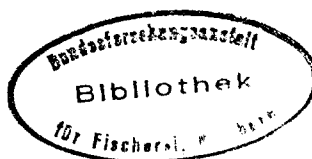


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REPORT OF THE
Working Group on Seabird Ecology

ICES Headquarters
30 March to 1 April 1998

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1 INTRODUCTION

1.1 Participation

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

R.T. Barrett	Norway
P.H. Becker	Germany
C.J. Camphuysen	Netherlands
G. Chapdelaine	Canada
P. Fossum	Norway
R.W. Furness (Chair)	UK
S.P.R. Greenstreet	UK
M.F. Leopold	Netherlands
J.B. Reid	UK
M.L. Tasker	UK

1.2 Terms of Reference

At the 84th Statutory meeting, it was agreed that the Working Group on Seabird Ecology should produce a Report and that the Working Group should meet at ICES headquarters in Copenhagen from 30 March to 1 April 1998 (3 days). The terms of reference were:

- a) review the consumption of pre-recruit fish by seabirds and evaluate the extent to which this may provide an indicator of recruitment;
- b) review evidence for annual, seasonal and spatial variation in the species and size of prey fish taken by seabird predators, and where possible relate these to variations in the prey populations. Such a review should also consider selection of prey according to body condition and the problems, if any, of extrapolating adult diets from food fed to chicks;
- c) review evidence for decadal scale variations in seabird distributions, population sizes, reproduction and food habits, and evaluate the extent to which these may be linked to the North Atlantic Oscillation and other physical cycles;
- d) consider the publication of the report of this meeting in the *ICES Cooperative Research Report* series;
- e) consider future work programme in relation to the remit of the Oceanography Committee and the development of the ICES Five-Year Plan, including co-operation with other Working Groups;
- f) liase with the MAWG.

1.3 Health Warning

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

Since C.RES.1997/1:6 concerning the preparation of a *Cooperative Research Report* based on last year's report (C.M.1997/L:3) has not yet been produced the Working Group propose to include text from this report into the planned *Cooperative Research Report* which will include analysis based only on a thorough vetting of data and continued intersessional discussion. A recommendation was drafted to reflect this (see Section 6).

1.4 Overview

The Working Group on Seabird Ecology met for 3 days (30 March to 1 April 1998), and was attended by 10 appointed participants from five countries. We reviewed, and here report in some detail, on topics a-c from our terms of reference. Topics d-f were discussed in plenary and deliberations on these issues are summarised in Section 5.

1.5 Acknowledgements

The Working Group wishes to thank ICES and their staff for providing rooms for our meetings, computing and photocopying facilities. We are particularly grateful to Dr J.W. Hurrell for making available to us the North Atlantic Oscillation index values for each year 1880-1997.

2 CONSUMPTION OF PRE-RECRUIT FISH BY SEABIRDS AND THE POSSIBLE USE OF THIS AS AN INDICATOR OF FISH STOCK RECRUITMENT

2.1 Introduction - background to fish stock assessment

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

In order to address this term of reference it is necessary to define exactly what is meant by the terms "recruitment" and "pre-recruit". A quick poll of WG members revealed that these terms meant different things to different people. Many considered "recruits" to be those fish maturing in a particular year to become part of the spawning stock. Consequently relatively old fish of some considerable length, two year old cod of 300 cm or more for example, could be considered as "pre-recruits" because they had yet to mature. This definition however, is not the one adopted by members of the working groups carrying out assessments of, for example, the demersal fish stocks. They consider recruits to be those fish entering the population of a particular species at the youngest exploited age, i.e. fish of an age which occur in the catch or discard data. This varies between species. Thus the youngest haddock and whiting which occur in catches are 0-group fish in the latter part of the year, while cod and saithe of this age are rarely encountered in the catch. Consequently the assessment working groups consider cod and saithe recruits to be 1-group fish turning up in the catches in the year following their birth. As a result of these between species differences, the VPA population assessments provide estimates of the numbers of 0-group whiting and haddock for quarters 3 and 4 in any given year, but not for the equivalent aged cod and saithe.

The numbers of recruits (0-group whiting and haddock in year x and 1-group cod and saithe in year $x+1$, where year x refers to the year class) can be calculated back down a time series using straight forward VPA. However, at the time when each working group meets, an estimate of the numbers of fish in the current recruiting year class is required in order to attempt to extrapolate forward to predict future recruitment. Clearly catch data for these fish are unavailable. In order to estimate current, or future recruitment, fisheries survey data are used. The historic VPA recruitment estimates are regressed against recruitment indices for the various species derived from survey data and, using the relationship obtained, the most recent survey recruitment indices are used to estimate the current numbers of fish in the recruit age classes. For species such as cod and haddock, the relationship between recruitment indices derived from survey data and the VPA recruit estimates are fairly close; the survey data provides a reasonably accurate estimate of current recruit numbers. However, for species such as whiting and saithe, this is not the case. For these species it would be particularly useful if alternative means of estimating the numbers of recruits were available. Even in the case of haddock and cod it is worth exploring whether seabird diet data might provide a useful independent estimate to compare with young fish surveys or fisheries-derived estimates.

Assessments of the major roundfish species are carried out over a large geographic scale. The stock "units" were re-evaluated as recently as 1995, following which, ACFM concluded that, for assessment purposes, the stocks of whiting and cod in VIId (eastern Channel) should be combined with those in the North Sea. Conclusions for the IIIa (Skagerrak) stocks were less clear cut, but there were indications that the cod and haddock stocks were linked with those in the North Sea and that there were therefore grounds for combining these assessments. Most seabird diet data have been collected during the breeding season and generally reflects the diets of birds feeding in the immediate vicinity of particular colonies. It is questionable whether data collected on such a limited spatial scale could ever be used to provide indices of numbers of recruits in areas as large as the North Sea, Skagerrak and eastern Channel combined, but we address this issue with real data below.

The backcast VPA estimates of the numbers of recruits in past years is highly dependent upon estimates of natural mortality (by definition, these age classes do not occur in the catch so fishing mortality is zero). Constant values of natural mortality have been assumed for each species in carrying out the VPA assessments. If, however, natural mortality has varied as a result of between year variation in the diet of seabirds, then the VPA estimates of the numbers of recruits in each year could be seriously in error. Furthermore, the predation loading inflicted by seabirds on young gadoid species (e.g. Barrett et al. 1990) may be independent of the numbers of young gadids available to seabirds, and may instead be dictated by fluctuations in the abundance of pelagic species such as mackerel, herring, sprats and

sandeels, which tend to be the preferred prey of most seabird species. Such a situation has been demonstrated for common seals in the Moray Firth (Tollit et al. 1997).

2.2 Introduction - background to seabird feeding ecology

Because most seabirds feed their chicks small fish, often the juvenile stages of large fish, studies of seabird diet can provide information on the local abundance of the youngest age classes (0- and 1-group) of fish in the immediate area around a seabird colony. As reproductive success of seabirds depends on the availability of adequate food resources, several parameters of their reproductive biology or diet and feeding can be used as indicators of the availability and distributions of prey species on which they feed (reviewed by Montevecchi, 1993). However, breeding seabirds only sample fish within a short distance of their colony. Foraging ranges vary among species, and according to food abundance, but tend to be tens of kilometres at most. Thus diet, provisioning rate, or some surrogate measure such as chick growth rate, of seabirds at a single colony cannot sample an entire fish stock. The extent to which local sampling may reflect the wider situation is uncertain, but will be considered below.

Fish stocks are sampled on a daily basis by seabirds whose diet is likely to reflect relative abundance of fish, both by size (year class) and by species. Among the different species of seabirds available for research, the generalists will have diets that are most likely to reflect the overall, local fish community structure, while specialists' diets will reflect yearly or within-season differences in stocks of a particular species or group of species. Examples of specialist feeders are the sandeel-dependent seabirds of Shetland (Martin, 1989; Monaghan et al., 1989), the herring-dependent puffins in western Norway (Anker-Nilssen 1992) and the terns in the south-eastern North Sea that prey mainly on sandeels and clupeoids. Cormorants and gannets are good examples of fish-eating seabirds that may take a large variety of fish species. Diets of cormorants include both demersal and schooling, pelagic fish. Gannets sample from the pelagic fish in surface waters. As a consequence, the local and temporal variation in gannet or cormorant diet can reflect differences in relative prey abundance.

It is important to note that there are major differences between species of seabirds and between populations of a single species in different regions. For example, the sandeel 'crisis' in Shetland in the 1980s caused different responses in different seabird species in Shetland. Arctic tern and kittiwake diet remained predominantly sandeel during the period of food shortage, but these birds failed to breed successfully. In contrast, gannets switched diet to other fish species and their breeding success was unaffected. Guillemots continued to feed almost exclusively on sandeels yet their breeding success was also unaffected. Great skuas switched diet away from sandeels and their breeding success was reduced, but not as much as that of kittiwakes. Breeding numbers of Arctic terns fell drastically as these birds mostly chose not to breed while sandeels were scarce, whereas great skuas continued to attempt to breed even though food was short. Great skuas incurred reductions in adult survival rate through having to work harder for food, whereas Arctic terns possibly did not because they mostly refrained from breeding. Thus each seabird species may respond in a species-specific way to a change in food abundance, and may depend on different prey species, or combinations of species, in different regions. We show below, that kittiwake populations in different parts of Norway show opposite responses to increased local abundance of herring - in one case kittiwake breeding success increases with herring abundance and in the other it decreases. Such local relationships are to be expected since responses depend both on the ecology of the seabird species but also on the combination of preferred prey fish species on which the birds depend.

Total food availability will affect seabird condition in terms of average body mass, breeding output, growth and survival of young. Different parameters that can be measured in seabirds may thus provide information on total food abundance and the composition of the fish community on which the birds feed. In situations where young fish make up most of the diets, seabirds may provide an additional means to sample younger stages of fish at a high temporal resolution, and at low cost compared to traditional ways of monitoring fish. Using the additional indications provided by seabirds may add little to assessment costs.

2.3 Seabirds as samplers of 0-group fish: case studies on cormorants/shags

Cormorants and shags regurgitate indigestible prey remains in discrete pellets, probably on a daily basis (Barrett et al. 1990). These pellets are relatively easily collected and can be analysed for the presence of fish otoliths, or other identifiable remains, which can be related to fish size. As such, these pellets provide an easy means to sample the diet and to get information on the state of the fish community at high temporal and spatial resolution.

Unfortunately, few long-term data sets exist for cormorant diets in relation to prey availability in any one locality. However, there is evidence that, for example, double-crested cormorant diet can change considerably over time, in response to changes in the prey fish community (Rail & Chapdelaine 1998).

Here we consider the potential of cormorants and shags to be used as a tool in assessing the relative abundance of 0-group gadoids and flatfish, using case studies made in European waters. The first is a study on shags feeding mainly on saithe in Norway, the second is on cormorants feeding mainly on flatfish in the Wadden Sea.

2.3.1 Shags and saithe, Norway

0-group saithe live in shallow, inshore waters that are notoriously difficult to sample. It is relevant to note that the relationship between VPA estimates of 1-group saithe and the numbers of young fish detected in surveys is very weak (ICES 1997c). In such a situation, "systematic surveys of prey harvests of shags breeding on inshore islands as supplementary inputs to [models on fish abundance]" could be useful (Barrett 1991). Pellets were sampled in the 1985 and 1986 breeding seasons on Bleiksøy, N. Norway (69°17'N, 15°53'N). Gadoid otoliths, all believed to be saithe, made up 81% and 58% of all items identified in these two years and the birds mainly took 0- and 1-group fish. When comparing 1985 to 1986, in the second year the diet contained fewer saithe with a shift toward a higher proportion of older fish. This indicates that 1986 was a poor year for 0-group recruits in the area. This corroborated results of newly developed 0-group surveys which ran in 1985-92. It is worth noting here that the data from sampling shag diet provided indications of low saithe production two or three years sooner than could be determined from VPA data (ICES 1997c).

2.3.2 Cormorants and flatfish, Dutch Wadden Sea

Cormorant pellets from several major roosts (1993) and one colony (1992) were sampled in late summer at locations throughout the Dutch Wadden Sea. Flatfish were the most important prey, representing 73% of the total diet by numbers (Van der Veer et al. 1998). Total consumption of flatfish was estimated at 28.5 million fish, of which 44.6% were plaice, 30.9% dab, 21.7% flounder and 2.8% sole. Flatfish abundance was estimated from a combination of a dedicated 0-group flatfish survey and the Demersal Young Fish Surveys. Cormorant predation was estimated to range from 30-50% of the total mortality of the 0-group fish of these species. Both the figures for consumption and for fish abundance should be taken with considerable caution, as the first are as yet uncorrected for lost otoliths (by digestion) and fish abundance may have been underestimated. Despite these uncertainties, and also considering that absolute numbers of flatfish were low in the years of study, these figures still suggest that cormorant predation was significant and that these birds relied on juvenile flatfish to a large extent. This implies that the cormorants sample 0-group fish with great efficiency and that at least relative differences between species of fish should be represented in the birds' diet.

Clearly, studies that only lasted 1-2 years cannot be used to describe long-term changes in fish stocks. Acquiring longer time series of diet analyses seem promising, however. Cormorants have established several breeding colonies in the Dutch Wadden Sea in recent years, so there is now also potential for studies that relate diet to breeding parameters such as growth rate and survival of chicks in these parts.

2.4 Pre-recruit herring and common tern reproduction

Pre-recruit fish have special importance as food for small seabirds such as terns. These birds have difficulty taking fish longer than 20 cm. Small fish species or juvenile fish therefore form the basis of their diet, consequently terns may be especially useful as indicators of pre-recruit fish abundance. Their overall energy reserves are low, so food availability immediately affects body condition and reproduction in adults (Monaghan et al., 1989; Frank and Becker, 1992; Wendeln, 1997) and growth of young (Becker and Specht, 1991; Mlody and Becker, 1991). They transport single food items in the bill, making it easy to obtain information on prey identity. Common and Arctic terns are distributed widely around the coasts of the North Sea, and the accessibility of many colony sites make them ideal as monitors of the temporal and spatial variations of 0-group fish. Thus the breeding failures among Arctic terns in Shetland during the 1980s (Furness, 1987; Monaghan et al., 1989, 1992; Uttley, 1992) coincided with a period of exceptionally low sandeel recruitment (Kunzlik et al. 1989). In the southern North Sea, however, sandeels are not important prey for terns. Instead, clupeoids, especially herring, but also sprat, are the dominant prey of terns (Frank, 1992; Frick and Becker, 1995; Tasker and Furness, 1996; Becker, 1996b; Stienen and Brenninkmeijer, 1998). Thus in this section, we link common tern reproduction in the Wadden Sea with IBTS information collected by ICES on herring stock size. In a long-term project, two colonies in the German Wadden Sea, Minsener Oldeoog and Banter See, Wilhelmshaven, have been studied since 1981, to look for relationships between breeding performance parameters and fish availability. A preliminary analysis has already been presented by Becker (1996b).

2.4.1 Correlations of Herring population parameters

Herring larval abundance for the whole North Sea and for just the south-eastern North Sea are significantly and positively correlated, indicating that variation in the abundance of herring larvae over the North Sea as a whole parallels

that in the south-eastern North Sea alone. Larval abundance and the IBTS herring index are also correlated (1-ring, Table 2.1, ICES 1997a,b). The 1995 value, however, does not fit the regression line. The IBTS herring estimate of the 1995 year class appears to be an outlier (ICES 1997b).

2.4.2 Correlations between pre-recruiting clupeoids and diet of common tern chicks

Clupeoids are the most important common tern food in the Wadden Sea (see 2.3). On Minsener Oldeog and Baltrum, they represent 29-70% of the chick diet (mean=49%, 9 years; Frank, 1992, 1998; Frick and Becker, 1995; Frank, 1998; Ludwigs, 1998). In the colony Banter See in Wilhelmshaven, 3-15% of the chicks' food (mean=10%, n=6; unpubl. data) and 11-48% of the courtship food are clupeoids (mean=24%, n=7 years; Wendeln, 1997 and unpubl.). The common terns feed on 0-group herring, 1-group herring, and on 1-group sprat which are about 6-13 cm long during spring in the Wadden Sea.

It is difficult to distinguish visually between herring and sprat in the bill of a tern. Herring was, however, the dominant species in the local waters: in stow net catches during 8 years (1985-1996) on Minsener Oldeog, sprat dominated the clupeoids (92%) in 1994 only, corresponding to a very high IBTS sprat index (year class 1993, ICES 1997a). In the other years, herring dominated (92-99%; Behnke, 1996; Ludwigs, 1998) in the stow net catches, and in the samples of dropped clupeoids recovered from the vicinity of nests.

In the Wadden Sea colonies, the amount of clupeoids in chick diet was positively correlated with the herring larvae density in the south eastern North Sea (c.f. Figure 2.1, Minsener Oldeog, $r_s=0.70$, $p<0.05$, $n=9$, Table 2.2; with IBTS herring index $r_s=0.45$, $n=9$, n.s.; but not with IBTS sprat index $r_s=0.03$, $n=9$, n.s.). In the Banter See colony, the amount of clupeoids in chick diet was positively correlated with herring larvae abundance ($r_s=0.95$, $p<0.05$, $n=6$, Table 2.3) and IBTS herring index ($r_s=0.89$, $p<0.05$, $n=6$). A high clupeoid proportion in tern diet apparently indicates a good stock of pre-recruiting clupeoids, especially herring.

There was no significant correlation between herring larvae density and amount of clupeoids in tern diet in the same year.

2.4.3 Relationships between recruiting clupeoids and the reproduction of terns

Minsener Oldeog

Between 1981 and 1997, tern breeding success fluctuated greatly between 0 and 1.6 chicks per pair per year, owing to variation in the annual food availability as well as to the influence of predators (Becker, 1998).

Comparison of herring larvae density and common tern chick losses through starvation, over a 17 year period (1981-97), showed that common terns lost fewer chicks and survivors grew better (here we are looking at chick growth rate as a surrogate for food provisioning rate) in years with high rate of herring larvae density (Fig. 2.2). There are significant correlations between herring larvae production two years before and common tern chick growth rate, fledging age and chick loss (Table 2.2, Fig. 2.3). The linear modelling of chick growth rate vs herring larvae index for the south east North Sea was $y=2.95x + 5.517$. Consequently, an increase of the larvae index by 0.1 would increase the chick growth rate by 0.3 g/d, and reduce the chick losses. No significant correlations were found with sprat index.

Banter See, Wilhelmshaven

The number of fledglings per pair per year varied between 0.2 and 2.4 chicks (1991-1997; Becker, 1998). The correlations of reproductive parameters with herring stock density were similar to those at Minsener Oldeog (Table 2.3, Fig. 2.4). Chick loss through predation was not so important as on Minsener Oldeog, and the reproductive success increased positively with herring availability (but n.s., Table 2.3). Chick growth was especially good in 1994, the year with high sprat abundance (see also Minsener Oldeog Fig. 2.3). Thus sprat abundance can confuse the relationship with herring abundance, but in most years sprat abundance was too low to cause this problem.

The regression of chick growth rate on the herring larvae index (Fig.2.4) was $y=4.0x+6.845$. Thus an increase in the herring index value of 0.1 would improve chick growth by 0.4g/d. Using the herring larvae density or abundance for the same year the terns bred, the correlations described above were not significant at either colony.

2.4.4 Conclusions

Although not related to herring larval production in the same year (these larvae being too small to provide much food for terns), the data show that the reproduction of terns on the southern North Sea coast is strongly linked to the annual stock of juvenile herring, their main food source. Consequently, terns can be used in addition to the fisheries' data to indicate abundance of the young herring stock. Conversely, fisheries' data on clupeoids may be used to predict growth and reproductive success of terns. A reduced common tern breeding population in the Wadden Sea in 1996 and 1997 (Südbeck and Hälterlein 1998) also may be due to the reduced occurrence of juvenile clupeoids. Despite the short foraging range of breeding common terns (max ca 7 km), the correlation with herring abundance over the entire south-eastern North Sea is quite strong. This suggests that herring are fairly uniformly distributed over this region, or at least that local abundance near these tern colonies is closely related to abundance at the wider scale.

However, to conclude that tern breeding ecology can be used as a measure of herring juvenile abundance, some important points have to be clarified:

- Decisive for the terns was the herring year class two calendar years before the respective breeding season (i.e. 1-ring in the breeding season, Fig. 2.1), or the sprat year class one year before the tern breeding (age 1 in the breeding season). This may indicate that the 1-group herring is more important for tern reproduction than 0-group. This should be investigated further.
- The correlations of tern data with the herring larvae abundance estimates are much closer than those with IBTS herring index (1-ring). This suggests that the sampling of larvae gives a better annual figure of the herring population 1 year later than the sampling of 1-ringers in the current year. Fish catches of 1-ringers may be taken more by chance than larvae sampling.
- The dependence of the reproduction of terns on pre-recruit clupeoids should be verified at another colony site, for example on Griend in the Dutch Wadden Sea where terns are also studied (by Stienen and Brenninkmeijer).
- To investigate interactions between seabird reproduction and fish stocks, breeding seabird numbers or overall breeding success are often considered, but parameters more directly linked to food availability such as chick growth, rate of chick starvation or fledging success should be assessed as they may be expected to provide a more direct and sensitive indicator of food supply (Table 2.2). The data presented also underline the importance of long term data series as the key tool to understand interactions between seabirds and fish.

2.5 Norwegian spring-spawning herring and north Norwegian seabirds

The Norwegian spring-spawning stock of the Atlanto-Scandian herring has shown huge fluctuations in size during the last half century. Between 1957-1971, it collapsed from ca. 18 million tonnes to an estimated 12000 tonnes, remained very low (<1 million tonnes) until 1985, and has since been increasing (ICES 1997c).

Norwegian seabirds feed their chicks mainly on small fish, samples of which are easy to obtain. Several studies have documented that several seabird species feed significant amounts of 0- and 1-group herring to their chicks and studies along the coast of Norway have shown that the amounts of herring in the samples vary considerably from year to year (Barrett et al. 1987, Barrett 1996). This has been highlighted in two long-term studies on two colonies in North Norway, Hernyken at Røst (67°26'N, 11°52'E) and Hornøya in East Finnmark (70°22'N, 31°10'E). Close correlations exist between the amount of herring fed to chicks and independent assessments of amounts of young herring in the sea (Anker-Nilssen 1992, Anker-Nilssen & Øyan 1995, Barrett & Krasnov 1996).

2.5.1 Røst

There is clear evidence that seabirds breeding at Røst, Lofoten Islands breed successfully only when larval and 0-group stages of herring are abundant. In years with low abundance of herring, puffins and common guillemots have produced few chicks of poor quality, or no chicks at all, and kittiwakes have had reduced breeding success (Bakken 1989, Anker-Nilssen 1992, Anker-Nilssen & Øyan 1995, Anker-Nilssen et al. 1997).

There is, however, no clear causal relationship between breeding success and abundance of herring larvae. Between 1979-1994, herring content in puffin chick diet varied between 0% and 89% wet mass, with sandeels, saithe and haddock making up most of the remainder. There is no simple relationship between the amount of herring fed to the

chicks and 0-group abundance. This is possibly due to a preference for other prey species such as sandeels or saithe which tended also to be abundant in years with high herring abundance (e.g. 1983, 1992, 1994).

Although Anker-Nilssen et al. (1997) demonstrated a strong positive relationship between breeding success and independently obtained indices of 0-group herring abundance over a 22 year period (1975-1996, Fig. 2.5, $r_s=0.898$, $p<0.001$), there was a clear threshold above which fledging success was at a maximum and could not increase with increases in herring abundance. This suggests that any changes above e.g. 1.0 in the presently-used logarithmic index of herring 0-group abundance (ICES 1997c) will not be detectable in puffin breeding success alone. A similar positive relationship between kittiwake breeding success and 0-group herring abundance at Røst was also found between 1980-1996 (Fig. 2.6, $r_s=0.815$, $p<0.001$, Anker-Nilssen et al. 1997), but again there is a threshold above which breeding success does not increase further. Because the species composition of the diet does not relate directly to the availability of herring, and due to the shape of the relationship curves between availability of 0-group herring and breeding success, it is impossible to predict levels of herring 0-group fish at scales finer than high (log. index >1.0) or low (<0.3) from breeding success data.

Puffin diet data from several northwestern Norwegian colonies have, however, indicated the presence of some 0-group herring in the Barents Sea in years when surveys failed to document any (1981, 1982, 1986, 1987, index=0, Barrett et al. 1987, Barrett 1996, ICES 1997c).

2.5.2 Hornøya

Whereas seabirds breeding at Røst depend heavily on herring to feed their chicks, the main diet of seabird chicks in the southern Barents Sea consists of varying proportions of herring, sandeels and capelin (Barrett & Krasnov 1996). Sandeels and capelin are caught mainly as adult fish (Barrett & Furness 1990, Barrett & Krasnov 1996), and it has proved impossible to relate amounts of capelin caught by puffins, kittiwakes or common guillemots with independent measures of capelin abundance, probably due to the differences in spatial scale at which the parameters were measured (Barrett & Krasnov 1996). There was, however, a suggestion that the kittiwakes found smaller capelin (mean 114 ± 40 mm) in 1989 than in all but one of the other years (130-140 mm, 1980-1994), due to low recruitment of capelin after the collapse of the stock in 1987.

The herring, however, are consumed by seabirds as 1-group fish, and while there were no relationships between the previous years' 0-group herring abundance indices and the amount of herring in the chick diet on the Kola Peninsula, there were clear positive correlations for kittiwakes, common guillemots and puffins further west on Hornøya (Fig. 2.7). There are also positive correlations between herring content in the diet of common guillemot and puffin chicks and independent assessments (ICES 1997c) of 1-group herring in the Barents Sea ($r^2=44\%$, $df=9$, $p=0.027$ and $r^2=76\%$, $df=8$, $p=0.000$ respectively, Barrett unpubl.). The correlation for kittiwakes was not significant ($r^2=32\%$, $df=10$, $p=0.07$). Food data collected nearly every year since 1980 showed that herring first appeared in food samples in 1985, was absent in the late 1980s and appeared again in 1990. In 1993 and 1994 herring constituted $>90\%$ of kittiwake diet samples and 30-50% of the puffin and common guillemot diet samples. The appearance in 1985 corresponds with the only large cohorts of 0-group herring spawned in the 1980s (1983, 1984), whereas the presence in all diets in the early 1990s corresponds with several years of successful spawning (1989-1994, ICES 1997c).

Contrary to the situation at Røst, it seems that increased amounts of herring in chick diet corresponds to a decline in the breeding success of kittiwakes at Hornøya ($r^2=0.821$, $p>0.01$, $n=10$, Anker-Nilssen et al. 1997). There were, however, no significant relationships between kittiwake breeding success and indices for the 1-group or the previous years' 0-group herring abundance. At present, the only parameters for seabirds on Hornøya which corroborate the fisheries' assessments of the 0- and 1-group cohorts of herring in the Barents Sea are the amounts of herring in the diets of chicks of kittiwake, common guillemot and puffin.

2.6 Conclusions

We conclude that there are some case studies of seabirds that show fairly strong correlations between diet composition or food provisioning (or a surrogate measure of this such as chick growth rate) and the abundance of pre-recruit fish. Fisheries-derived and survey-derived estimates of recruitment apply to entire stocks or to very large geographical areas, so are on a much larger spatial scale than the distribution of fish providing food to seabird chicks at a particular colony. Nevertheless, correlations between common tern breeding parameters and herring abundance in the south-eastern North Sea provide an example of a correlation where it seems that the local performance of terns does reflect the changes in herring abundance over a larger scale. This may not always be the case. Thus it would be essential to be very cautious if using seabird data to infer the level of recruitment into a fish prey population over a wide area. In addition to the

relationships discussed here, good examples can be found in the literature, as for example Montevecchi & Myers (1995), Montevecchi (1993).

2.7 REFERENCES

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Table 1 Spearman correlation coefficients between various parameters estimating the clupeoid stock in the North Sea (IBTS). n = 17 year classes (1979-1995)

	IBTS herring Index North Sea	IBTS Sprat Index North Sea	IBTS clupeids	Herring larvae density
IBTS Sprat North Sea	-.07			
IBTS clupeoids	.76 ***	.52 *		
Herring larvae density	.43	-.44	.14	
Herring larvae abundance	.77 ***	-.04	.62 **	.59*

Table 2 Spearman correlation coefficients between clupeoid stock data of the North Sea (IBTS) and seabird data (common tern, Minsener Oldeog, 1981-1997)

	Herring larvae density South East (n=17)	Herring larvae abundance North Sea (n=17)
% clupeoids in chick diet (n=9)	.70 *	.32
growth rate of chicks (n=14)	.74 **	.58 *
growth rate of fledged chicks (n=11)	.77 **	.73 *
% chick losses by food shortage (n=17)	-.58 *	-.49 *
age of fledging (n=13)	-.56 *	-.46
chick fledged/pair	.23	.17
no. breeding pairs	-.32	-.47

Table 3 Spearman correlation coefficients between clupeoid-data for the North Sea (IBTS) and Seabird data (common tern, Wilhelmshaven, 1991-1997). n = 7, except % clupeoids in chick diet

	IBTS Herring Index	IBTS Sprat Index	IBTS Clupeoids	Herring larvae density	Herring larvae abundance
	North Sea	North Sea		South East	North Sea
% clupeoids in chick diet (n=6)	.89 *	.43	.43	.66	.95 **
growth rate of chicks	.21	.89 **	.75	.79 *	.61
growth rate of fledged chicks	.36	.68	.49	.94 **	.77 *
chicks fledged/pair	-	.75	.61	.50	.32

HERRING

spawning
(autumn)



IBTS
larvae
sampling



IBTS
index
(1 ring)



year x - 2

year x - 1

year x

years

breeding
season

COMMON TERN

Figure 2.1. Data sampling of herring recruits and common tern reproduction. Key tern diet is herring spawned in autumn two calendar years (20 months) before the tern breeding season. These herring are sampled by the IBTS surveys during spring as larvae the year before the tern breeding season, and as 1-ringers in the same season as tern breeding.

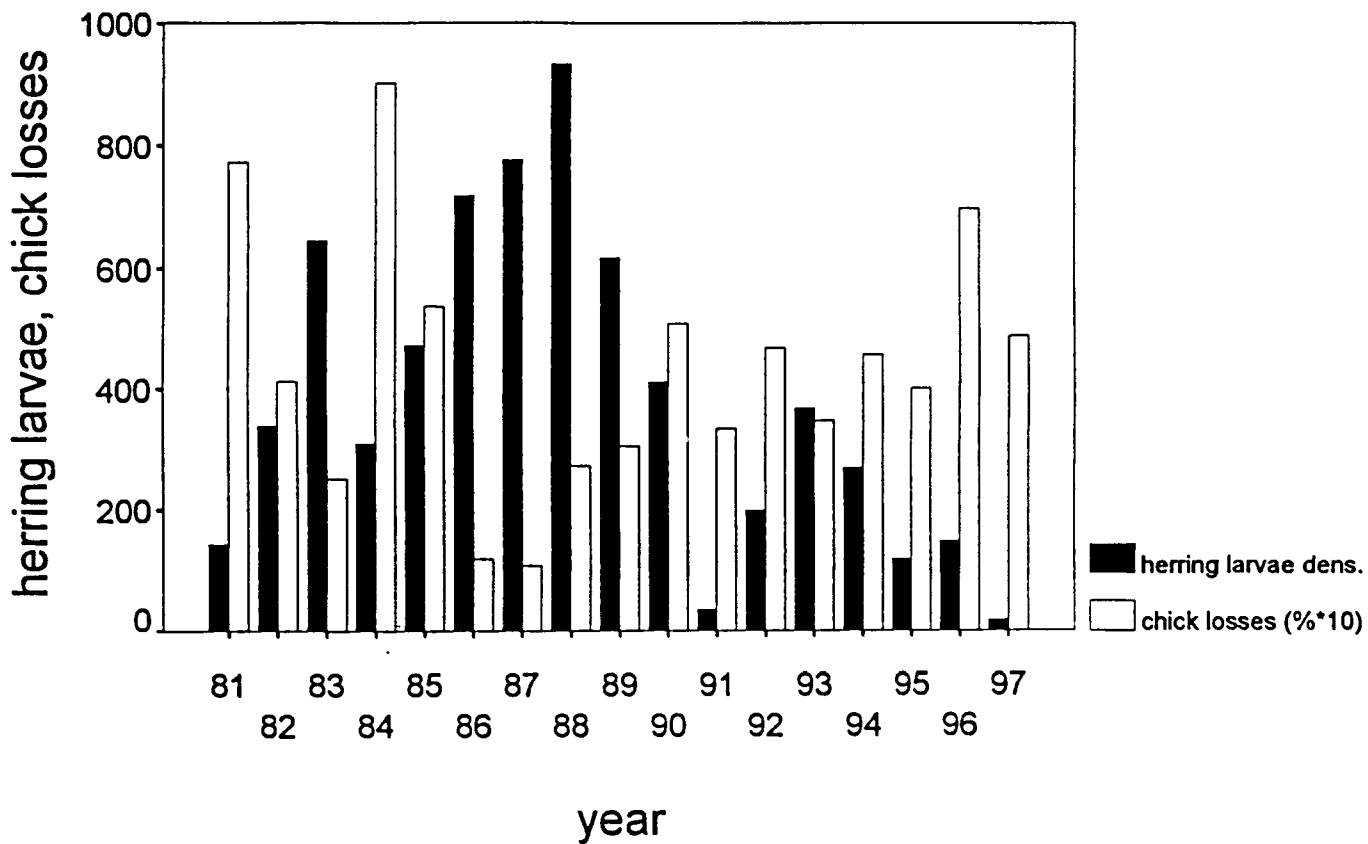


Figure 2.2. Time trends of herring larval density (south-east North Sea, $\times 1000$; year class= year-2; IBTS) and losses of common tern chicks (in $\% \times 10$) on the Wadden Sea island Minsener Oldeog, southern North Sea coast, from 1981-1997. Becker, unpubl. data.

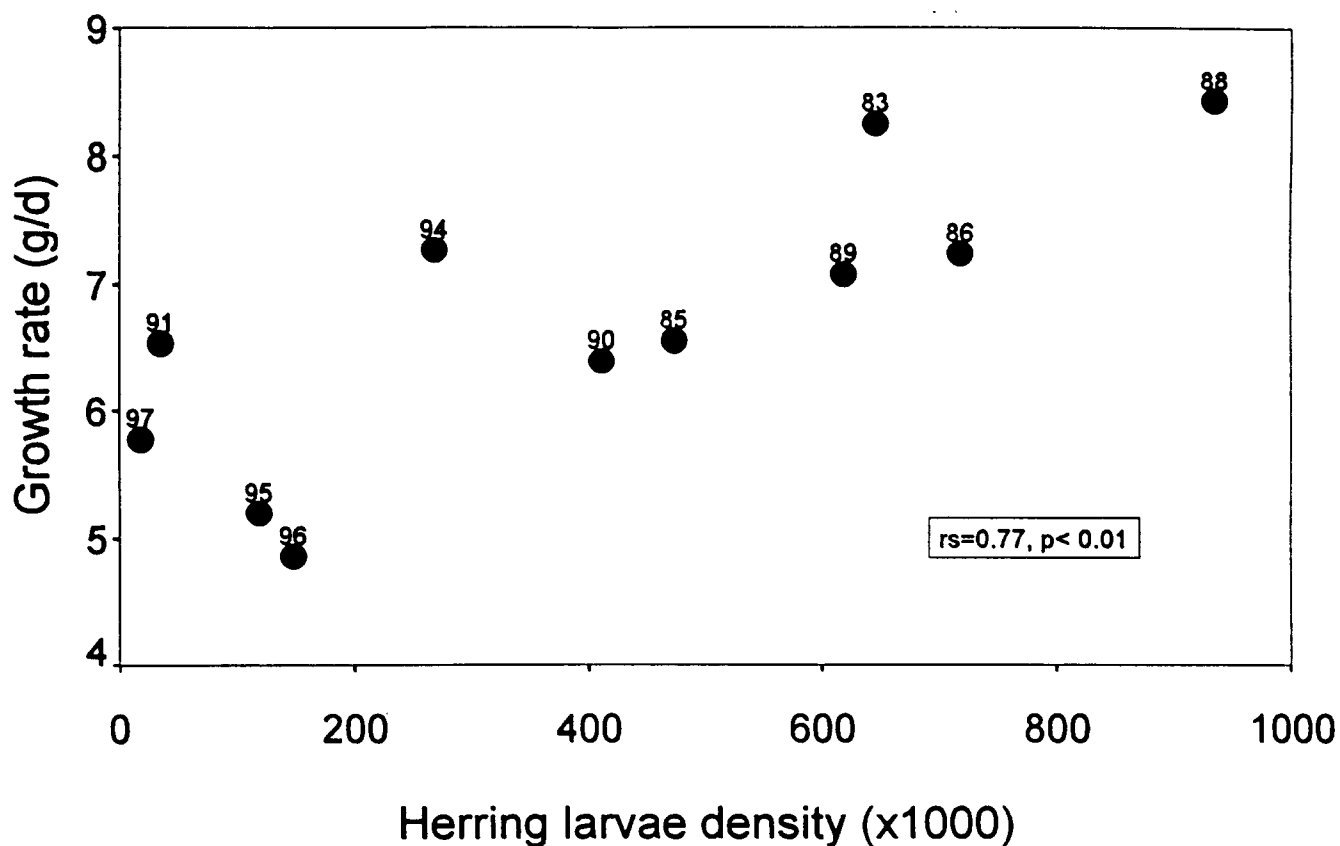


Figure 2.3. Correlation of herring larval density (south-east North Sea, x1000; year class= year-2; IBTS) with growth rate of common tern chicks that fledged on the Wadden Sea island Minsener Oldeog, southern North Sea coast, from 1981-1997. Becker, unpubl. data.

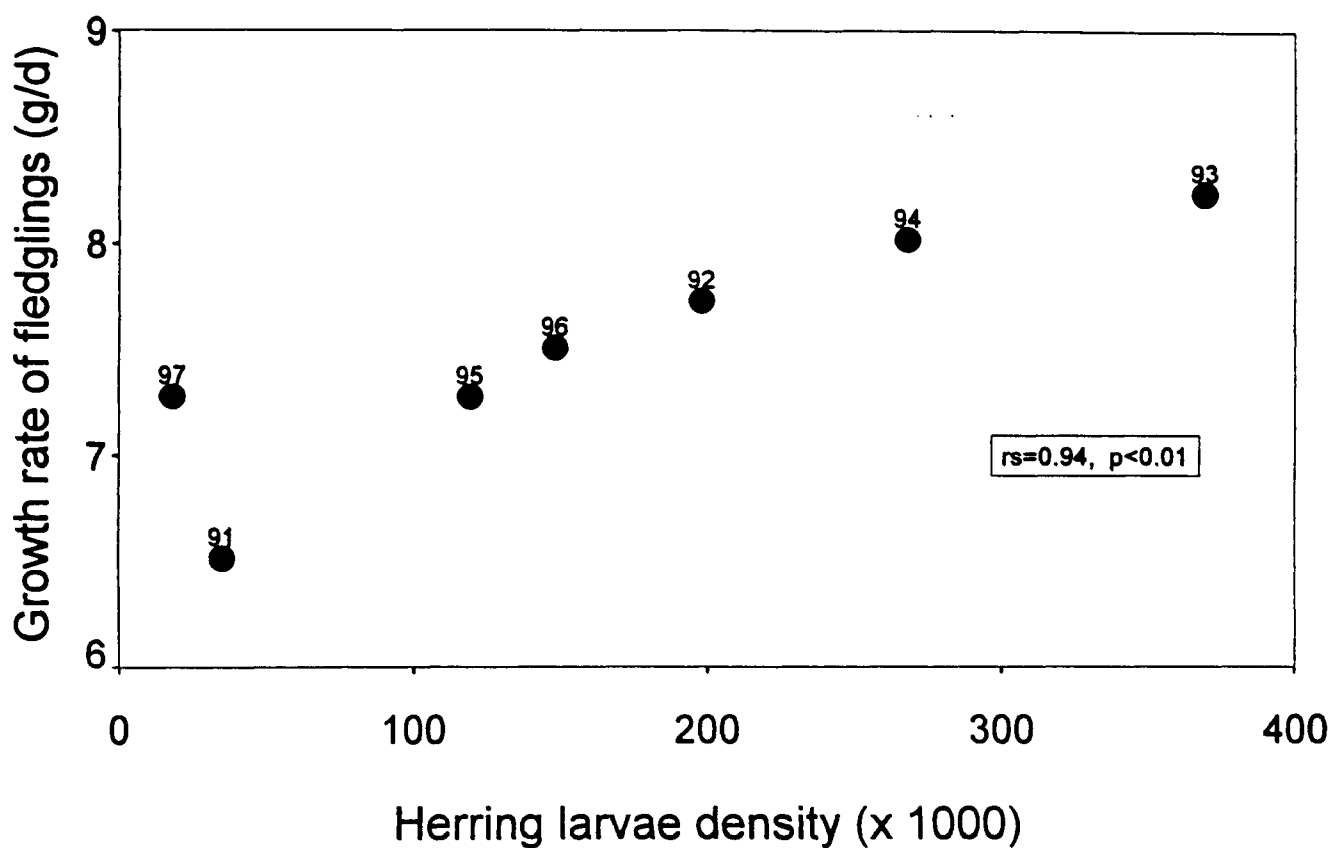


Figure 2.4. Correlation of herring larval density (south-east North Sea, x1000; year class= year-2; IBTS) and growth rate of common tern chicks that fledged at Banter See, Wilhelmshaven, southern North Sea coast, from 1991-1997. Becker, unpubl. data.

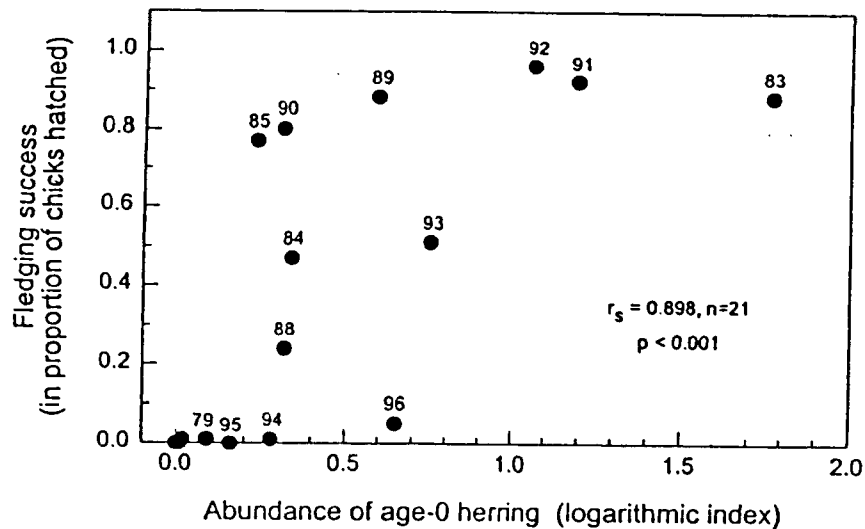


Figure 2.5. The relationship between the abundance indices of age-0 herring in the Barents Sea and adjacent waters in early autumn and the fledging success of puffins at Røst, northern Norway, in 1975-1996. Eight points are located close to the origin. From Anker-Nilssen et al. 1997.

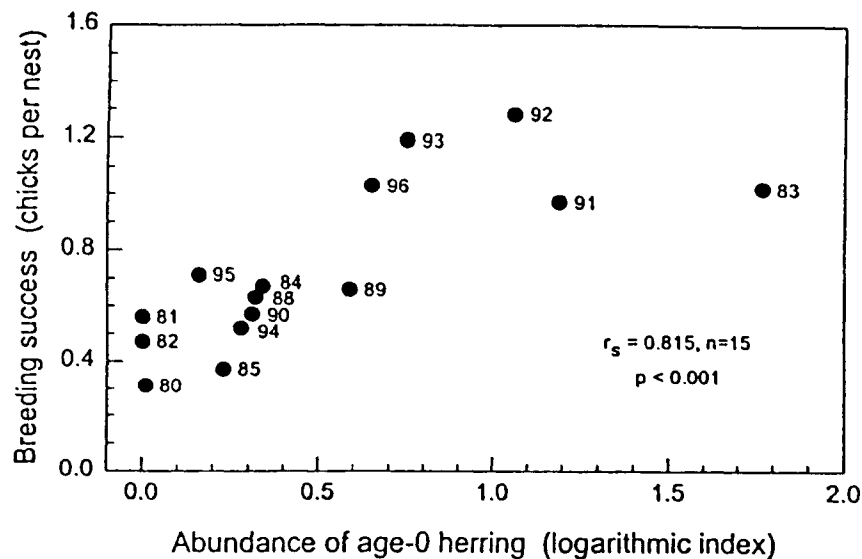


Figure 2.6. The relationship between the abundance indices of age-0 herring in the Barents Sea and adjacent waters in early autumn and the breeding success of kittiwakes at Røst, northern Norway, in 1980-1996. From Anker-Nilssen et al. 1997.

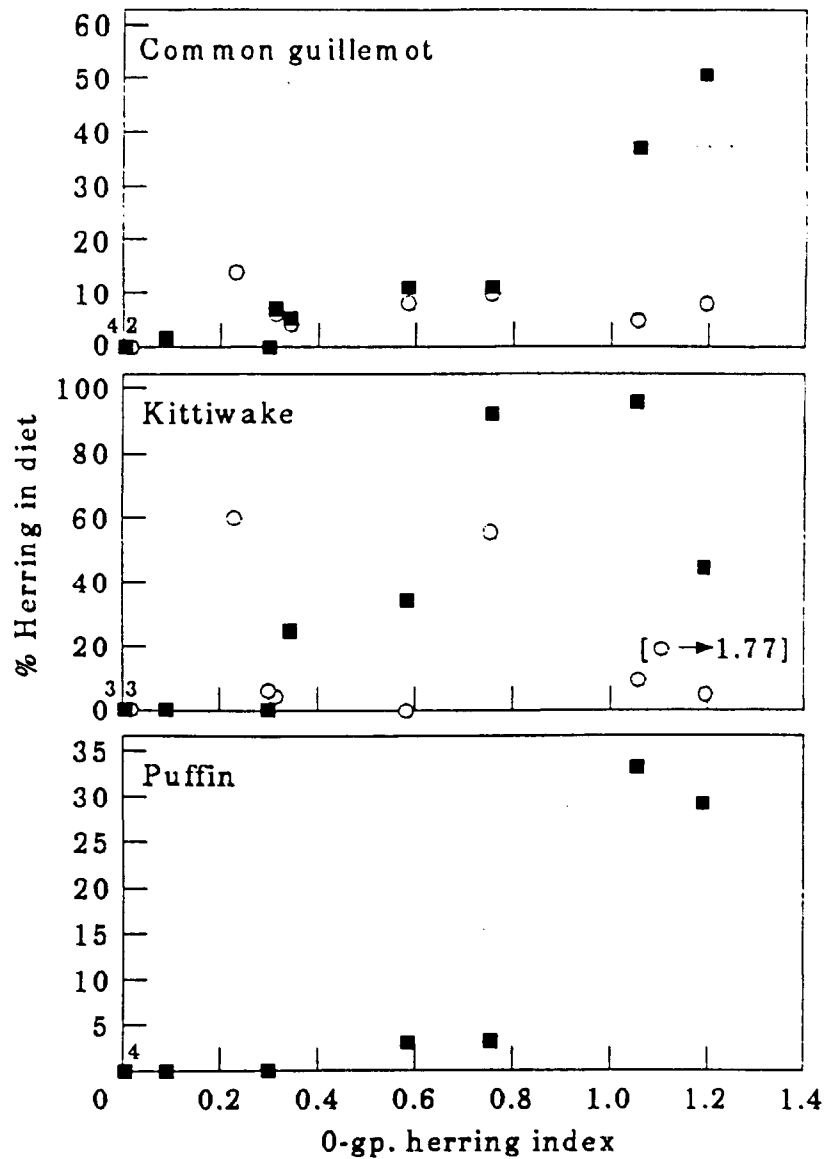


Figure 2.7. The relationship between the percent of herring in guillemot, kittiwake and puffin chick diet on Hornoya (north Norway) (solid squares) and Kharlov (northwest Russia) (open circles), and the log index of 0-group herring abundance in the previous year. Each graph has several points at the origin, not plotted. From Barrett and Krasnov 1996.

3 VARIATION IN PREY TAKEN BY SEABIRDS

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

3.1 Introduction

Seabird diet in the ICES area has been described by studies that have used a variety of techniques; principally these are: analysis of regurgitated samples from living birds or from the contents of regurgitated pellets, observations of prey being carried to chicks and analysis of stomach contents of dead birds killed either deliberately or accidentally, for instance in an oil spill or as by-catch (Duffy and Jackson, 1986). Each technique used has some bias attached; these biases may be large and unquantifiable. Analyses of regurgitated samples or of otolith pellets are likely to miss small prey items with few or no hard parts. Observations of prey brought to colonies may not represent adult diet, and may also be biased by the difficulty of identifying prey from a distance. Killing live birds may be the least biased method, but there may in turn be problems in ensuring that a representative sample of birds is taken. There may also be substantial cultural difficulties in killing birds (e.g. Coleridge, 1854). Analysis of the stomach contents of oil spill victims may be biased by behavioural changes of birds prior to death. It may therefore often be difficult to distinguish real patterns in seabird diet from patterns caused by the study method.

There have been many studies of seabird diet; rather than review these exhaustively for evidence of dietary variation at various spatial and temporal scales, these studies have been gathered into a database which is described below. Examples to describe the various aspects of variation have then been drawn from this database to form this section of the report. We also draw attention to Tasker and Furness (1996) who briefly reviewed dietary variation of seabirds in the North Sea.

3.2 Database description

A relational database was established by members of the working group to facilitate this and future reviews of the diet of seabirds. For all seabirds within the ICES and NAFO areas, dietary information was collected from published (including 'grey literature') and unpublished sources, and coded in a standard format. The first version of this database was launched (SEABDIET 1.0) at this meeting. Each reference is coded with the ICES or NAFO area in which the samples were collected, such that most frequent prey items can be searched from the database using area codes. It contains 838 study reports (diet studies of a given predator at a given time and place) covering 38 species of birds and 518 different prey types. For the present review, a list of 1680 references dealing with seabird diets was consulted. These references are not included in the present document, but are available in digitised format for future consultation. We are aware that the database is still incomplete and it will be enlarged in the future.

3.3 Variation in species and size of seabird prey

3.3.1 General considerations

Several general points should be noted in relation to this review. First, prey abundance may be very different from prey availability. While 'prey populations' may remain constant over time or may be equally abundant in neighbouring areas, spatial differences or temporal changes in prey availability can influence whether or not such prey is taken. Secondly, there has been a tendency to study those organisms that appear in seabird diets, rather than the full range of potential prey items. There is rarely any insight as to why a potential prey item is not taken. Food aversions, other than the complete unsuitability of prey (too large, out of reach), are normally ignored. A third point is that modern technology has challenged a number of common assumptions on foraging performance. Seabirds tagged with satellite and/or radio transmitters or other data loggers can be followed and detailed activity and prey consumption on their feeding trips recorded (Wanless *et al.*, 1985; Wilson *et al.*, 1986; Burger and Wilson, 1988; Wanless *et al.*, 1992; Briggs *et al.*, 1993; Weimerskirch and Robertson, 1994; Falk and Møller, 1995; Georges *et al.*, 1997). These studies, despite the possible negative effects of some devices on foraging performance, have demonstrated that the feeding range of some seabirds is considerably greater than previously assumed, and that the diving depth of birds previously assumed to be surface feeders may be comparatively large. All of these studies indicate that assumptions on the size of foraging niches are usually too limited.

Some studies may assume that a change in prey consumption by a predator population from one study to the next represents a change in the availability of the original prey stock. However, optimal diet models predict that predators will select the most 'profitable' prey in terms of yield per unit handling time of each food type encountered and rank this relative to profitabilities of other types. The implication is that a forager should always accept the most profitable food type and that it should accept successively less profitable types only when encounter rates with higher ranking types fall below critical levels (Hughes, 1993). This would mean that the representation or the absence of a given prey in the diet could have been caused by changes in the availability of another prey species perhaps as a consequence of changes in the local abundance (Tollitt *et al.* 1997). Optimal diet theory predicts that the diet of a species should expand and contract according to the quality and availability of alternative foods.

3.3.1.1 Most frequently recorded food items

Most seabirds, even those with highly specialised foraging methods, appear to feed on a great variety of prey types, though primarily on small pelagic fishes, squids and crustaceans (Montevecchi 1993). However, relatively few prey items are taken as staple foods (represented in at least 50% of the diet samples in a study), while many organisms are only rarely recorded in dietary studies. A survey of the available literature on seabird diets contained in SEABDIET 1.0 found that 13 prey species or groups have each been recorded in at least five studies as 'staple food' in any species of North Atlantic seabird, either in the form of discards from fisheries or as prey taken during more 'natural' feeding (Table 3.1).

Table 3.1 The foods most commonly taken by North Atlantic seabirds (SEABDIET 1.0 database) in no order of priority.

Capelin	Sandeel
Whiting	Polar cod
Offal	Squid
Butterfish	Herring
Sprat	Euphausiids
Norway pout	Gadoid spp.
Gobies	

Sandeels (in particular *A. marinus*), capelin, polar cod, clupeoid fish (herring and sprat), a variety of small crustaceans (mainly Euphausiids and amphipods), and squid (usually unidentified Cephalopods, *Loligo* spp and *Gonatus* spp), in decreasing order of importance, were the most frequently encountered staple foods (at least 10 studies). Staple foods (>50% of the diet by mass) or common prey (26-50%), at any year of study in a given area, are in this study considered 'preferred prey', whereas infrequently taken prey items (2-25%) or rare prey are considered 'alternative prey'.

3.3.1.2 Prey size

The size of fish prey of North Atlantic seabirds generally varies between 100 and 300 mm, although larger as well as smaller prey are also taken (Table 3.2). Not surprisingly, larger seabirds tend to feed on larger prey than smaller species, as clearly demonstrated in the studies of the use of discards by scavenging seabirds in the North Sea (Camphuysen *et al.*, 1995) but also in other multi-species diet studies (e.g. Swennen and Duiven, 1977; Knopf and Kennedy, 1981; Götmark, 1984; Sanger and Ainley, 1988; Camphuysen, 1990, 1996). There are notable exceptions. Gannets, the largest seabird breeding in the North Atlantic, are capable of taking larger prey than most other seabirds (e.g. roundfish of 300-450 mm). They can, however, take small sandeels and capelin; these have been recorded as staple food in Scottish and Newfoundland colonies in response to the sometimes abundant supply of these fish in these areas (Montevecchi and Porter, 1980; Martin, 1989).

Table 3.2 Size range (fish length in mm) of fish prey in some North Atlantic seabirds (SEABDIET 1.0 database)

Species	Min	Max
Red-throated diver	42	- 200
Great northern diver	35	- 500
Fulmar	40	- 330
Gannet	70	- 550
Shag	80	- 160
Great skua	100	- 360
Black-headed gull	35	- 210
Common gull	60	- 210
Lesser black-backed gull	40	- 470
Herring gull	20	- 530
Great black-backed gull	20	- 450
Kittiwake	50	- 360
Arctic tern	30	- 160
Common tern	30	- 160
Guillemot	20	- 270
Brünnich's guillemot	126	- 184
Razorbill	20	- 237
Black guillemot	40	- 220
Puffin	10	- 170

Few studies have described the size selection of prey, partly because the food resource cannot easily be described in terms of size frequencies. With size selection experiments in 'naturally foraging' seabirds being very rare, the results from observations of experimental discarding provide some indications of size selection in relation to prey offered (Camphuysen *et al.*, 1995; Table 3.3).

Table 3.3 Median length (cm) of roundfish and median width of flatfish (0.5 cm) consumed by scavenging seabirds (arranged by body mass) in relation to the size of roundfish and flatfish offered in sessions of experimental discarding in the North Sea (from Camphuysen *et al.*, 1995).

Species	body mass (g)	roundfish		flatfish	
		consumed	offered	consumed	offered
Kittiwake	300-500	15	18	3.5	6.5
Common gull	300-500	14	15		
Fulmar	700-900	16	18	3.5	6.5
Lesser black-backed gull	700-1000	18	18	4.5	6.5
Herring gull	800-1200	18	19	5.0	6.5
Great skua	1300-1800	25	19		
Great black-backed gull	1100-2000	24	18	6.5	6.5
Gannet	2800-3200	25	19	6.5	6.5

These results show firstly that smaller scavenging seabirds under similar conditions select smaller food items than larger seabirds, and secondly that larger seabirds may select considerably larger roundfish than are generally available. It has been shown that the tendency for smaller seabirds to take small prey is at least partly motivated by the presence of other, more powerful scavengers or more dominant conspecifics. An increase in handling time would increase the risk that a fish was lost through kleptoparasitism (Hudson, 1989; Hudson and Furness, 1989). Size selection under natural conditions in foraging seabirds is an aspect which deserves more attention in future studies.

3.3.2 Annual variation

There are few long-term studies of seabird diets. Examples of dietary change between years are more numerous and the following examples illustrate the scale of change which has been observed.

Large changes in staple foods from one prey species/group to another are not uncommon in seabird populations. Changes in diet composition may be sudden or more gradual. Sudden changes are usually more easily linked with a drastic change in foraging conditions or prey abundance than are gradual changes. An excellent example of a combination of rather sudden and gradual shifts is provided by diet studies of great skuas in Shetland (Furness, 1997). In the late 1970s, when the breeding population of great skuas on Foula reached its highest level ever, the diet of great skuas was dominated by sandeel (Table 3.4). After 1979, sandeels were suddenly considerably less important and over 50% of the samples studied comprised a mixture of whitefish, most probably obtained as discards. A shift from sandeel towards whitefish discards had been observed also in 1974 and 1975. Since 1983, seabird predation by great skuas has increased significantly. Interestingly, when sandeel gradually returned in the diet of great skuas in the 1990s, and while discards remained in the diet, the habit of bird predation persisted.

Table 3.4 Representation of sandeel *A. marinus*, whitefish discards, birds and other prey (% frequency of occurrence in all samples studied per year) in the diet of great skuas on Foula (Shetland Islands), simplified after Furness (1997)

Year	sandeel	discards	birds	other
1973	71	27	2	0
1974	24	71	5	0
1975	21	69	6	4
1976	72	26	2	0
1977	59	35	4	2
1978	64	35	1	0
1979	41	54	3	2
1980	17	74	6	3
1981	18	77	4	1
1982	13	80	3	4
1983	9	70	17	4
1984	0	74	23	3
1985	1	72	20	7
1986	0	81	14	5
1987	9	77	10	4
1988	1	72	24	3
1989	2	67	29	2
1990	1	38	38	23
1992	15	66	25	7
1993	31	87	11	10
1994	19	81	13	34
1995	73	63	3	24
1996	55	73	42	23

The collapse of sandeel stocks around Shetland in the 1980s provided a number of examples of annual variation in seabird diet, involving several species of seabirds in a single area. Surface feeding birds, such as arctic terns and kittiwakes, experienced great difficulty in obtaining sufficient prey, and breeding failures or abandoned breeding attempts were widespread in the archipelago (Monaghan *et al.*, 1989; Hamer *et al.* 1991, 1993). Other seabirds, such as the gannet, showed marked shifts in their diets in response to this crash towards a wider prey spectrum that included much herring and gadoids (Martin 1989). Species, such as the guillemot and shag, which dive to pursue fish underwater, were hardly affected by the collapse and continued feeding chicks with sandeels and to reproduce with reasonably high fledging rates.

In northern Norway, changes in the stocks of capelin in the 1970s and 1980s were tracked by changes in breeding performance of seabirds in the area (Wright *et al.* 1996). In 1986, when the capelin stock was at its lowest, several species of seabird produced very few young. Massive declines in both the number of breeding guillemots at northern Norwegian colonies and of guillemots on their wintering grounds were recorded. Since 1989, capelin stocks have increased and bird numbers have started to recover. In this instance, there was no alternative in the late 1980s to capelin in the diet, so that switching was not possible. Since then, herring stocks have increased in the area, and this species has reappeared in bird diets. This may be a reversion to the situation in the 1930s and 1940s when Belopol'skii (1957) recorded herring as important constituent of the summer diet of many seabirds breeding in the region.

3.3.3 Seasonal variation

Much of the dietary work carried out on seabirds has been from or around colonies in the breeding season. Even within that window of courtship, incubation, raising chicks and fledging of young, rather radical shifts in the diet (both of adults and in the prey delivered to the chicks) have been demonstrated. For example, the gradually altering energetic demands of the growing chick(s) has to be met with by the provisioning adults (Harris and Wanless, 1986; Anker-Nilsson and Nygård, 1989; Annett and Pierotti, 1989; Van Beers and Habraken, 1993; Hill and Hamer, 1994; Anker-Nilsson and Øyan, 1995). So, even in the absence of obvious changes in food resources, there may be differences in the exploitation of their prey by seabirds, which have to meet constantly changing energy and nutrient requirements during breeding. In the post-breeding season, most seabirds become more mobile, because the constraints imposed by central place foraging are no longer in effect. In winter, the energetic requirements may be elevated due to harsh environmental conditions, such as severe storms or very cold weather. Even from a purely energetic point of view, seasonal changes in diet and food preferences are likely to occur. Since many fish are known to show rather different distribution and activity patterns in the course of a year (e.g. spawning, buried phases in sand, migration), dietary changes in seabirds will probably be even more obvious between the seasons.

Elliot *et al.* (1990) demonstrated substantial changes in the diet of Brünnich's guillemots, such as shifts from predominantly fish in birds in the autumn to crustaceans in birds wintering off Newfoundland and Labrador (Table 3.5). Blake *et al.* (1985) produced similar information from various locations off the Scottish east coast, showing shifts in the relative importance of sandeels, clupeoid fish and gadoids in guillemot diets in the post- (August-October) and pre-breeding seasons (March-April). Camphuysen (1996) summarised published information on guillemot diets outside the breeding season in the North Sea and demonstrated consistent features, such as a greater importance of sandeels in late spring and early autumn, substantial use of prey that were available for only a short time (small scad in the southern North Sea), and a greater importance of clupeoids and gadoids in winter. Future versions of the diet database, SEABDIET, will facilitate a more detailed summary of seasonal changes in diets, for a considerably larger number of species. To achieve that, a substantial amount of so far unpublished data will need to be computer coded.

Table 3.5 Seasonal changes in diets of Brünnich's guillemots in Labrador and Newfoundland from birds shot at sea (% frequency in total number of stomachs examined per season per region), after Elliot *et al.* (1990).

Study area	Prey (genus/group)	Nov	Dec	Jan	Feb	Mar
E Newfoundland	Decapoda	0		3		1
	Euphausiacea		1	100	100	85
	Gammarus		5	1		1
	Hyperiidæ	3	6	3	22	31
	Thysanoessa			32	92	96
	Boreogadus	57	37	3	4	9
	Gadus	9	10	29	3	10

Study area	Prey (genus/group)	Nov	Dec	Jan	Feb	Mar
Labrador	Mallotus	18	87	3		
	Mollusca				1	2
	Nereis					1
	Cephalopoda	40	25			
	Decapoda	10	3			
	Euphausiacea	5	14			
	Gammarus		11			
	Hyperiidæ	13	7			
	Thysanoessa	6				
	Boreogadus	85	66			
NE Newfoundland	Gadus	26	3			
	Mallotus	65	29			
	Mollusca		3			
	Cephalopoda	13	7			
	Decapoda	2				
	Euphausiacea			4		
	Hyperiidæ	27				
	Boreogadus	51		88		
	Gadus	18				
	Mallotus	54				
S Newfoundland	Cephalopoda	74		4		
	Decapoda				3	5
	Euphausiacea				69	80
	Gammarus				1	
	Hyperiidæ				9	55
	Parathemisto				82	
	Thysanoessa				1	
	Boreogadus				12	5
	Gadus				9	5
	Mallotus				43	10
SE Newfoundland	Nereis				1	
	Decapoda				7	
	Euphausiacea				80	92
	Gammarus					2
	Hyperiidæ				7	26
	Boreogadus				16	33
	Gadus					5
	Mallotus				8	
	Mollusca				7	
	Cephalopoda				5	

3.3.4 Spatial variation

Spatial variation in seabird diets is particularly interesting on the small scale, as it indicates that local populations use different, but perhaps overlapping, food resources. A demonstration of regional variation in seabird diets was provided by Lilliendahl and Solmundsson (1997), who described summer food consumption of six seabirds in Iceland (Table 3.6). For razorbill, guillemot and Brünnich's guillemot, sandeels predominated in the diet (>50% in percent wet prey mass) to the south, west and east of Iceland, while capelin was their main prey (generally >90% of wet prey mass) in the north-west and north-east. Euphausiids were of significance mainly for Brünnich's guillemots, particularly to the east and north-west. Capelin formed nearly 100% of the prey of kittiwakes to the north, while sandeels predominated in the south and mixtures (capelin/sandeel and capelin/sandeel/Euphausiids and other prey) in respectively the west and east sectors. Fulmars have a more mixed diet in all sectors, although the overall trend of capelin consumption in the northern sectors and sandeels representing a significant part of the diet in the south and west can be seen also in this species. Much of this variation in seabird diet can be linked to oceanographic differences between regions.

Table 3.6 Summer prey (% wet mass, rounded figures to nearest 5%) of seabirds feeding off Iceland, as an example of spatial variation in diets. Shown are prey fractions representing at least 5% of wet mass.

Species/prey	sector S	sector W	sector NW	sector NE	sector E
Razorbill					
capelin		10	95	95	
sandeel	95	80		5	100
Euphausiids		5	5		
Guillemot					
capelin		30	90	90	5
sandeel	90	65			90
Euphausiids		5	5	5	
other	10				5
Brunnich's guillemot					
capelin		10	70	100	
sandeel		75			50
Euphausiids		5	25		50
other		10	5		
Puffin					
capelin		30	25	90	
sandeel	100	65	20		55
Euphausiids		5	10	5	40
other			45	5	5
Kittiwake					
capelin	15	55	95	100	40
sandeel	80	45			35
Euphausiids	5				10
other			5		15
Fulmar					
capelin		5	25	15	45
sandeel	60	40	5	10	
Euphausiids	5				10
other	35	55	70	75	45

Because the birds studied by Lilliendahl and Solmundsson (1997) were shot at sea (presumably at or near feeding locations) rather than at colonies, these results show the use of a common resource by predators with different foraging capabilities and prey preferences. So, while capelin is virtually absent from the diet of the three auk species east of Iceland, both fulmars and kittiwakes still consumed considerable amounts of these fish. As the latter are surface foragers and the former are deep diving seabirds (but capable of feeding near the surface as well as over 100m deep), we might conclude that these auks prefer sandeel over capelin as prey in these waters.

Camphuysen *et al.* (1995) experimentally discarded fish from survey vessels in seven subregions in the North Sea and Skagerrak in four seasons. There was considerable variation in the selection of discarded items by different species of scavengers in different areas through the year in relation to the type and size of discards. Spatial variation in consumption rates (% of the discarded fraction of the fish caught actually taken by seabirds) showed that competition for fishery waste is considerably more intense in some areas and less in others. This variation could not always be explained by the relative abundance of scavenging seabirds in relation to the number of fishing vessels in those areas. Specific dietary preferences of species of birds meant that some species did not occur at fishing vessels in some seasons because other food resources were exploited instead. For example, kittiwakes were abundant and widespread all year round, but were most common scavenging around fishing vessels only in winter and autumn. The reverse was true for the even more abundant fulmar, which obtained the greater part of discarded fish only in summer and spring (see also Camphuysen and Garthe, 1997). In brief, these studies demonstrated a mixture of spatial and seasonal trends in discard consumption by different seabirds, which was at least partly related to changes in dietary preferences or changing feeding opportunities in these birds.

3.4 Evidence for selection related to prey body condition

The quality of prey varies both between species and within species.

3.4.1 Differential prey selection between species

In an analysis of dietary selection, Harris and Hislop (1978) described the biomass and quality of various prey species fed to young puffins at ten colonies around Scotland during six years in the early 1970s. This dietary information was compared with the "availability" of these prey as described in experimental mid-water trawl catches made in areas off north and east Scotland. There are obvious methodological problems involved that are acknowledged by the authors. In terms of biomass, sandeels and sprats predominated in the diets of chicks at most colonies in most years. Rocklings and whiting formed a more important part of the diet at western rather than eastern Scottish colonies. In calorific terms, large sprat (>100mm long) had a considerably higher energy density (10.9 kJ/g wet weight) than any other prey species and were twice the value of saithe and whiting (5.1 kJ/g and 4.05 kJ/g respectively). Between these limits, in decreasing order, came rockling, small sprats (43-93mm long), sandeels and small larval forms. The percentage fat increases significantly in both sprat and sandeel with the length of fish (Love, 1970). The diet of these puffin chicks, when looked at in calorific terms, accentuates the importance of sprat and devalues the importance of whiting.

There was a broad similarity between the composition of trawl catches and puffin chick diets, with some exceptions. Sandeels were one hundred times as numerous as sprats in the trawl catches, but only three times as common in puffin chick loads, suggesting that puffins differentially select sprat. Rockling were uncommon in the trawl, but this may have been due to the young of this species living near the surface, above the level at which the trawl was fishing. Conversely, Norway pout and long rough dab were common in the trawl, but only recorded once each in puffin diets.

A later study, around the Isle of May off eastern Scotland, found that as the North Sea sprat stock declined, these were replaced in the diet by herring, whose stock was increasing (Hislop and Harris, 1985).

3.4.2 Differential selection of prey within species

Several authors have suggested that seabirds may differentially select individuals of the same species with higher calorific values. The most obvious selection would be for different sized individuals of the same species (e.g. Harris and Hislop, 1978). Wright and Bailey (1993) showed that diving birds tended to bring in a higher proportion of older age-classes sandeels than would be expected if they were selecting fish randomly. Becker (unpubl.) examined the changes in size classes of fish brought to chicks by common terns at Wilhelmshaven. There was a clear and significant difference in size of fish fed to chicks of different ages (Table 3.7) (χ^2 for herring/sprat = 78.1, $p < 0.001$; χ^2 for smelt = 93.3, $p < 0.001$).

Table 3.7 Proportions (%) of size classes (multiples of bill length) of fish fed to different ages of common tern chicks at Wilhelmshaven in 1995 (Becker, unpubl.)

Age	Smelt			Sprat/herring		
	0-7 days	8-14 days	>14 days	0-7 days	8-14 days	>14 days
Fish size class						
1	19.7	2.7	2.9	37.7	15.3	3.6
2	62.5	48.1	36.5	56.9	60.2	60.8
>2	17.8	49.2	60.6	5.4	24.4	35.5
Sample size	152	187	170	130	98	166

It may also be that seabirds prey selectively on ripe, pre-spawning fish rather than spent or non-spawning fish of the same size. Furness and Barrett (1985) found that guillemots at a colony in northern Norway took predominantly gravid female capelin, containing 6.6% lipid and 15.2% protein, which compared with spent fish containing only 2.5% lipid and 14% protein. These authors could not demonstrate whether guillemots prey selectively on the young ripe late-spawning capelin in the area or whether the behaviour of these capelin makes them more available to the birds. Montevecchi and Myers (1996) and Montevecchi (in prep.) also indicate some prey selection by guillemots on Funk Island, Newfoundland. Almost all capelin delivered to chicks between 1977 and 1994 were gravid female, providing higher energy densities than found with male or spent female capelin (Montevecchi and Piatt 1984). In contrast, Montevecchi and Myers (1996) found that gannets landed about equal proportions of male and female capelin. Guillemots hunt by pursuit diving underwater, so may have a greater opportunity to assess the state of individual fish than would the plunge-diving gannet. In addition, greater selectivity is to be expected among single prey loading species (e.g. guillemots or terns) than among multiple prey loading species (e.g. gannets, puffins).

3.5 Differences between adult and chick diet

A simultaneous study of diet as assessed by three methods was carried out by Harris and Wanless (1993) on shags on the Isle of May in the Firth of Forth during the chick-rearing period. Regurgitated samples were collected from chicks, stomach contents of adults were sampled by flushing with water and mucous pellets (which contain hard parts of prey) were retrieved from a roost site. The roost site samples (mostly non- and failed breeders) were from a wider spectrum of prey than the chicks. Stomach contents of adults returning to feed chicks were very similar to those regurgitated by the chicks (i.e. almost entirely sandeels), however Wanless *et al.* (1993) concluded that adults ate a wide spectrum of fish from other fish families and probably digested these before returning to the colony. Fish in these families had low calorific densities compared to sandeels indicating that adults transported highest calorific items for their chicks.

Courtship feeding of females by their mates is a feature of the biology of several seabirds. P.H. Becker (unpublished) contrasted the sizes of fish fed to females and to chicks (Table 3.8). In general females were fed on a significantly wider size range of fish than were chicks (χ^2 for herring/sprat = 80.1, $p < 0.001$; χ^2 for smelt = 70.2, $p < 0.001$)

Table 3.8 Proportions (%) of size classes (multiples of bill length) of fish fed to female and chick common terns at Wilhelmshaven in 1995 (Becker, unpubl.)

Fish size class	Smelt		Sprat/herring	
	Females	Chicks	Females	Chicks
1	19.6	6.9	20.7	17.6
2	32.6	43.1	31.1	56.9
3	34.6	41.3	32.4	23.1
>3	13.2	8.7	15.8	2.5
Sample size	613	813	241	615

3.6 Discussion

From the examples of annual, seasonal and spatial variation in seabird diets provided in this chapter it may seem that we have a reasonable overview of its variability in most common species of seabirds in the ICES area. In fact, this is not the case. Of 767 studies in which the study season was specified, 64% were conducted during the breeding season or in summer. Only 8% of all studies were conducted in the pre-breeding season, 12% during post-breeding (early autumn) and 15% in winter. Logistic problems have prevented large scale studies of the diets of most pelagic seabirds outside the breeding season, simply because most birds are 'out of reach' (away from land). From the examples given earlier and from many published papers on variability in seabird diets, it should be emphasised that the results obtained in one area, in one season, in any one year are not necessarily valid with that same predator species in other circumstances. However, on the larger scale it will soon be possible to come up with some generalisations. There is no need to become side-tracked as a result of the immense variation in prey, since most items form only a very small part of the diet. Rather few species/types are 'preferred' prey for seabirds while very many should be labelled 'occasional prey'. It is very important, however, that additional information is collected on seabird prey preferences, particularly outside the breeding season and away from the colonies.

A second point which should be highlighted, particularly from the fisheries point of view, is that very few studies have tried to address the aspect of prey selection from a known resource of potential prey. There are very obvious methodological problems involved with the assessment of food resources (a function of prey stock size, suitability and availability) for piscivorous seabirds, but in the absence of any insight it remains speculative why certain seabirds rely on sandeels in one year and perhaps clupeoid fish in the next. Size selection (e.g. Swennen & Duiven 1977, 1991, Camphuysen *et al.* 1995), differential selection of prey of a certain 'quality' or calorific value (e.g. Harris & Hislop 1978, Wright & Bailey 1993) and prey choice or dietary shifts in relation to the prey stock (e.g. Doornbos 1979, Vader *et al.* 1990) are very important aspects which all deserve a lot more attention in future studies.

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4 EVIDENCE FOR DECADEAL SCALE VARIATIONS IN SEABIRD POPULATION ECOLOGY AND LINKS WITH THE NORTH ATLANTIC OSCILLATION

4.1 Introduction

The North Atlantic Oscillation (NAO) has an influence not only on the physical oceanography of the North Atlantic (Levitus et al. 1994, Hurrell 1995), but also on zooplankton (Fromentin and Planque 1996) and fish (Friedland et al. 1993). Thus an influence of the NAO on higher trophic levels of the North Atlantic and North Sea may be anticipated. Seabirds characteristically have high adult survival rates and deferred maturity, coupled with low reproductive rates. Thus we may expect some parameters of the ecology of seabird populations to be buffered against such environmental fluctuations. In particular, we can predict that breeding numbers may not respond to the NAO or may show a long time-lag in response, whereas breeding success might correlate with the NAO as a consequence of its influence on preferred prey populations of the seabirds.

Studies of seabird populations in the California Current (Ainley et al. 1995) demonstrated that the El Nino-Southern Oscillation (ENSO) caused spectacular changes in food supply to seabirds, leading to correlations between seabird breeding parameters and variation in the Southern Oscillation and/or the Aleutian low pressure system, both of which affect sea-surface temperature and thermocline depth. Some seabird species showed stronger links than others with these physical parameters. Cormorants and gulls showed stronger variations in breeding success than did common guillemots, as might be anticipated given the smaller clutch size and the greater volume of sea used by foraging common guillemots.

Montevicchi and Myers (1997) attributed a century-long increase in northern gannet numbers in Newfoundland with warming surface water conditions and increased availability of mackerel. A major dietary change during the 1990s to colder-water conditions in the north-west Atlantic led to a change in prey stocks from warm-water pelagic fish and squid to cold-water fish. In this report we have concentrated our efforts on searching for any evidence that the NAO influences numbers or breeding ecology of seabirds in the north-east Atlantic. Our analysis is constrained by the fact that, while there are data sets for seabird breeding numbers over many decades, data on breeding success or diet at particular sites rarely provide more than a run of 10 years, and most sets start during the 1970s or 1980s.

4.2 Materials and methods

Four data-sets, or extracts therefrom, were used in bivariate correlation analyses to detect possible associations between the NAO and aspects of seabird breeding ecology.

The UK Seabird Monitoring Programme (Thompson *et al.* 1996) monitors seabird populations at several colonies around the coasts of Great Britain and Ireland. In addition to breeding numbers and overall success, various detailed aspects of breeding performance are also measured, mainly at four key sites. Data on breeding numbers and breeding success of several species from a selection of years (between 1986 and 1996) and colonies were used in the analyses.

The second data-set on bird populations used includes breeding numbers of various species nesting along the coast of the German Wadden Sea and Helgoland. This is a long term data-set, which, for some species dates from 1950 (Becker and Erdelen 1987, Halterlein and Sudbeck 1997, and unpublished data; unpublished data of Becker, Verein Jordsand and Institut fur Vogelforschung). The third seabird data-set used in the analyses was numbers of breeding pairs and breeding success of common terns between 1981 and 1997 on Minsener Oldeoog, an island in the German Wadden Sea (Becker 1998).

Data on the NAO were slightly amended from Hurrell (1995). The winter (December through March) NAO index was used and is based on the difference of normalised sea level pressures (SLP) between Lisbon, Portugal and

Stykkisholmur, Iceland. The SLP anomalies at each station were normalised by division of each seasonal pressure by the long term (1864-1983) standard deviation.

4.3 Results

No significant correlations were found between the NAO index and breeding population sizes or breeding success of various species breeding at several UK seabird colonies (Tables 4.1 and 4.2). In addition, correlations between breeding success of kittiwakes for seven or more years between 1986 and 1996 at 49 colonies in Britain and Ireland and the NAO gave 31 negative and 18 positive correlations. Four were significant at the 5% level, two of these were positive and two were negative correlations. We conclude from this result that there is no reason to believe that the factors that the NAO index represents affects kittiwake breeding success.

No significant relationship was found between the NAO index and breeding numbers of cormorant, Arctic tern or common tern in the German Wadden Sea as a whole. However, there were significant associations between the NAO and numbers of other breeding seabirds here (Table 4.3). In some cases, the relationship was very strong.

No correlation was detected between either breeding numbers or breeding success of common terns on Minsener Oldeoog in the German Wadden Sea and the NAO (Table 4.4).

Table 4.1 Relationships between seabird breeding numbers at various UK seabird colonies and the NAO Index. Pearson correlation coefficients, r , are presented with associated p values. All correlations are non-significant.

Species	Sites	Dates	r	p
Guillemot	Skomer, Isle of May, Fair Isle	1986-96	.051	.883
Razorbill	Skomer, Isle of May	1986-96	.165	.629
Puffin	Isle of May	1983-1993	.142	.738

Table 4.2 Relationships between seabird breeding success at various UK seabird colonies and the NAO Index. Pearson correlation coefficients, r , are presented with associated p values. All correlations are non-significant.

Species	Sites	Dates	r	p
Fulmar	Fair Isle, Shetland	1986-96	-.058	.866
Fulmar	Isle of May, SE Scotland	1986-96	.088	.796
Fulmar	Farne Islands, NE England	1986-96	-.258	.445
Fulmar	Troswick Ness, Shetland	1986-96	.351	.290
Gannet	Fair Isle, Shetland	1986-96	.415	.204
Gannet	Noss, Shetland	1986-96	-.169	.620
Gannet	Bempton, NE England	1986-96 (excluding 1985)	-.087	.812
Shag	Canna, NW Scotland	1986-96	-.239	.480
Shag	Fair Isle, Shetland	1986-96	.141	.678
Shag	Isle of May, SE Scotland	1986-96	-.262	.437

Species	Sites	Dates	r	p
Kittiwake	St. Kilda, NW Scotland	1986-96 (excluding 1995)	-.397	.256
Kittiwake	Isle of May, SE Scotland	1986-96 (excluding 1987)	.076	.834
Guillemot	Fair Isle, Shetland	1987-96	-.237	.510
Guillemot	Isle of May, SE Scotland	1986-96	.082	.810
Razorbill	Isle of May, SE Scotland	1986-96	.369	.265

Table 4.3 Relationships between seabird breeding numbers on the German Wadden Sea coast and the NAO Index. Pearson correlation coefficients, *r*, are presented with associated *p* values. An asterisk (*) indicates statistical significance.

Species	Dates	r	p
Fulmar	most years, 1953-96	.371	.022 *
Cormorant	1971-96	.183	.370
Herring gull	most years, 1950-93	.456	.004 *
Lesser black-backed gull	most years, 1950-93	.480	.002 *
Common gull	most years, 1950-93	.566	.000 *
Kittiwake	most years, 1953-96	.423	.008 *
Black-headed gull	most years, 1950-93	.565	.000 *
Sandwich tern	most years, 1909-96	.264	.015 *
Arctic tern	various, 1982-96	.316	.317
Common tern	various, 1982-96	.485	.156
Arctic/common tern	most years, 1950-93	.145	.385
Guillemot	most years, 1953-96	.536	.001 *
Razorbill	most years, 1953-96	.414	.010 *

Table 4.4 Relationships between common tern breeding numbers and success on Minsener Oldeog, German Wadden Sea, and the NAO Index between 1981 and 1997. Pearson correlation coefficients, *r*, are presented with associated *p* values. Both correlations are non-significant.

Measure	r	p
No. Breeding pairs	.233	.368
Chicks fledged per pair	.252	.329

4.4 Discussion

No correlations were found between the breeding success of seabirds and the NAO index during the last decade. As expected, no significant relationships were found between numbers of seabirds breeding around the UK. Significant correlations were detected, however, between breeding numbers of fulmar, herring gull, common gull, lesser black-backed gull, black-headed gull, kittiwake, Sandwich tern, razorbill and guillemot on the German coast, and the winter NAO index.

That so many significant correlations should be found between breeding numbers and the NAO when no relationship was suspected, is puzzling. Such a finding would be expected if high correlations also existed among population sizes of these species. Indeed, such high, positive correlations do prevail among population levels of all these species (all pairwise Pearson correlation coefficients, $r > .755$, $p < .001$). This indicates that a common factor may account for the observed results. Such a common factor, of course, could be the influence of the NAO on food resources. However, the feeding requirements and general feeding ecology of those species involved is so diverse as to render this unlikely. Furthermore, if the NAO were to contribute to processes underlying seabird population patterns, then seabird life history parameters would lead to the expectation that there would be a time lag in the manifestation of NAO effects. An identical effect of the NAO index is unlikely in the case of the black-headed gull, as unlike the other species considered, the black-headed gull is not closely linked with fish foods gathered at sea, but feeds mainly on *Nereis* in the Wadden Sea, and additionally inland (Gorke 1990).

If the common cause of recent seabird population increases (the Dutch and German Wadden Sea data indicate that these date from the 1970's) is not the NAO then a more local explanation need be sought. It is likely that the general, sustained increase is due to recovery of these populations following a major pollution incident in the Dutch and German parts of the Wadden Sea in the late 1960's when large amounts of organochlorine pesticides contaminated these waters from the Rhine river (Becker 1991). The immediate effect of this was widespread mortality of seabirds in the Wadden Sea resulting in depressed population sizes, from which there has been a gradual increase in breeding seabirds. This population recovery has coincided with an increase in strength of the NAO since the 1970's but there remains no evidence of a causal link between the two.

4.5 References

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5 RESPONSES TO TERMS OF REFERENCE D-F

5.1 d) 'Publication of Working Group Report':

After discussion, the WG suggest that parts of this report (Chapters 2-4) should be put together with Chapters 2-4 and 6 from ICES CM 1997/L:3 (Report of the Working Group on Seabird Ecology Glasgow November 1996) which have already been reviewed by the Oceanography Committee and the Marine Habitat Committee, and a resolution for their publication in the *ICES Cooperative Research Report* series was adopted at the 1997 Annual Science Conference 85th Statutory Meeting. We agreed that the individual Chapters should be given author attributions to indicate which WG members were responsible for particular Chapters.

5.2 e) 'Future Work Programme':

The WGSE has had little connection with Oceanography. Indeed, we have not had any Oceanographers present at any of the Working Group meetings. While there are no doubt aspects of Seabird Ecology that we could consider alongside experts in Oceanography, and such interdisciplinary interactions would be greatly welcomed by WGSE and could be productive, the terms of reference set for the Working Group have predominantly involved issues related to fish consumption by seabirds and possible impacts of fisheries on seabird populations. These topics would seem to fall more closely within the area of scope of the Living Resources Committee and the Marine Habitat Committee. Possibly the WGSE would fit best under Marine Habitat Committee. Nevertheless, as a Working Group we are very happy to be under the umbrella of the Oceanography Committee, and we do not perceive a need to change the arrangement from our perspective. What we do consider important is that WGSE should remain as a single entity and should not be divided as has happened with marine mammals.

We have suggested bridging between Working Groups by holding a mini Symposium on 'Processes influencing trophic transfer to top predators' (including seabirds, marine mammals and predatory fish). The closest links and areas of common interest between WGSE and others are likely to be with WGECCO, WGMMPD, WGMMA, WGEAMS. WGSE has not so far included pollutant studies in terms of reference but notes that work on pollutants in seabirds is extensive. Another obvious area for development of work within WGSE is on issues where there are current concerns over potential conflicts between fisheries and seabird conservation. Aspects of these have been included in the Recommendations listed below.

5.3 f) 'Liaison with MAWG':

We will provide this report to the Chair of MAWG and offer to assist as best we can with provision of relevant seabird ecology data or interpretation, relevant to MSVPA. We will try to develop inputs useful to MAWG through work as recommended in 6.2.i. below.

6 RECOMMENDATIONS

6.1 The Working Group makes the following proposals:

1. That parts of this report (Chapters 2-4) should be put together with Chapters 2-4 and 6 from ICES CM 1997/L:3 (Report of the Working Group on Seabird Ecology Glasgow November 1996) which have already been reviewed and approved by the Chairmen of the Oceanography Committee and the Marine Habitat Committee, and a resolution for their publication in the *ICES Cooperative Research Report* series was adopted at the 1997 Annual Science Conference 85th Statutory Meeting. Individual Chapters should be given author attributions to indicate which WG members were responsible for particular Chapters.
2. That the Working Group on Seabird Ecology should meet at ICES Headquarters for five days in April 1999 to undertake the following work:
 - i) To assess food consumption by seabirds in the ICES area, focusing primarily on areas other than the North Sea;

Justification: The group modelled food consumption by seabirds in the North Sea at their first meeting. This information has been used subsequently by a variety of groups including the North Sea Ministerial meeting and MAWG. Information on seabird distribution and diet has continued to be gathered since the model was constructed, and information has been collected in waters to the west of the North Sea and in the Baltic. Information may be available around Iceland and in the western North Atlantic. These systems outside the North Sea have different avifaunas to those in the North Sea and are therefore likely to be characterised by different consumption patterns. This information should be of interest to other ICES working groups, and potentially to OSPAR and HELCOM.

ii) review the data available for describing interannual to interdecadal variation in seabird distribution at sea, in connection to both their reproductive performance and winter survival and in relation to variation in diet.

Justification: various sets of data suggest that seabird distributions, mortality patterns and diet vary considerably from year to year, or longer term, yet models of prey consumption by seabirds use data averaged across years. There is a need to examine the variability in these patterns.

iii) interessionally to continue to add to the database of seabird diet composition;

Justification: this database was established prior to the March 1998 WGSE meeting, but is incomplete. It provides a useful and detailed summary of data on seabird diets by species and size of prey, by season and location. It is extremely useful as a source for data for many tasks by the WGSE.

iv) compare seabird community structure in east and in west Atlantic, in relation to differences in the fish stocks and fisheries practices of these regions;

Justification: The seabird communities in the east and west Atlantic comprise essentially the same species, but differ considerably in relative abundance. These differences may provide insights into the influences of fish stocks and fisheries on seabird community structure by comparing and contrasting the fish stocks, fisheries practices and seabird communities between the regions.

v) review the usefulness of seabirds as monitors of pollutants in marine ecosystems;

Justification: much research on pollutants in seabirds has been published, but little effort has been made to evaluate the extent to which studies with seabirds may add to the understanding of pollutant dynamics in marine food chains as assessed from studies of fish and marine invertebrate animals. Detailed knowledge of seabird ecology, together with the ease of sampling seabirds (especially eggs, feathers and blood), and the propensity of seabirds to integrate pollutant signals over convenient spatial and temporal scales may argue for their use as complementary to sampling of seawater, invertebrates, or other marine vertebrates.

6.2 Chairmanship

Due to other commitments the Chairman informed WGSE that it was no longer possible for him to continue as Chairman. This decision was accepted with reluctance by the group who unanimously nominated Dr Mark Tasker pending the approval of the Oceanography Committee.

7 ANNEXES

7.1 7.1 Names and Addresses of Participants

Table 7.1 Address list for participants in the Copenhagen meeting of the ICES Working Group on Seabird Ecology, 30 March - 1 April 1998.

Name	Address	Telephone	Facsimile	E-mail
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7.2 Scientific names of seabird and fish species mentioned in the text

a) SEABIRDS

Common name	Scientific name
red throated diver	<i>Gavia stellata</i>
great northern diver	<i>Gavia immer</i>
fulmar	<i>Fulmarus glacialis</i>
cormorant	<i>Phalacrocorax carbo</i>
double crested cormorant	<i>Phalacrocorax auritus</i>
shag	<i>Phalacrocorax aristotelis</i>
gannet	<i>Morus bassanus</i>
great skua	<i>Catharacta skua</i>
Arctic skua	<i>Stercorarius parasiticus</i>
black-headed gull	<i>Larus ridibundus</i>
common gull	<i>Larus canus</i>
herring gull	<i>Larus argentatus</i>
lesser black-backed gull	<i>Larus fuscus</i>
great black-backed gull	<i>Larus marinus</i>
kittiwake	<i>Rissa tridactyla</i>
common tern	<i>Sterna hirundo</i>
Arctic tern	<i>Sterna paradisaea</i>
Sandwich tern	<i>Sterna sandvicensis</i>
common guillemot	<i>Uria aalge</i>
Brunnich's guillemot	<i>Uria lomvia</i>
razorbill	<i>Alca torda</i>
black guillemot	<i>Cepphus grylle</i>
puffin	<i>Fratercula arctica</i>

b) FISH

Common name	Scientific name
sprat	<i>Sprattus sprattus</i>
herring	<i>Clupea harengus</i>
capelin	<i>Mallotus villosus</i>
smelt	<i>Osmerus eperlanus</i>
whiting	<i>Merlangius merlangus</i>
Norway pout	<i>Trisopterus esmarkii</i>
saithe	<i>Pollachius virens</i>
cod	<i>Gadus morhua</i>
haddock	<i>Melanogrammus aeglefinus</i>
polar cod	<i>Boreogadus saida</i>
rockling spp.	often <i>Ciliata mustela</i>
scad	<i>Trachurus trachurus</i>
mackerel	<i>Scomber scombrus</i>
sandeel	<i>Ammodytes marinus</i>
butterfish	<i>Pholis gunnellus</i>
dab	<i>Limanda limanda</i>
long rough dab	<i>Hippoglossoides platessoides</i>