detail than was possible within the framework of this preliminary study. The project proposed here has to be conducted by an marine ornithologist with knowledge of North Sea fisheries. As detailed below, the project requires about 32 man months (28 effective working months) with an estimated budget of salary plus *f* 65,500 expenses (excluding supervision, incidental expenses).

7.2. Planning of proposed research

The planning for a project in terms of time required for analysis and writing and costs can be described as follows. Budgetted time includes time for the integration of data sets and computer processing and analysis.

Breeding seabirds Contacts with ornithologists in (at least) Norway and Britain are needed (correspondence, travel expenses). A study of literature and reports to summarize trends in numbers and breeding success. Library visits (travel expenses), costs for copying papers, costs to buy reports. Time needed: 2 months. Costs: travel expenses two times abroad, library visits, correspondence, photocopies estimated *f* 4,000.

Seabirds at sea Computer runs of SAST seabirds at sea data should be ordered, analysed and plotted on maps and in matrices. Costs include these computer runs, 1-2 visits to Aberdeen, costs to use PC for plotting and analysis. A study of literature and reports to summarize trends in distribution and numbers of surveys not included in the SAST data base. Library visits (travel expenses), costs for copying papers, costs to buy reports. Time needed: 4 months. Costs: SAST computer runs *f* 3,000, travel expenses two times abroad, library visits, correspondence, photocopies estimated *f* 4,000 (excluding PC use).

Seabird migration Seawatching reports should be obtained, and contacts with teams of seawatchers may be required (correspondence). Published data should be analysed and worked into standard formats to allow PC processing. Time needed: 2 months. Costs: travel expenses, library visits, correspondence, photocopies estimated *f* 2,000 (excluding PC use).

Seabird mortality The most recent trends in strandings and data from dissected seabirds should be analyzed to study origin, sex and age composition of wrecked birds. A study of literature and reports to summarize trends abroad and surveys not included in the NSO data base. Library visits (travel expenses), costs for copying papers, costs to buy reports. Time needed: 2 months. Costs: travel expenses library visits, correspondence, photocopies *f* 1,000.

Seabird diets and energy requirements A study of literature and reports to summarize the diet and energy requirements of seabirds outside the breeding season. Library visits (travel expenses), costs for copying papers, costs to buy reports. Contacts with specialists abroad are required (correspondence). Time needed: 2 months. Costs: travel expenses library visits, correspondence, photocopies estimated *f* 1,000.

Prey fish distribution, fish stocks and fisheries An analysis of the IYHS and IYFS focussing on the selected fish species and the preparation for PC processing. Library visits (travel expenses), costs for copying papers, costs to buy reports. Contacts with fisheries specialists are required (visits, correspondence). The same is valid for an analysis of EGFS, SGFS and acoustic surveys in the North Sea and landings statistics. Time needed: 10 months. Costs: travel expenses two times abroad, library visits, correspondence, photocopies, unexpected computer runs RIVO estimated *f* 15,000 (excluding PC use).

Use personal computer and laser printer An AT PC will be required for permanent use (estimated *f* 4,500), prints on laser printers can be bought per print (estimated 2500 prints * *f* 0.25). Further costs include diskettes and paper. Costs: estimated *f* 5,500.

Final report Time and costs for writing, preparing figures and tables, lay out, cover, printing, presentation, distribution. Time needed: 6 months. Costs: estimated *f* 30,000.

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Appendix 1. List of fish names used in this report (sequence and nomenclature according to Wheeler 1978)

Spurdog *Squalus acanthias* **Doornhaai**
Starry Ray *Raja radiata* **Sterrog**
Conger Eel *Conger conger* **Zeepaling**
Herring *Clupea harengus* **Haring**
Sprat *Sprattus sprattus* **Sprot**
Pilchard *Clupea pilcharda* **Sardien**
Twaite Shad *Alosa fallax* **Fint**
Allis Shad *Alosa alosa* **Elft**
Anchovy *Engraulis encrasicolus* **Ansjovis**
Peruvian Anchovy *Engraulis ringens*
Salmon *Salmo salar* **Zalm**
Trout *Salmo trutta* **Zeeforel**
Smelt *Osmerus eperlanus* **Spiering**
Capelin *Mallotus villosus* **Lodde**
Argentine *Argentina sphyraena* **Kleine Zilversmelt**
Greater Argentine *Argentina silus* **Grote Zilversmelt**
Pearlsides *Maurolicus muelleri* **Lichtend Sprotje**
Crucian Carp *Carassius carassius* **Kroeskarper**
Angler *Lophius piscatorius* **Zeeduivel**
Cod *Gadus morhua* **Kabeljauw**
Arctic Cod *Boreogadus saida* **Poolkabeljauw**
Haddock *Melanogrammus aeglefinus* **Schelvis**
Whiting *Merlangius merlangus* **Wijting**
Blue Whiting *Micromesistus poutassou* **Blauwe Wijting**
Poor Cod *Trisopterus minutus* **Dwergbolk**
Norway Pout *Trisopterus esmarkii* **Kever**
Bib *Trisopterus luscus* **Steenbolk**
Pollack (or Coalfish) *Pollachius pollachius* **Witte Koolvis**
Saithe *Pollachius virens* **Koolvis**
Torsk *Brosme brosme* **Lom**
Five-bearded Rockling *Ciliata mustela* **Vijfdradige Meun**
Four-bearded Rockling *Enchelyopus cimbrius* **Vierdradige Meun**
Ling *Molva molva* **Leng**
Hake *Merluccius merluccius* **Heek**
Viviparous blenny *Zoarces viviparus* **Puitaal**
eelpout *Lycodes spp.* **wolfsvissen**
Garfish *Belone belone* **Geep**
Sand-smelt *Atherina presbyter* **Koornaarvis**
Stickleback *Gasterosteus aculeatus* **Driedoornige Stekelbaars**
Nine-spined Stickleback *Pungitius pungitius* **Tiendoornige Stekelbaars**
Nilsson's Pipefish *Sygnathus rostellatus* **Kleine Zeenaald**
Red-fish *Sebastes marinus* **Roodbaars**
Tub Gurnard *Trigla lucerna* **Rode Poon**
Red Gurnard *Aspitrigla cuculus* **Engelse Poon**
Grey Gurnard *Eutrigla gurnardus* **Grauwe Poon**
Bull-rout *Myoxocephalus scorpius* **Zeedonderpad**
Hooknose *Agonus cataphractus* **Harnasmannetje**

Lumpsucker *Cyclopterus lumpus* **Snotolf**
seasnails *Liparis spp.* **slakdolven**
Scad *Trachurus trachurus* **Horsmakreel**
sea-breams *Pagellus spp.* **zeebrasems**
Red Mullets *Mullus surmuletus* **Mul**
blennies *Blennius spp.* **slijmvissen**
Catfish *Anarhichas lupus* **Zeewolf**
Butterfish *Pholis gunnellus* **Botervis**
Sandeel *Ammodytes tobianus* **Zandspiering**
Raitt's Sandeel *Ammodytes marinus* **Noordse Zandspiering**
Greater sandeel *Hyperoplus lanceolatus* **Smelt**
Dragonet *Callionymus lyra* **Pitvis**
Sand Goby *Pomatoschistus minutus* **Dikkopje**
Two-spotted Goby *Gobiusculus flavescens* **Blonde Grondel**
White Goby *Aphia pellucida* **Witte grondel**
Crystal Goby *Crystallogobius linearis* **Kristalgrondel**
gobies *Gobius spp.* **grondels**
Mackerel *Scomber scombrus* **Makreel**
Brill *Scophthalmus rhombus* **Griet**
Turbot *Scophthalmus maximums* **Tarbot**
Megrim *Lepidorhombus whiffiagonis* **Scharretong**
Scaldfish *Arnoglossus laterna* **Schurftvis**
Plaice *Pleuronectus platessa* **Schol**
Flounder *Pltichthys flesus* **Bot**
Dab *Limanda limanda* **Schar**
Lemon Sole *Microstomus kitt* **Tongschar**
Witch *Glyptocephalus cynoglossus* **Hondstong (Witje)**
Long Rough Dab *Hippoglossoides platessoides* **Lange Schar**
Halibut *Hippoglossoides hippoglossoides* **Heilbot**
Sole *Solea solea* **Tong**
Solenette *Buglossidium luteum* **Dwergtong**

VERZENDLIJST

1 - 20	Auteur
21 - 27	Bestuur Vogelbescherming
28 - 34	Bestuur Nationaal Comité Wintervoedering van Vogels
35	Koninklijke Bibliotheek, Depot Nederlandse publikaties (Den Haag)
36	Bibliotheek NOU (Amsterdam)
37	Natuurbeschermingsraad (Utrecht)
38	CRMH (Den Haag)
39	Bibliotheek RIVM (Bilthoven)
40	Bibliotheek RIN (Arnhem)
41	Bibliotheek RIN (Den Burg)
42	Bibliotheek RIVO (IJmuiden)
43	Stichting Onderzoek der Zee (SOZ/NWO)
44	Ministerie van Verkeer en Waterstaat (Den Haag)
45	Directie Noordzee van V&W (Den Haag)
46	Dienst Getijdewateren (Den Haag)
47	Ministerie van Landbouw, Natuurbeheer en Visserij (Den Haag)
48	Directie NMF van LNV (Den Haag)
49	Ministerie VROM (Den Haag)
50	Natuurmonumenten ('s-Graveland)
51	Stichting Natuur en Milieu (Utrecht)
52	Werkgroep Noordzee (Amsterdam)
53	Stichting Zeevogels Olievrij (Zeist)
54	Nederlandse Zeevogelgroep (Oudeschild)
55	Centre Naturopa (Straatsburg)
56	ICBP (Cambridge)
57	ICES (Kopenhagen)
58	RSPB (Sandy, UK)
59	NOF (Trondheim)
60	DOF (Kopenhagen)
61	DBV (Bonn)
62	SAST (Peterborough, UK)
63	Shetland Bird Club (Denrossness, Shetland)
64	Seabird Group (Sandy)
65	Canadian Wildlife Service (Dartmouth, Nova Scotia)
66-70	Bespreekexemplaren tijdschriften
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4 Poorter E.P.R. 1990. Pleisterplaatsen van de Nederlandse Lepelaars *Platalea leucorodia* in de Europese trekbaan. [in Dutch with a French and a Spanish summary].

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KORTE BIJDRAGEN

BROEDENDE GEELPOOTMEEUWEN *LARUS CACHINNANS MICHAHELLIS* TE IJMUIDEN

YELLOW-LEGGED HERRING GULLS BREEDING AT IJMUIDEN

FRED COTTAAR
Lutulistraat 42, 2037 CB Haarlem

At IJmuiden, The Netherlands, a ♀ Yellow-legged Gull has been found breeding, paired to a ♂ Lesser Black-backed Gull, from 1987 onwards. When forced to leave its former nesting place by predating Red Foxes in 1989, the precise nesting location on a roof became known and biometrical data on the eggs of this pair were collected in three consecutive years (table 1). Moreover, the bird itself was caught, ringed and measured (table 2) in 1994. In 1996 a ♂ Yellow-legged Gull, paired to a ♀ Lesser Black-backed Gull, was caught, ringed and measured (table 2).

Sinds 1987 wordt er in IJmuiden met succes gebroed door een ♀ Geelpootmeeuw *Larus cachinnans michahellis*, gepaard met een ♂ Kleine Mantelmeeuw *L. fuscus*. Nadat de afgelopen jaren de precieze broedlocatie op een dak kon worden vastgesteld, werden gegevens over de eieren verzameld (tabel 1) en kon het broedresultaat worden bepaald. Tevens werden de hybride jongen voorzien van kleurringen, zodat ze later zouden kunnen worden herkend. Het ♀ werd op 23 mei 1994 gevangen en geringd met behulp van een inloopkooi. De toen vastgestelde maten staan vermeld in tabel 2. De vermelde snavelmaten zijn genomen vanaf de inplant van de snavel in de schedel en dus niet vanaf de bevedering. Vergelijking met door Cramp (1985) opgegeven snavelmaten voor *michahellis* is daardoor niet mogelijk. De afgelopen drie jaren was de plaatstrouw opmerkelijk. Er werd steeds op precies dezelfde locatie binnen de kolonie gebroed. Deze plaats-

Tabel 1. Maten van de eieren (lengte x breedte, mm) van ♀ Geelpootmeeuw gepaard met ♂ Kleine Mantelmeeuw.
Table 1. Measurements of eggs (length x width, mm) of ♀ Yellow-legged Gull paired with ♂ Lesser Black-backed Gull.

	ei 1 *egg 1*	ei 2 *egg 2*	ei 3 *egg 3*
1994	70.3 x 51.2	70.3 x 50.4	68.8 x 50.5
1995	72.5 x 51.6	69.6 x 52.0	70.3 x 49.8
1996	69.4 x 51.7	69.5 x 49.8	66.4 x 50.0

Tabel 2. Biometrische gegevens van adult ♀ en adult ♂ Geelpootmeeuw, beide gepaard met Kleine Mantelmeeuw.
Table 2. Biometrical data of adult ♀ and adult ♂ Yellow-legged Gull, both paired with Lesser Black-backed Gull.

	adult ♀	adult ♂	
snavellengte (schedel) *bill length (skull)*	66.0	71.2	mm
snavelhoogte (gonys) *bill height (gonys)*	18.0	19.3	mm
koplengte *total head*	115.3	120.7	mm
vleugel *wing*	406	439	mm
tarsus	65.5	70.2	mm
gewicht *weight*	780	1050	g

trouw was ook al opgevallen op een eerdere broedplek op het Forteiland in de monding van het Noordzeekanaal. Deze werd in 1989 echter verlaten als gevolg van het ten tonele verschijnen van de Vos *Vulpes vulpes*. De aankomstdatum van het ♀ in de kolonie was de afgelopen drie jaren steeds in de eerste decade van maart (7 maart 1994, 4 maart 1995 en 8 maart 1996). Door de regelmatige verschijningen van Geelpootmeeuwen in en rond de kolonies van IJmuiden de afgelopen jaren, was het geen grote verrassing dat er in 1996 een nieuw broedgeval op het dak plaatsvond. In dit geval was het een ♂ Geelpootmeeuw, gepaard met een ♀ Kleine Mantelmeeuw. Ook dit exemplaar werd, op 3 juni 1996, met behulp van een inloopkooi op het nest gevangen, gekleurringd en gemeten (tabel 2).

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DE VANGST VAN STERNS EN HET VERWIJDEREN VAN RINGEN IN AFRIKA: EEN PROBLEEM

THE PROBLEM OF TERN CATCHES AND THE REMOVAL OF RINGS IN AFRICA

ERIK W.M. STIENEN & ALLIX BRENNINKMEIJER
DLO-Instituut voor Bos- en Natuuronderzoek, Postbus 23, 6700 AA Wageningen.

In the West African winter quarters the practice of catching European terns has traditionally been widespread. Birds are caught for food or for pleasure. Although in some countries measures have been taken to discourage these practices and the incidence of catching terns seems to have decreased in Ghana, recent research indicates that terns may sometimes be caught to obtain the rings as a trophy. Some birds appear to have been released after the ring has been removed. An analysis of ringing recoveries of Dutch Sandwich Terns was carried out, revealing that of 48 ringed birds captured, at least ten birds were released alive after removal of the ring, while 14 birds were released with or without ring and of 14 more individuals nothing was recorded (Table 1). Thus, the the analysis of ringing recoveries of European terns may not be useful to determine mortality rates. A further analysis of the scope of this problem seems to be necessary.

Dat sterns een grote aantrekkingskracht hebben op mensen, staat buiten kijf. Denk maar aan de vele organisaties die een sternsoort in hun logo hebben opgenomen. Deze aantrekkelijkheid heeft de sterns in het verleden echter ook vaak parten gespeeld. In het begin van de twintigste eeuw werden aanzienlijke aantallen sterns in de broedtijd geschoten ten behoeve van de dames-mode-industrie. Veren van sterns en zelfs volledige vogels werden gebruikt om als versiering van hoeden te dienen. De jacht op sterns en het op grote schaal rapen van eieren zijn in het begin van de twintigste eeuw de belangrijkste oorzaken voor een forse afname van het aantal broedende Visdieven *Sterna hirundo* en Grote Sterns *S. sandvicensis* in Nederland geweest. Nadat de sterns wettelijk beschermd werden, namen de aantallen vanaf 1910 weer gestaag toe (Stienen & Brenninkmeijer 1992, Brenninkmeijer & Stienen 1992). De jacht op sterns blijft echter een belangrijke sterfte-oorzaak van sterns. Uit de literatuur blijkt, dat er in de Westafrikaanse overwinteringsgebieden (Ivoorkust, Mauretanië, Ghana, Senegal, Sierra Leone, Togo en Liberia) duizenden vogels zijn gevangen (Mead 1978, Dunn 1981, Meininger & Boersma 1988, Staav 1990). In Senegal worden volgens schattingen jaarlijks 5000-20 000 sterns gevangen (Meininger 1988). De vogels dienen als voedsel, maar worden vooral ook voor het plezier gevangen. De plaatselijke jeugd vangt de sterns met behulp van strikken of haakjes, waarbij een visje als aas

Tabel 1. Terugmeldingen van op Griend geringde Grote Sterns uit Afrika.
Table 1. Recoveries in Africa of Sandwich Terns ringed at Griend (Wadden Sea).

Categorie	n	(%)	Sub-categorie	n	(%)
Gevangen *captured*	48	(56)	Los met ring *released with ring*[1]	14	(29)
			Onbekend vast/los *unknown, released?*	14	(29)
			Los zonder ring *released without ring*	10	(21)
			Dood *dead*	6	(13)
			Vastgehouden *in captivity*	4	(8)
Dood gevonden *found dead*	16	(19)			
Onbekend *unknown*[2]	9	(10)			
Dood (geschoten) *dead (shot)*	7	(8)			
Ziek, verzwakt *weakened*	4	(5)			
Gevonden en los *found and released*	2	(2)			

[1] Zowel de individuen die met zekerheid zijn losgelaten met ring als diegene waarvan onzeker is of ze al dan niet met ring zijn losgelaten. [2] Individuen waarvan alleen het ringnummer is gemeld.

dient. Een zeer zorgwekkende zaak is dat ook jacht op de sterns wordt gemaakt puur en alleen voor de ringen. Er zijn voorbeelden bekend van beloningen voor het inleveren van ringen, die door de plaatselijke autoriteiten uitgeloofd worden (om het vangen te ontmoedigen!). Daarnaast worden de ringen gebruikt om er sieraden van te maken (o.a. Dunn 1981). In verschillende West-Afrikaanse landen zijn maatregelen getroffen om het vangen van sterns te ontmoedigen (voorlichting) en in Ghana is de jacht ook daadwerkelijk afgenomen (P.L. Meininger, pers. meded.).

In het begin van de jaren negentig was de drukte rondom het vangen van sterns wat geluwd. Onlangs verscheen echter een artikel dat ons de ogen weer deed openen. Becker & Wendeln (1996) doen reeds jaren onderzoek aan een visdievenkolonie nabij Wilhelmshaven in de Duitse Bocht. Daarbij maken ze gebruik van zogenaamde 'microtags', kleine transponders om individuen te identificeren zonder dat de noodzaak bestaat om ze te vangen. Alle kuikens uit die populatie worden voorzien van een microtag en van een stalen ring. In 1994 werd het signaal van een individu opgevangen dat geen metalen ring meer bezat. Hier kon onmogelijk sprake zijn van ringverlies door slijtage, omdat het hier een stalen ring en een jong individu betrof. De ring was kennelijk van de poot gehaald, waarna de vogel weer was losgelaten. Een analyse van de Duitse ringgegevens liet zien dat een aanzienlijk deel van de in Afrika gevangen Visdieven en Grote Sterns teruggemeld waren als 'levend losgelaten zonder ring'. Dit was voor ons reden om eens in onze eigen administatie te duiken. Sinds 1992 hebben wij op Griend jaarlijks ongeveer 2500 pulli van de Grote Stern geringd. Hiervan zijn ondertussen heel wat vogels teruggemeld. De resultaten zijn zorgwekkend. Op 56% van de terugmeldingen uit Afrika (n= 86) stond vermeld 'gevangen' (tabel 1). Hiervan werden er 24 (50%) volgens de melder ook weer losgelaten. Van de gevangen individuen werd van 10 vogels (21%) voor het loslaten eerst de metalen ring verwijderd. Vier sterns werden na vangst vastgehouden en zes zijn na vangst dood teruggemeld (gedood?). Van de overige 14 gevangen sterns (29%) is niet bekend of ze zijn losgelaten, vastgehouden of gedood. Naast de gevangen sterns is de categorie dood ook van belang (n= 23, 27%), waarvan 70% dood werd gevonden en de overige 30% als slachtoffer door menselijk toedoen (geschoten, visnet, verkeer, draden enz.) werd teruggemeld (tabel 1). De overige categorieën zijn slechts klein en worden hier niet verder besproken. Het blijkt, dat de aantallen gevangen sterns in Afrika nog steeds aanzienlijk zijn en dus een zorgelijke zaak vormen. Ook het verwijderen van ringen is een groot probleem. Het maakt het schatten van de jaarlijkse mortaliteit op basis van ringgegevens vrijwel onmogelijk.

Het is waarschijnlijk dat de vogels van deze behandeling in Afrika schade ondervinden. Het verwijderen van de ringen (zeker van stalen ringen) is zonder speciaal gereedschap onmogelijk zonder dat de vogel ernstig letsel wordt toegebracht (mogelijk met de dood als gevolg). Op Griend hebben we in 1995 en in 1996 verscheidene Grote Sterns waargenomen met littekens, verwondingen of vergroeiingen aan een poot. Mogelijk is dit veroorzaakt door het verwijderen van de ringen. Het is dus zeer wenselijk dat er een nader onderzoek wordt ingesteld naar de huidige omvang van het vangen van sterns en het verwijderen van de ringen in Afrika.

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NASCHRIFT VAN DE REDACTIE Een probleem is dat het niet duidelijk is hoe het Vogeltrekstation (VT) de schriftelijke terugmeldingen omzet in EURING-codes. Vaak is dit 'gevangen, verder lot onbekend' of 'gevangen en losgelaten'. Inzage bij het VT in de originele correspondentie van West-Afrikaanse melders zou over dit vraagstuk wellicht enige opheldering kunnen verschaffen. Naar eigen inschatting zijn de meeste in West-Afrika gevangen sterns overigens wel degelijk afgemaakt of aan de gevolgen van de vangst overleden. Senegalese jongens breken in de regel meteen een vleugel van gevangen sterns. Mogelijk betrof het Duitse geval een grote uitzondering... (PLM)