

**REPORT OF THE  
WORKING GROUP ON SEABIRD ECOLOGY**

**Wilhelmshaven, Germany  
20–23 March 2000**

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## **1 INTRODUCTION**

### **1.1 Participation**

The following nominated members of the Working Group participated in the meeting (see Annex for addresses):

|                     |             |
|---------------------|-------------|
| Tycho Anker-Nilssen | Norway      |
| Rob Barrett         | Norway      |
| Peter H. Becker     | Germany     |
| Kees Camphuysen     | Netherlands |
| Gilles Chapdelaine  | Canada      |
| Gail Davoren        | Canada      |
| Bob Furness         | UK          |
| Stefan Garthe       | Germany     |
| Ommo Hüppop         | Germany     |
| Bill Montevecchi    | Canada      |
| Mark Tasker (Chair) | UK          |

### **1.2 Terms of reference**

At the 86<sup>th</sup> Statutory meeting, it was agreed that the Working Group on Seabird Ecology should produce a Report and that the working Group should meet in Wilhelmshaven, Germany from 20–23 March 2000 (4 days) (C.Res. 1999/2C04). The terms of reference were to:

- a) review the sensitivity of seabird populations to changes in life history parameters;
- b) review the extent to which fisheries have altered the composition of seabird communities;
- c) continue to assess food consumption by seabirds in the ICES area;
- d) review the contents of the database on seabird diet composition;
- e) establish the means to develop awareness of the relevance of seabird ecology to ICES science and advice;
- f) collate information on the distribution and possible consumption of fish offal and discards by seabirds in the Baltic Sea, by species and ICES Sub-Division [HELCOM 1999/5: 2000/];
- g) consider, and where feasible, develop data products and summaries that can be provided on a routine basis to the ICES community via the ICES website;
- h) examine the 1999 Oceanography Committee Working Group reports and the Terms of Reference for 2000 to identify where inter-group input could be provided or required, with the view to formulating key questions requiring inter-disciplinary dialogue during concurrent meetings of the Committee's Working Groups in 2002.

### **1.3 Justification of terms of reference**

a) At present monitoring of seabird populations is carried out primarily using counts of numbers and assessments of breeding success. Changes in food supply may affect other life history parameters. These other parameters may be of greater importance in driving population dynamics. The review should examine the desirability, feasibility and practicality of monitoring other parameters. The meeting was planned for the immediate aftermath of a conference on seabird reproduction to be held in Wilhelmshaven, so a wider range of knowledge than might usually be available could be called upon for the review.

b) It is known that fisheries have changed the size spectrum of fish populations in a way that is likely to have increased potential foods for seabirds. Fisheries have also provided large quantities of waste that are consumed by seabirds. It is not clear how these new foods and increased food supply has changed the overall seabird community. The review will make comparisons worldwide, but will focus on the ICES area.

c) The Working Group started work on modelling food consumption in the North Sea at their first meeting. Work continued for areas outside the North Sea in 1999. Data for further areas to the west of the British Isles are available and may be forthcoming elsewhere. This information should be of interest to other ICES Working Groups, and potentially to OSPAR and HELCOM.

d) This database was established prior to the March 1998 WGSE meeting and has been added to since. It is though still incomplete. It provides a useful and detailed summary of data on seabird diet by species and size of prey, by season and

by location. WGSE were unable to review it in an updated version at the 1999 meeting. It has been further updated, and is a vital source of information for WGSE.

e) the Group feels that its products and science could be made better use of within ICES. The Group will consider the usefulness of mechanisms such as a section in the ICES web site for promoting products such as the seabird Diet database, or as a source of other relevant information.

#### **1.4 Summary**

The Working Group on Seabird Ecology met for four days (20–23 March 2000), and was attended by eleven nominated representatives from five countries. We were able to address all terms of reference and the results are reported here. Some of the terms of reference are of a review or discussion nature, which no doubt will be able to be added to in the future.

We did not have sufficient time to complete an exhaustive review of the sensitivity of seabird populations to changes in life history parameters, even with regard only to influences of food abundance and hence to possible effects of fisheries. However, it is clear that different species of seabirds respond differently depending on their particular life history strategies, and that the ideal programme of seabird monitoring would consider not only breeding numbers and breeding success, but would include attention to other aspects of seabird life history parameters, especially adult survival and recruitment rate. There is a need for further review of literature, demographic models and field techniques available in order to develop a better understanding of the ways in which seabird monitoring programmes might be improved by taking these parameters into account.

With respect to the effects of fisheries on seabird populations, both negative and positive impacts can occur at multiple spatial and temporal scales. Commonly, effects on population abundance are difficult to demonstrate, even if they are very likely to exist. To make things more complicated; a single fishery can potentially have simultaneous positive and negative impacts on a species of seabird. The potential effects of shifts in age and size-structure of fish in the North Sea as a result of overfishing large predatory fish are very difficult to quantify, but are likely to be or have been substantial. Discards and offal as an extra source of food were probably most significantly positive effects for birds like the northern fulmar and several species of gulls.

The food consumption estimates presented in this report are preliminary and do not cover all areas of interest for ICES. Also, the consumption model we have applied will need future refinement of many of the parameters. In general, information on the distribution, diets and energy budgets of seabird outside the breeding season are scarce and new data could easily alter our assessments considerably. Nevertheless, the results illustrate the magnitude of seabird consumption, which is above one million tonnes per year in Canadian waters and in the range of 0.6–1.0 million tonnes per year in each of the Barents, Norwegian and Baltic Seas. Furthermore, they demonstrate some important differences and similarities between the different areas considered.

Most striking, perhaps, is the very similar consumption estimates (1.0 million tonnes per year) for the NW Atlantic area and the Barents Sea, despite seabird numbers in the Canadian region being estimated at twice those of the Barents Sea (Table 4.12). The difference in numbers is largely explained by the huge numbers of small-sized seabirds, mainly Leach's storm-petrels and visiting little auks appearing in Canadian waters. The two regions are also amazingly similar with respect to the balance between fish and invertebrate prey with a slightly higher consumption (almost 50% of the total) of fatty fish species (the most important being capelin, herring and sandeels) while fish species with lower energy content constitutes less than 10% of the total consumption.

Although there has been only a very limited amount of work on the consumption of discards by seabirds in the Baltic Sea, it is evident that herring gulls consume a high proportion of the offal and discard production in this area. A few discards are too large for gulls to swallow (predominantly cod over 27cm) but there is evidence of gulls selecting roundfish discards and not taking some flatfish discards. The data suggest that gulls consume considerably more than half of the discards and almost all of the offal discharged by Baltic fisheries. In addition, it appears that herring gull distribution in the Baltic in winter is determined to a considerable extent by the local distribution of discarding fishing vessels, which are concentrated in the southwest Baltic. Whether the provision of discards and offal from Baltic fisheries has affected the population trends of gulls in the Baltic is not known.

#### **1.5 Acknowledgements**

The Working Group thanks Franz Baierlein, Peter Becker, Elke Wiechmann, Monika Exning and Martin Wagener at Institut für Vogelforschung, Wilhelmshaven for the provision of facilities and excellent support at the meeting. We

thank other staff at the Institut for their tolerance of our sometimes intrusive presence. We thank the ICES Secretariat for their rapid and very helpful support, and Geir Gabrielsen (absent member of the Group) for input to Section 4.

## 2 REVIEW OF THE SENSITIVITY OF SEABIRD POPULATIONS TO CHANGES IN LIFE HISTORY PARAMETERS

### 2.1 Introduction

Seabird numbers in a population change as a consequence of births, deaths, immigration and emigration (Figure 2.1). Much effort has been put into surveillance of the size of seabird populations, and almost all of this effort has been directed at the census or sample monitoring of breeding numbers. This is largely because it is very much easier to make accurate counts of breeding numbers, or nests, than it is to count all birds in seabird populations. For example, in many seabird species some immature birds visit colonies but some remain at sea far from the colonies and mixed with immatures from other populations. However, changes in breeding numbers may reflect not only births, deaths, immigration and emigration, but also changes in age of recruitment (defined here as first breeding), changes in the proportion of established breeders that choose not to breed in a particular year (non-breeding), or changes in timing or synchrony of breeding that can be confounded with changes in breeding numbers if, as is often the case, census counts of nests or breeders are made on a particular date in the breeding season.

Life history theory envisages trade-offs between components of fitness, such as survival and reproductive investment (Roff 1992, Stearns 1992, McNamara and Houston 1996). Long-lived birds, such as most seabirds (Furness and Monaghan 1987), may be expected to respond to adverse environmental conditions (such as reductions in food abundance, increased predation or bad weather) by reducing their investment in current reproduction in order to increase residual reproductive value and maximise lifetime reproductive success (Monaghan *et al.* 1989, Montevecchi 1993, Sæther *et al.* 1993, Pyle *et al.* 1997, Oro and Pradel 2000). Based on such life history considerations, Cairns (1987) proposed a model of seabird responses to reduced food supply in which slight reductions affect breeding adult activity budgets and diet selection but not breeding success or adult survival rate. In his model, moderate reductions would also affect chick growth and breeding success, but only severe reductions in food supply would cause a reduction in adult survival rates, by which time effects on breeding success would be catastrophic. Monaghan *et al.* (1992) proposed that arctic terns *Sterna paradisaea* followed such a pattern of reproductive investment, abandoning current breeding effort when body condition fell below a threshold that might begin to affect survival prospects of the parents. Similarly, Wernham and Bryant (1998) showed inter-year reproductive costs for Atlantic puffins *Fratercula arctica*, supporting the hypothesis that such long-lived birds reduce the 'quality' of their offspring or abandon a breeding attempt rather than compromise their survival and future opportunities to reproduce. A few studies have validated a corollary of this model, showing that the demography of long-lived birds may tend to be driven by variations in reproductive output across years or by the balance between immigration and emigration, since adult survival rates would be expected to remain rather constant and not vary with food supply (Pons and Migot 1995, Oro *et al.* 1999). However, in contrast to predictions of life history theory, several recent experimental studies in which reproductive effort of adults was manipulated by adjustment of brood sizes have shown that in black-legged kittiwakes *Rissa tridactyla* adult survival rate is considerably reduced in birds that invest more in current reproduction (Erikstad *et al.* 1995, Jakobsen *et al.* 1995, Golet *et al.* 1998). Thus the framework of life history theory leads us to anticipate that seabird breeding numbers (equivalent to estimated 'population size') may vary as a consequence of life history trade off by seabirds.

Monitoring seabird breeding numbers alone, will not only fail to provide any indication as to the cause of a measured change in numbers, but also may present a less than optimal approach to detecting change, since specific life history parameters may vary more strongly in response to changes in food supply than would breeding numbers. For example, breeding success may show strong relationships with food supply but despite this there may be little consequent impact on breeding numbers, as a result of various forms of buffering of breeding numbers. Also, while change in food abundance may affect breeding success, small and often undetected changes to adult survival might have a more significant influence on population change. There is therefore a need to evaluate the strength of influence of different life history parameters on seabird population dynamics, with a view to considering the best approach to monitoring seabird populations to identify influences of changes in food availability that may result from changes in fisheries or fish stocks.

There is good evidence that changes in food availability can affect the reproductive output of seabirds and can correlate with overall changes in population size (Croxall and Rothery 1991). The locations of seabird colonies and numbers of breeding pair numbers are relatively well documented in the ICES area. However, owing to the life history characteristics of seabirds – k-strategy with high annual survival rates and low reproductive outcome – short-term changes in numbers or reproductive outcome caused by reduction of the food supply are difficult to detect by estimating population size at breeding sites. In particular, due to the delayed maturity of seabirds, changes may only become

obvious many years later in the breeding pair numbers, while current monitoring programmes usually do not include counts of the non-breeding part of the population, immature (=prebreeders, =subadults) and non-breeders (=established breeding adults that choose not to breed in a particular year).

Reproductive success, on the other hand, is a parameter indicating the actual environmental situation at the breeding site during a respective year. Productivity is not necessarily a very sensitive indicator of reproductive performance (Hunt *et al.* 1986) and is not only influenced by food supply. Many other factors may affect it, such as predation, weather, flooding and others (e.g., Becker 1998). Another limitation is that the indicative value of productivity is restricted mainly to the environmental situation during the reproductive period, excluding other periods of the year.

In consequence, to use seabirds as indicators of food supply, other life history parameters should be selected in addition. In this chapter we briefly review life history traits with respect to their desirability, feasibility and practicability as characteristics for monitoring seabird population dynamics as response to changes in food supply.

## 2.2 Population characteristics in seabirds

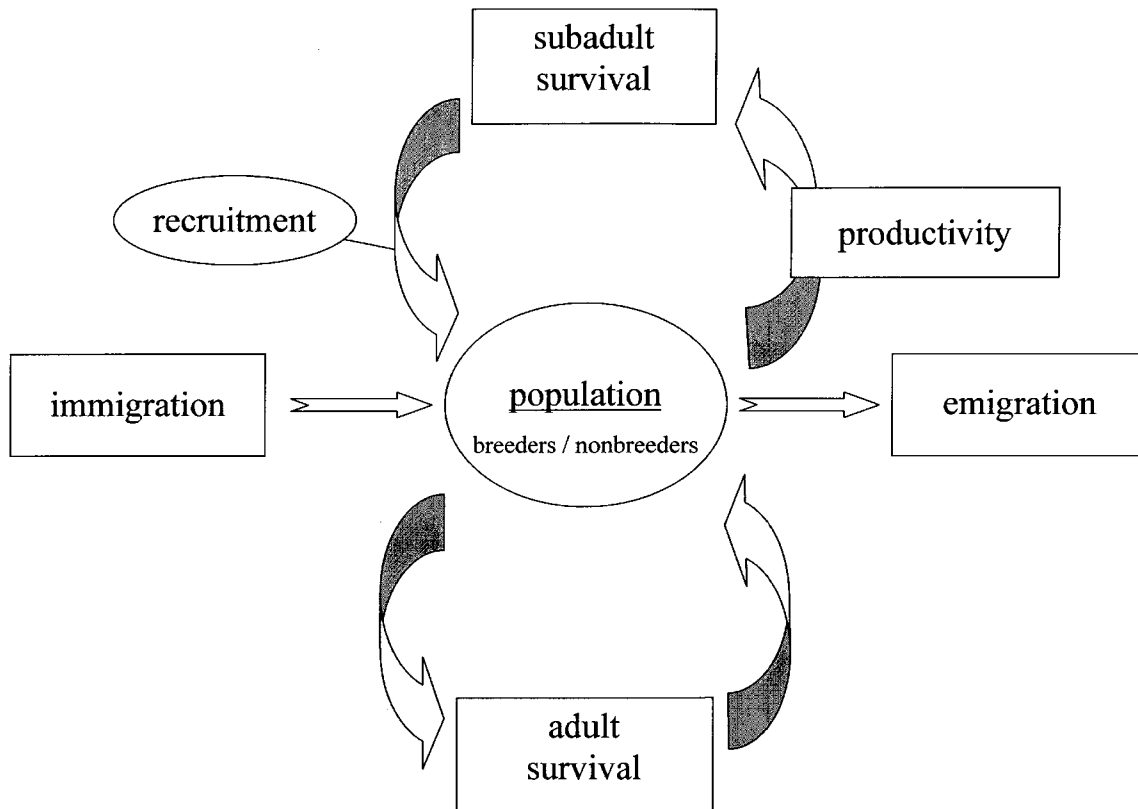
In general, seabirds represent extreme K-selected species. Adult survival is generally high, and annual reproductive output low. Many species delay first breeding until several years old (Table 2.1). In consequence, the non-breeding part of the population is high.

**Table 2.1.** Some mean demographic and biological characteristics of the main families of seabirds. From Croxall and Rothery (1991).

| Group                           | Age (years) at first breeding | Adult annual survival rate (%) | Clutch size | Chick-rearing period (days) |
|---------------------------------|-------------------------------|--------------------------------|-------------|-----------------------------|
| <i>Sphenisciformes</i>          |                               |                                |             |                             |
| Spheniscidae (penguins)         | 4–8                           | 75–85 (-95)a                   | 1–2         | 50–80 (-350)b               |
| <i>Procellariiformes</i>        |                               |                                |             |                             |
| Diomedeidae (albatrosses)       | 7–13                          | 92–97                          | 1           | 116–150 (-280)c             |
| Procellariidae (petrels)        | 4–10                          | 90–96                          | 1           | 42–120                      |
| Hydrobatidae (storm petrels)    | c4–5                          | c90+                           | 1           | 55–70                       |
| Pelacanoididae (diving petrels) | 2–3                           | 75–80                          | 1           | 45–55                       |
| <i>Pelacaniiformes</i>          |                               |                                |             |                             |
| Pelacaniidae (pelicans)         | 3–4                           | c85                            | 2–3         | 55–60                       |
| Sulidae (gannets, boobies)      | 3–5                           | 90–95                          | 1–2 (-3)d   | 90–120 (-170)e              |
| Phaethontidae (tropic birds)    | ?                             | ?                              | 1           | 60–90                       |
| Fregatidae (frigate birds)      | ?c9–10                        | ?                              | 1           | 140–170+                    |
| Phalacrocoracidae (cormorants)  | 4–5                           | 85–90                          | 2–3         | 60–90                       |
| <i>Charadriiformes</i>          |                               |                                |             |                             |
| Alcidae (auks)                  | 2–5                           | 80–93                          | 1–2         | 15–20                       |
| <i>Lariiformes</i>              |                               |                                |             |                             |
| Laridae (gulls)                 | 2–5                           | 80–85                          | 2–3         | 25–50                       |
| Sternidae (terns)               | 2–5                           | 77–90                          | 1–3         | 25–40                       |
| Stercorariidae (skuas)          | 3–8                           | c93                            | 2           | 25–40                       |

a) emperor penguin; b) emperor penguin 170 days, king penguin 350 days; c) great albatrosses; d) boobies; e) red-footed booby to 140 days, Abbott's booby to 170+ days.

The regulation of a seabird population is schematically shown in Figure 2.1. Most important parameters are adult survival, reproductive success, subadult survival to recruitment, as well as immigration and emigration. The two last parameters are difficult to study; therefore in population models immigration and emigration are usually considered to be equal (emigration -immigration=0).



**Figure 2.1.** Scheme of the most important parameters regulating seabird populations

For conservation as well as in order to use seabird populations as indicators for the marine environment it is important to know what parameters are especially sensitive and important in determining trends in the size of the population. A simulation modelling analysis enables us to make assessment of the theoretical sensitivity of seabird populations to changes in the demographic parameters. To demonstrate this we analysed the effects of a 5 per cent negative change in adult survival, subadult survival to breeding and reproductive success on a flourishing population, as well as an increase in the age of first breeding. We performed the calculations on the basis of parameters in actual populations of three species with different life styles (Table 2.2). To indicate one extreme of life history strategy we selected the especially K-selected fulmar *Fulmarus glacialis*. Towards the opposite extreme, with relatively low adult survival but high breeding output we selected the example of the shag *Phalacrocorax aristotelis*, and the common tern *Sterna hirundo* was selected as an example of an intermediate species (Table 2.2).

The model is a modification based on Croxall and Rothery (1991):

$$R_{t+k} = N_t \times b_t \times s_j \times (sa)^{k-1} \times s_a$$

where

- $R_{t+k}$  = size of a cohort of potential recruits available in a population
- $N_t$  = number of breeding pairs  $k$  years previously
- $b_t$  = number of chicks fledged per pair  $k$  years previously
- $s_j$  = the first-year survival rate
- $(sa)^{k-1}$  = the annual survival rate from then until recruitment
- $k$  = age at recruitment
- $s_a$  = annual adult survival rate

The modelling output reveals that in fulmar and common tern, adult survival rate was the most sensitive parameter (Table 2.3). A reduction in adult survival by 5% causes a stronger response of population size than a change in the other parameters. In the common tern a reduction of subadult survival has an intermediate effect. In both species a shift of breeding success and age of first breeding have lesser effects on population change (Table 2.3). In the shag, however, the change of each parameter has a similar effect on the population, respectively. Owing to low adult survival a delay in the age of first breeding causes the strongest effect on population, in contrast to the other species.

The examples demonstrate the specific importance of adult survival and also of subadult survival on population size in seabirds. They indicate also the interspecific differences owing to various life history strategies. To understand the dynamics of a population in question it is necessary to gather information on these important population parameters.

**Table 2.2.** Population parameters of three species of seabirds leading to a population increase. Data from Birkhead and Furness (1985; fulmar and shag) and from Wendeln and Becker (1998) and Becker (unpubl.)

|   | Fulmar | Shag  | Common tern |
|---|--------|-------|-------------|
| Adult survival  | 0.97   | 0.82  | 0.90        |
| Sub-adult survival to breeding                                  | 0.63   | 0.39  | 0.34        |
| Breeding success<br>Chick Pair <sup>-1</sup> year <sup>-1</sup> | 0.49   | 1.84  | 1.20        |
| Age at first breeding   | 8      | 3     | 3           |
| Population change   | + 12%  | + 18% | + 10%       |

**Table 2.3.** Population change in %, if population parameters are reduced by 5% (age of first breeding increased by 1 year) in three seabird species. The data are calculated using a simple population model and are based on the sources of Table 2.1.

| Population parameters         | Fulmar | Shag | Common tern |
|-------------------------------|--------|------|-------------|
| Adult survival                | -5%    | -5%  | -5%         |
| Subadult survival to breeding | -1%    | -5%  | -3%         |
| Breeding success              | -1%    | -4%  | -1%         |
| Age at first breeding         | 0%     | -7%  | -1%         |

### 2.3 Interactions between life history parameters

Life history theory predicts that selection should favour allocation of time and resources toward the stage of the life history at which survival or reproduction is least variable, all other things being equal (Stearns 1992). In long-lived birds such as seabirds, survival of offspring is commonly variable and unpredictable, and selection should weight adult survival more heavily than fecundity (e.g., Goodman 1974, Charlesworth 1980). Several studies have shown that adult survival in many species of seabirds, including black-legged kittiwakes, is high and rather constant (e.g., Weimerskirch *et al.* 1987, Aebischer and Coulson 1990, Hatch *et al.* 1993, Erikstad *et al.* 1995, Pugsek *et al.* 1995, Cam *et al.* 1998, Frederiksen and Petersen 1999, Wendeln and Becker 1999), although adverse environmental conditions can decrease survival in specific years (e.g., Rattiste and Lilleleht 1995, Harris *et al.* 1997, Oro *et al.* 1999).

Strong inferences show that intraspecific density-dependent competition for food has the potential to act as a regulating mechanism, especially during the breeding season. In several species reproductive performance or chick growth and quality are reported to be lower in highly populated colonies (Birkhead and Furness 1985; Croxall and Rothery 1991).

Body condition is an important parameter related to reproductive performance and output as found in wandering albatross *Diomedea exulans* (Weimerskirch 1992, Weimerskirch *et al.* 1997), blue petrel *Halobaena caerulea* (Chastel *et al.* 1995) and common tern (Frank and Becker 1992, Wendeln and Becker 1999). Impaired condition during reproduction can lead to an interruption of breeding or to brood reduction in order to avoid an increased risk of mortality (blue petrel Chaurand and Weimerskirch 1994 a,b; king penguin *Aptenodytes patagonicus* Olsson 1997; arctic terns, Monaghan *et al.* 1989, 1992).

In guillemots *Uria aalge* on Skomer, Lindner *et al.* (2000) showed a positive correlation of survival between adults and subadults of a year class, indicating that both age groups are influenced by the same factors outside the breeding season. The same tendency was found by Becker (unpubl.) in common terns (adult survival and subadult survival to age 2:  $r_s=0.46$  ( $n=6$ , n.s.)). The two year classes 1992 and 1993 had lesser subadult return rates (0.24 on average) than the 4 following year classes (0.45). In addition, a lower percentage of the former returned already at age 2 (67%/92%), and they recruited later (3y recruits 38%/57%). These data indicate poor wintering conditions for the year classes 1992 and 1993 as well as for the adults wintering in Africa in these years.

The effects of egg size on chick survival and recruitment to the breeding population is unclear. For instance, Hipfner (2000) showed that guillemot chicks hatching from replacement eggs with 25 % less albumen had similar hatching success, fledging mass and survival to breeding age (5 years old) as first eggs. Alternatively, the opposite result was found in another study on guillemots (Van Pelt and Monaghan 2000). The discrepancy may be due to divergent foraging conditions among colonies. Nonetheless, egg size appears to directly affect the size of chicks upon hatching. Chicks that hatch from a larger egg have larger skeletal features (Hipfner and Gaston 1999); however, chick growth also depends on the provisioning rates of parents.

These examples may show the dynamic interactions between the life history traits, and they underline the necessity to look to many of the relevant population parameters to be able to find the causes for population changes and influences of changes in food supply.

#### 2.4 Monitoring of important life history parameters in seabirds

In Table 2.4 we have listed the life history parameters most relevant for integrated population studies in seabirds. We distinguish between different degrees of desirability to measure a specific characteristic, of the feasibility and practicability to record it (financial and/or logistic reasons; man power).

In this report we concentrate on the parameters of highest desirability, adult survival and subadult survival to breeding. The review of the techniques to study all the parameters listed, however, would require more time and space than is available here.

**Table 2.4.** Monitoring of important life history parameters

| Parameter   | Desirability | Feasibility | Practicability |
|---|--------------|-------------|----------------|
| <b>Population</b>                                       |              |             |                |
| - population size (breeders)                            | +++          | +++         | +++            |
| - incidence of non-breeding                             | +            | +           | -              |
| - adult survival  | +++          | ++          | +              |
| - subadult survival to breeding                         | +++          | ±           | -              |
| - recruitment   |              |             |                |
| % of fledglings   | ++           | ±           | -              |
| % recruits in population                                | +            | ±           | ±              |
| - recruitment age                                       | +            | ±           | ±              |
| - immigration rate                                      | +            | -           | -              |
| - emigration rate                                       | +            | -           | -              |
| - sex ratio of the breeding population                  | ±            | -           | -              |
| - mean age of breeders                                  | ++           | ±           | -              |
|   |              |             |                |
| <b>Reproduction and food provisioning</b>               |              |             |                |
| - reproductive success                                  | ++           | ++          | ++             |
| - laying date   | +            | ++          | ++             |
| - clutch size   | +            | +++         | ++             |
| - egg size  | +            | +++         | ++             |
| - chick growth rate                                     | +            | ++          | +              |
| - mass of fledglings                                    | +            | ++          | +              |
| - adult nest and brood attendance;<br>provisioning rate | ++           | ++          | ±              |
| - degree of kleptoparasitism                            | +            | ++          | ±              |
|   |              |             |                |
| <b>Body condition of breeders</b>                       | +            | +           | +              |

+++ highest; ++ high; + moderate; ± more or less; - low

## **2.4.1 Adult survival**

### **2.4.1.1 Evidence that adult survival can vary as a function of food abundance**

Adult survival rate of breeding black-legged kittiwakes in Shetland shows a high variation, from 0.53 to 0.98 for both males and females (Oro and Furness, submitted), even higher than that recorded for the snow petrel *Pagodroma nivea*, a seabird that breeds in extreme environmental conditions and shows high annual variability in survival and fecundity (Chastel *et al.* 1993). That result contradicts the concept of the 'typical' seabird as having consistently high adult survival and strong buffering against environmental stress through variation in reproductive effort (Lindén and Møller 1989, Monaghan *et al.* 1989, Sæther *et al.* 1993, Oro *et al.* 1999). In fact, models indicate that much of the variation in Foula kittiwake adult survival rates can be attributed to measured environmental factors. Adult survival rate was higher in years when adult body mass towards the end of the breeding season was high, when 0-group sandeel abundance was high, and when breeding success of great skuas was low (Oro and Furness, submitted). Similarly, adult survival of great skuas was lower at Foula, Shetland during years of sandeel scarcity than it was when sandeels were in abundant supply (Cтры *et al.* 1998).

It is well known that when availability of food during breeding and especially during chick rearing is low kittiwakes may fail to breed successfully because they are beyond the limits of their buffering capacity (Walsh *et al.* 1991, Danchin 1992, Hamer *et al.* 1993). However, accurate measures of food availability and their inter-year variations are very difficult to obtain in natural conditions, and the influence of this environmental factor on adult survival is difficult to test. Of the two published studies on the effects of food availability on gull adult survival (Pons and Migot 1995, Oro *et al.* 1999), neither reported any relationship between the two parameters. However, adult survival of black-legged kittiwakes in Shetland was significantly correlated with the abundance of 0-group sandeels, although it was independent of 1+ group sandeel abundance (Oro and Furness, submitted). There is a negative correlation between 0-group recruitment and 1+ group abundance of sandeels in the large North Sea stock, but no significant correlation between 0-group recruitment and 1+ abundance in the Shetland stock (Furness 1999). Kittiwake breeding success in Shetland correlates with 1+ sandeel abundance and is independent of 0-group abundance, the opposite of the relationship for adult survival. However, these contrasts are not unexpected. The 0-group sandeels do not recruit until midsummer, but remain available to kittiwakes during July and August when 1+ sandeels tend to remain buried in the sand and so have become unavailable to surface-feeding seabirds. Results suggest that 0-group sandeels probably play an important role for adult kittiwakes to replenish body reserves depleted during breeding. Thus, adult survival would depend not only on the environmental conditions during breeding and the reproductive effort associated (see above), but also on those occurring just after breeding. In fact, several studies showed that adult mortality of kittiwakes and of gulls in general probably occur mostly after the breeding season (Coulson and Wooller 1976, Pugesek 1987, Reid 1987, Rattiste and Lilleht 1995, Pugesek *et al.* 1995). Conversely, abundance of 1+ sandeels, which are the main food of breeding kittiwakes from April to June, affects breeding success of kittiwakes but 0-group sandeels apparently recruit too late to do so even though they are fed to chicks (Galbraith 1983, Harris and Wanless 1990, 1997, Furness 1999).

### **2.4.1.2 Adult body condition and survival**

It has been suggested that a primary cause of adult mortality in gulls may be the loss of body mass (body condition) as the breeding season progresses (Coulson *et al.* 1983, Pugesek 1987, Pugesek 1990). However, few studies have assessed properly the costs of reproduction associated to adult survival in gulls and their results are controversial (Reid 1987, Pugesek and Diem 1990, Cam *et al.* 1998, Golet *et al.* 1998). Golet *et al.* (1998) and Golet and Irons (1999) showed that chick rearing caused a reduction in body condition and fat stores of breeding kittiwakes and led to a lower adult survival rate than in birds in which reproductive effort was experimentally reduced by removing their chicks. However, individuals which had produced a replacement clutch and raised the second brood successfully, no negative effects on survival rates were detected in Brunnich's guillemots *Uria lomvia* (Hipfner 2000) and in common terns (Wendeln *et al.* 2000).

### **2.4.1.3 Effect of predation on adult survival rate**

Kittiwake adult survival rate at Foula was reduced in years when great skua *Catharacta skua* breeding success was high (Oro and Furness, submitted). Most killing of kittiwakes by great skuas occurs when great skuas have chicks to feed (Furness 1987a, Hamer *et al.* 1991, Phillips *et al.* 1999), and it is therefore not surprising that the survival rate of adult kittiwakes was reduced in years when great skuas have more chicks. During years of great skua reproductive failure, the food requirements of the skua population will be much smaller as some birds that failed early will have dispersed, others will remain relatively inactive in the territory. In contrast, in years when chick survival is high despite low sandeel abundance, great skuas will have to work particularly hard in order to meet their chicks' food requirements and it is known that this involves increased killing of kittiwakes (Heubeck *et al.* 1997, 1999, Ratcliffe *et al.* 1998). There is

a strong correlation between sandeel (%) in great skua chick regurgitates and productivity of great skuas (Spearman rank correlation  $r_s = 0.915$ ,  $n = 12$ ,  $P < 0.001$ ). Sandeel availability has been low for great skuas during the whole study period, but when it was extremely low, breeding failure would mean that the food requirements of the great skua population would be much smaller as some birds that failed early will have dispersed, others will remain relatively inactive in the territory. In contrast, when breeding success of great skuas was higher because sandeel abundance was moderate, the extent of predation on kittiwakes would have been increased to meet the energy demand. If sandeel abundance were to return to the high levels prevailing in the 1970s, we would anticipate a low level of predation by great skuas on kittiwakes despite high great skua breeding success since the skuas would be able to meet their requirements easily by feeding predominantly on sandeels. This was the situation prevailing in the 1970s (Furness 1987).

#### **2.4.1.4 Practicability**

To calculate adult survival, local recordings (resighting, retrapping) are necessary year by year. Very large samples are required to detect a significant change in the survival rate. For instance, in the wandering albatross for a sample of 1000 birds the standard error of an annual survival estimate, assuming a 100 per cent recapture rate, is 0.8 per cent per annum (Croxall and Rothery 1991). For such long-lived birds a consistent reduction in survival of 1–2 per cent per year can be highly significant for the population. Also accurate estimates of survival in one year cannot be made until a further 2 to 3 years have elapsed, because of the extent to which birds are known to show intermittent breeding.

#### **2.4.2 Subadult survival to breeding**

Estimation of juvenile survival also needs large samples of birds. In species with long-deferred sexual maturity there will be a considerable delay in obtaining results (e.g., Harris *et al.* 1992). For some species, this may be short-circuited by obtaining estimates of survival from the birds that attend the colony in the years prior to that of recruitment.

Variation in the survival of subadults is much greater than in that of adults. In the common tern, adult survival was 0.90 (0.87 – 0.97,  $n=7$  years, coefficient of variation: 3.8%), subadult survival 0.38 (0.22 – 0.48,  $n=6$  year classes, coefficient of variation=37.5%; measured as subadult return rates, Wendeln and Becker 1998 and unpubl.). The difference suggests higher susceptibility of immature seabirds for environmental impacts like food shortage outside the breeding season, with strong influences on the population change.

A problem in estimating subadult survival is that only local recruits can be covered. That means that return rate is measured; the percentage of emigrated birds cannot be recorded. Another problem is that subadults normally cannot be recorded with high probability before they are breeders.

#### **2.4.3 Reproduction and food provisioning**

Estimation of breeding success is usually very straightforward, requiring only estimates of the breeding population size, mean clutch size, and the number of chicks fledging. However, as indicated by Hunt *et al.* (1986), breeding success is not necessarily a sensitive indicator of reproductive performance, and other indices, especially those relating to provisioning rate, might be preferable. The extent to which breeding success reflects food abundance seems to vary among seabird species, and this variation is somewhat consistent. For example, fulmars and common guillemots tend to show about the same breeding success in all colonies under almost all conditions of food abundance, weather and other environmental variation. At the other extreme, tern breeding success is highly variable from colony to colony and from year to year, being very severely affected by food abundance, but also by weather, disturbance, and predation impact (e.g., Becker 1998). It may be possible to select those seabird species in which breeding success relates to food abundance but is relatively unaffected by weather or predation. For example, in the kittiwake, selection of colonies that are not affected by predators permits monitoring of breeding success as a function of food abundance (Furness 1999).

##### **2.4.3.1 Laying Date**

Food availability can lead within populations to variation in the date of egg laying in a population among years (Birkhead and Harris 1985; common tern, Becker 1996). Environmental conditions that influence food abundance or accessibility, such as the extent of sea ice or stormy weather, may also be negatively correlated with lay date.

##### **2.4.3.2 Clutch Size**

The number of eggs laid depends on food availability in the breeding season (terns: Monaghan *et al.* 1992, Frick and Becker 1995, Becker 1998). For instance, the mean clutch size of herring gulls declined from 2.8 - 2.9 eggs per clutch

in years of high food availability to 2.7 in a low food year (Pons 1992). The sex ratio of the clutch also varies with food supply in sexually dimorphic species. For instance, females of lower body condition tend to bias the sex ratio of their clutch towards the sex that has a smaller body mass or lower growth rates (Nager *et al.* 2000, Kalmbach *et al.* 2000). This presumably increases the number of offspring parents can raise successfully (reproductive success). There is also a balance between the number of eggs produced and the size and/or quality of each egg (Birkhead and Harris 1985). Species that lay a single-egg clutch can not vary the size of their clutch when food availability varies but instead vary egg size.

#### **2.4.3.3 Egg Size and Quality**

Besides clutch size, egg size can also decline under extremely low food availability (Pons 1992). In a year of low food availability, lesser black-backed gulls given additional fish had larger clutch sizes and larger eggs than control birds (Bolton *et al.* 1992). Species that lay a single-egg clutch can regulate their reproductive effort by varying egg size or the amount of resources allocated to the egg (Birkhead and Harris 1985). Considerable variation in egg size (25–30 %) occurs among and within auk populations (Birkhead and Harris 1985). This reflects variation in female mass or body condition (Birkhead and Harris 1985) and, thus, egg size is indirectly affected by food availability through adult body condition.

#### **2.4.3.4 Adult nest and brood attendance, and provisioning rates**

The rate of provisioning depends on food availability and again varies considerably among and within populations and years (e.g., Gaston 1985). Some seabirds have flexible time and energy budgets during the breeding season and are thus able to maintain provisioning rates under moderate declines in foraging conditions (e.g., Burger and Piatt 1990). When foraging conditions decline further, however, parents become unable to maintain provisioning rates (Uttley 1992, Uttley *et al.* 1994). Some species can also alter the resting time at sea while breeding (e.g., Monaghan *et al.* 1994) but this does not allow adults to maintain provisioning rates. This indicates the importance of non-foraging time in other critical activities (e.g., digestion).

Many species of seabirds are unable to alter time budgets either at the colony or at sea and, thus, lower food availability results in reduced chick growth. Whether a species is capable of time-buffering is shown by cross-fostering and twinning experiments, or experimentally increasing the clutch size (Birkhead and Harris 1985).

#### **2.4.3.5 Growth Rates of Chicks**

Growth rates depend on food availability during breeding (Gaston 1985, Mlody and Becker 1991, Klaassen *et al.* 1992). In common terns breeding in the Wadden Sea, there is a close relationship between the supply of young herring and the growth rate (Greenstreet *et al.* 1999). This occurs because parents rank their own survival over the survival of their chicks in any given year and, thereby avoid jeopardising their own future reproductive potential.

Chick growth will reflect foraging conditions especially in species that cannot alter their time budgets (some procellariiformes, terns). Many procellariiformes alternate between foraging trips to maintain their own body condition and provisioning trips (Chaurand and Weimerskirch 1994b, Weimerskirch *et al.* 1997, Weimerskirch 1998). The parent's body mass appears to play a central role in such foraging/provisioning decisions.

#### **2.4.3.6 Mass of Fledglings**

Fledging mass depends on food availability during the breeding season, varies between years and reflects the amount of energy reserves of fledgling and, thus, how long a bird can withstand starvation. Therefore, mass at fledgling should be positively correlated with the probability of recruitment to the breeding population. Becker (1999) and Becker *et al.* (2000) showed for common terns and Hipfner (2000) for guillemots that higher body mass at fledging resulted in an earlier age of recruitment into the breeding population and a higher probability of being resighted at the colony. Davoren and Montevecchi (2000) also suggested that a guillemot colony with a stable population had lower chick condition (mass/wing length) than a colony with an increasing population growth. Other studies on guillemots that employed ringing techniques, however, found no relationship between fledging mass and the probably of being resighted at the colony as prospectors or recruits (Hedgren 1981, Harris *et al.* 1992). This discrepancy has led researchers to suggest that characteristics of fledglings other than mass (e.g., wing length, wing loading) are important to the survival of guillemots as they depart the colony and in their first year at sea (Hipfner and Gaston 1999).

#### **2.4.3.7 Degree of Kleptoparasitism**

Kleptoparasitism (or predation) at the colony may determine provisioning rates of chicks depending on the extent and consistency (Veen 1977, Furness 1987b, Gorke 1990, Ludwigs 1998). Marked intraspecific kleptoparasitism in a colony indicates food shortage (Ludwigs 1998). Finney *et al.* (2000) showed that provisioning rates of Atlantic puffin parents were lower in areas where gulls were present versus areas where gulls were absent; however, this did not affect the growth rates of chicks or breeding success.

#### **2.4.3.8 Reproductive Success**

Reproductive success appears to be the least sensitive parameter in reflecting prey availability or foraging conditions because it is influenced by other factors like predation, weather or flooding. Additionally, parents are able to buffer provisioning rates, chick growth and mass of fledging. Reproductive success is positively correlated with the quality and age/experience of the breeders (e.g., Coulson and Thomas 1985, Wendeln and Becker 1999, Weimerskirch 1992). In years of severe prey scarcity (e.g., off Peru during ENSO events), however, seabirds may abandon breeding attempts.

#### **2.4.4 Body condition of breeders**

Body condition of adults is an important parameter linked with other life history characteristics such as reproductive performance, adult survival (see 2.3, 2.4.1) or with recruitment (e.g., Porter and Coulson 1987, Becker 1999). Body mass can be measured easily after catching the bird, mainly possible during incubation or chick rearing. However, the stage of the breeding cycle and of the incubation shift of the weighed bird should be known and taken into account, as they influence body mass (e.g., Frank and Becker 1992, Wendeln and Becker 1996, Golet *et al.* 1998, Golet and Irons 1999). In some studies adult weight has been recorded remotely and automatically (Sibly and McCleery 1980, Monaghan *et al.* 1989, Frank and Becker 1992, Wendeln and Becker 1996).

#### **2.5 Possibilities of integrated population monitoring in seabirds**

The use of seabirds as monitors of the marine environment is becoming increasingly widespread. Monitoring of parameters other than population size, breeding success and performance is usually regarded as necessary information for interpreting changes. As is shown above, the relevance of the various population parameters will depend on the life-style of the species concerned. For extreme K-selected species the order of parameters measured may be adult survival, subadult survival and breeding success.

The different population parameters integrate environmental effects over different time spans. Different lag times before the effects can be measured and different accuracies with which effects are likely to be detected have to be considered (Croxall *et al.* 1988).

Logistically costly, long-term monitoring of seabird populations is rare (Nisbet 1989, Wooller *et al.* 1992). Nevertheless, there are some good examples of integrated long term studies: wandering albatross (Weimerskirch and Jouventin 1987, Croxall *et al.* 1992, Weimerskirch 1999), short-tailed shearwater *Puffinus tenuirostris* (Wooller *et al.* 1989, Bradley *et al.* 1991, 1999), kittiwake (Coulson and Thomas 1985, Porter and Coulson 1987, Thomas and Coulson 1988); puffin (Harris and Wanless 1991, Harris *et al.* 1997); great skua (Furness 1987a); common tern (Becker and Wendeln 1997, Becker *et al.* 2000). Such studies require special sites which allow good access, a long term perspective, an engaged team of researchers, the necessary financial basis and effective data management (Bradley *et al.* 1991). In addition the use of new field techniques, e.g., field readable rings or remote and automatic recording of subadults and adults by passive transponders (Becker and Wendeln 1997, Becker *et al.* 2000) may help to increase the efficiency of integrated population monitoring in seabirds.

#### **2.6 Conclusion**

We have not had sufficient time to complete an exhaustive review of the sensitivity of seabird populations to changes in life history parameters, even with regard only to influences of food abundance and hence to possible effects of fisheries. However, it is clear that different species of seabirds respond differently depending on their particular life history strategies, and that the ideal programme of seabird monitoring would consider not only breeding numbers and breeding success, but would include attention to other aspects of seabird life history parameters, especially adult survival and recruitment rate. There is a need for further review of literature, demographic models and field techniques available in order to develop a better understanding of the ways in which seabird monitoring programmes might be improved by taking these parameters into account.

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### **3 REVIEW OF THE EXTENT TO WHICH FISHERIES HAVE ALTERED THE COMPOSITION OF SEABIRD COMMUNITIES**

#### **3.1 Introduction**

There are direct and indirect effects of fisheries on seabirds. Most direct effects involve killing of seabirds by fishing gear or by culling, while indirect effects mostly work through the alteration in food supplies of birds (Tasker *et al.* 2000). Seabird mortality in long-line fisheries or in other fishing gear can lead to drastic population declines and may bring certain vulnerable species to the brink of extinction, but even the (persistent) disturbance of birds due to some fishing activities, such as some aquacultural pursuits, may negatively affect seabird numbers (Davidson and Rothwell 1993). On the other hand, seabirds may also benefit from fisheries, because many fishing activities increase the food supply or enhance the availability of prey for seabirds. The practice of discarding unwanted fractions of a commercial catch is clearly beneficial for scavenging seabirds (e.g., Camphuysen *et al.* 1995). Furthermore, major shifts in fish stock composition, for example due to overfishing of large predatory fish, have led to a (relative) increase in smaller fish, suitable for consumption by seabirds. The most prominent fishery effects have recently been summarised by Tasker *et al.* (2000). We will not repeat that review, but instead concentrate on alterations in seabird communities that may have been influenced by fisheries.

Proving the scale of fisheries effects can be difficult due to confounding and interacting combinations with other anthropogenic effects such as pollution, culling, hunting, disturbance or with more natural oceanographic factors that can influence prey availability. In fact, fishery effects can be masked completely in seabird populations that are subject to major shifts due to these and other factors. Moreover, the life history patterns of seabirds can also buffer them to some extent from anthropogenic influences associated with fisheries. In the present review, we will show examples of major shifts in numbers of seabirds breeding around the North Sea and in the species composition of certain breeding areas and try to explain these shifts. We will also give examples of clear-cut fishery effects that are obvious and (directly) affect large numbers of birds, but that for some reason do not show up on the population level. First, however, we need to define what is meant by “the composition of seabird communities”.

#### **3.2 Seabird communities**

We distinguish two main types of seabird community. Seabirds may compete for or share breeding sites (*nesting community*) because of overlapping nesting habitat requirements or because they share a feeding area. Seabirds that share the same nesting area may however forage in widely separated areas and have a completely different prey spectrum, and some seabirds that nest far apart may interact while foraging in overlapping areas and perhaps even directly compete for prey (*feeding community*). While competition for nesting sites and for prey are perhaps the most thoroughly studied aspects of inter-specific interactions between seabirds, the activities of one species may also enhance the feeding opportunities of another. As a result, a shift in a seabird community through a change in the abundance of one species (for example influenced by fisheries) may affect another species simultaneously, even though that fishery plays no obvious role in the feeding ecology of the latter. For example, social feeding pursuit diving common guillemots and razorbills significantly enhance the feeding opportunities of surface plunging kittiwakes (Camphuysen and Webb 2000). Hence, a mass mortality of auks in gill-nets could indirectly have a negative impact on kittiwakes even although they themselves do not get entangled. Also, seabirds sharing the same breeding community (e.g., terns and gulls or gannets and common guillemots), but differing in feeding ecology, may compete for nesting space, so that the foraging success of the one species may indirectly affect the nesting space of the other (e.g., Howes and Montevecchi 1993).

So, while species in a given area may share a certain nesting community, a feeding community, both or neither, any aspects affecting a given seabird species may work through community interactions to affect other species indirectly. As the effects of fisheries on seabirds are usually ambiguous, we concentrate on the examination of clear trends in population levels, downward or upward, on a moderately large spatial scale (e.g., SE North Sea, Shetland area, British Isles, etc.) for groups of species that share particular prey and foraging techniques. Such changes should lead also to shifts in relative abundance and species composition within seabird communities.

#### **3.3 The difficulty of detecting fishery effects**

From the above it is clear that fisheries effects may act directly on a species or indirectly through the wax or wane of either a competitor or a “co-operator” in mixed feeding systems. All other factors being equal, the numbers of seabirds breeding or feeding in a given area should reflect the carrying capacity of that region in terms of amount of food available. Prey availability is not the same as the size of prey stocks present, for several factors influence the accessibility of prey for seabirds and the profitability (in terms of intake rates achievable) of a given area. Prey

availability may fluctuate independently of prey stocks and prey availability is also different for species using different foraging and feeding techniques.

Fishery effects can be strong, so that populations grow or decline, but fishery effects are often indirect and may be subtle, for instance the reproductive output, activity patterns or time budgets of birds may alter. Fishery induced increases in food supply often result in an increase in 'secondary prey', that is not preferred when 'normal' prey is sufficiently abundant (e.g., Furness and Hislop 1981). A clear cut negative effect of fisheries, such as the bycatch of large numbers of seaduck, may be very hard to quantify, because a complete census of birds that 'disappear' to breed in vast Russian and Scandinavian forests is simply not feasible. Perhaps most important, however, is that fishery-induced changes in fish stocks are often very difficult to distinguish from natural variation or environmental impacts on fish, so that the next step, an effect on fish predators (such as birds), will become even more obscure.

### 3.4 Direct effects on communities: seabirds drowning in gill nets

#### 3.4.1 Northern Norway

Among seabirds in the Northeast Atlantic, the pursuit-diving auks, common guillemots, razorbills and Atlantic puffins are the most vulnerable to entrapment in gillnets and other fixed fishing gear. Gillnets set for cod off northern Norway killed very large numbers of Brunnich's guillemots and common guillemots between at least 1965 and 1985 (Strann *et al.* 1991). In early spring 1985 the estimated kill of both species totalled was greater than 100 000 birds. In this same area, summer driftnet fisheries for salmon used to regularly drown thousands of local breeding birds (Vader and Barrett 1982, Strann *et al.* 1991). Numbers of common guillemots at Hjelmsøy declined from 220 000 in 1965 to 10 000 individuals by 1985. Brunnich's guillemots at this colony declined from >2000 to 220 in the same period (Vader *et al.*, 1990). The fishery has been closed since 1989 to conserve salmon stocks, but the auk populations had reached a critically low level and have so far not shown any signs of recovery (Lorentsen 1999). Common guillemot populations on Kharlov, Hornøya, and Syltefjord were not affected by the gill-net fisheries, because the foraging areas were located beyond the sea area with gill nets, and two of these populations increased steadily between the 1970s and mid 1980s (Figure 3.1). Recoveries of guillemots ringed as chicks on Helgoland since 1912 revealed an increase of the proportion killed in fishing gear from less than 4 % until 1969 to 42 % in the period 1989–94. However, the mortality rate remained virtually stable (Hüppop, 1996).

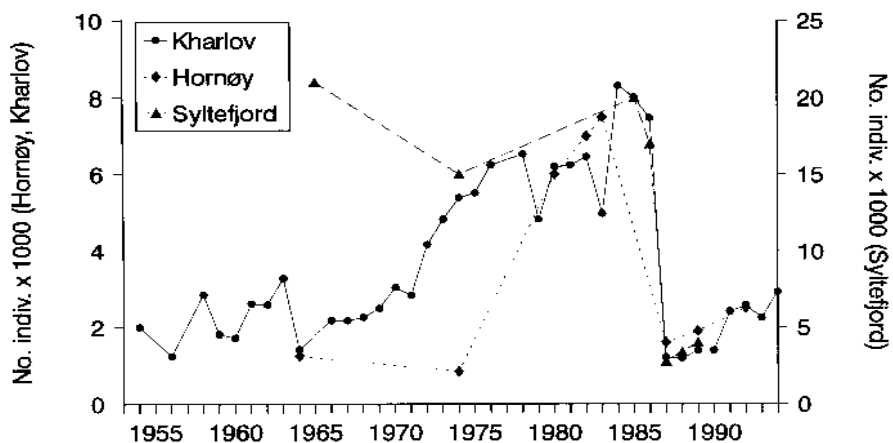


Fig. 3. Changes in the total numbers of breeding common guillemots *Uria aalge* (individuals) counted on Kharlov, Hornøya and Syltefjord since 1955.

Figure 3.1

### 3.4.2 Baltic

In the Baltic Sea, seaduck such as common eider, common scoter and long-tailed duck, divers, grebes and auks (mainly common guillemot and razorbill) are affected mostly by fixed nets in coastal or shallow offshore waters. Certainly in the case of the seaducks, very large numbers can be affected and locally, this may affect substantial proportions of wintering seaduck communities (Kirchhoff 1982; Kies and Tomek, 1990; Meissner 1992; Stempniewicz 1994). With a total of over 7 500 000 seaduck wintering in the Baltic (Durinck *et al.* 1994), however, the overall seaduck community effects may be relatively small but are most certainly very difficult to detect.

### 3.4.3 Britain and Ireland

Seabird bycatch impacts around Britain and Ireland tend to be of a localised nature, diluting any possible population effect (Tasker *et al.* 2000). Studies around Wales (Thomas 1992) and Scotland (Murray 1993; Murray *et al.* 1994) found no evidence of widespread impact, with at best 'hot spots' in mortality where nets were set immediately beside seabird colonies.

## 3.5 Indirect effects on seabird communities

### 3.5.1 The numbers of breeding *Larus* gulls and terns at the south-eastern North Sea

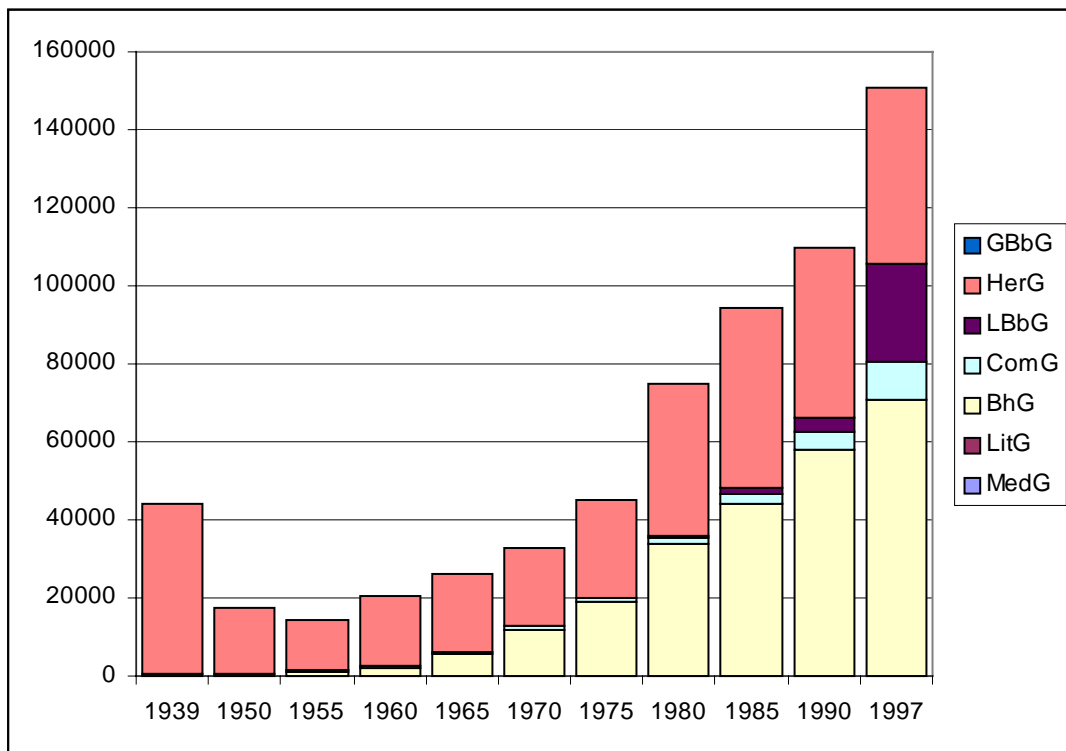
In the south-eastern North Sea, most European species of gulls *Larus* spp. have greatly increased in numbers and/or established new breeding colonies during most of the 20<sup>th</sup> century (Spaans 1998a,b; Garthe *et al.* 2000). In several of these species, most notably the black-headed, herring and lesser black-backed gulls, population increases have at times been very drastic. Such 'explosions' in the population have however only occurred in The Netherlands when control measures relaxed or when e.g., systematic eggging in dune areas had ceased. It has been widely assumed that the (human influenced) food availability of these birds has improved over time (e.g., discards, rubbish tips, littered beaches). Owing to control measures, gull numbers have been kept artificially low for most of the last century so that the carrying capacity of the area may have been much greater than has so far been reflected in numbers of nesting gulls. At present, several breeding populations of gulls are under pressure from predation by mammals and/or disturbance due to increased tourism. The main aspects influencing the increase and decrease of nesting gulls in the south-eastern North Sea might be summarised as follows (not in order of importance):

**Table 3.1.** Main factors influencing the increase and decrease of nesting gulls in the SE North Sea

|                             |                                  | Effect on population          | Scale   |
|-----------------------------|----------------------------------|-------------------------------|---|
| Exploitation<br>Persecution | eggging                          | negative                      | widespread, mainly early 20 <sup>th</sup> century   |
|                             | culling<br>killing adults        | negative<br>strongly negative | until late 1970s in Germany, until late 1960s in Netherlands<br>localised   |
| Predation                   | clutches, chicks<br>adults       | negative<br>strongly negative | widespread on mainland since late 1970s<br>occasional   |
| prey availability           | rubbish tips<br>littered beaches | positive<br>positive          | widespread, mainly 1960s-1980s, most covered up since<br>widespread since 1970s, mainly common, black-headed and herring gulls                    |
|                             | discards in commercial fisheries | positive                      | progressive increase throughout 20 <sup>th</sup> century, steep increase since 1960s, perhaps decline since late 1980s.                           |
|                             | eutrophication of coastal waters | positive                      | increase after 1945 and significantly in 1970s, phosphate decreased in 1980s, but this did not decrease N/P ratio, nitrogen levels remained high. |
|                             | agricultural development         | positive                      | gradual change throughout the 20 <sup>th</sup> century, particularly strong since the 1960s   |
| breeding habitat            | overfishing of small fish        | negative                      | increase throughout 20 <sup>th</sup> century, shortly interrupted during 2 <sup>nd</sup> World War leading to recovery of fish stocks             |
|                             | overfishing of predatory fish    | positive                      | increase throughout 20 <sup>th</sup> century, shortly interrupted during 2 <sup>nd</sup> World War leading to recovery of fish stocks             |
|                             | disturbance national parks       | negative<br>positive          | increased tourism, particularly since 1960s since since mid-1980s in Germany  |
| chemical pollution          | adults, clutches, chicks         | negative                      | 1950s-1980s   |

Table 3.2 is an attempt to quantify the possible impact of each of these factors on gulls in the south-eastern North Sea. It appears that gull populations must have been under severe pressure during the first half of the 20<sup>th</sup> century, mainly as a result of exploitation and persecution. The drastic increases in numbers could be anticipated from the 1960s onwards, on, in response to the relaxation of persecution and increased food supplies from commercial fisheries, rubbish tips and agriculture. This situation is apparently continues, although predation and disturbance are increasingly important as factors suppressing these trends.

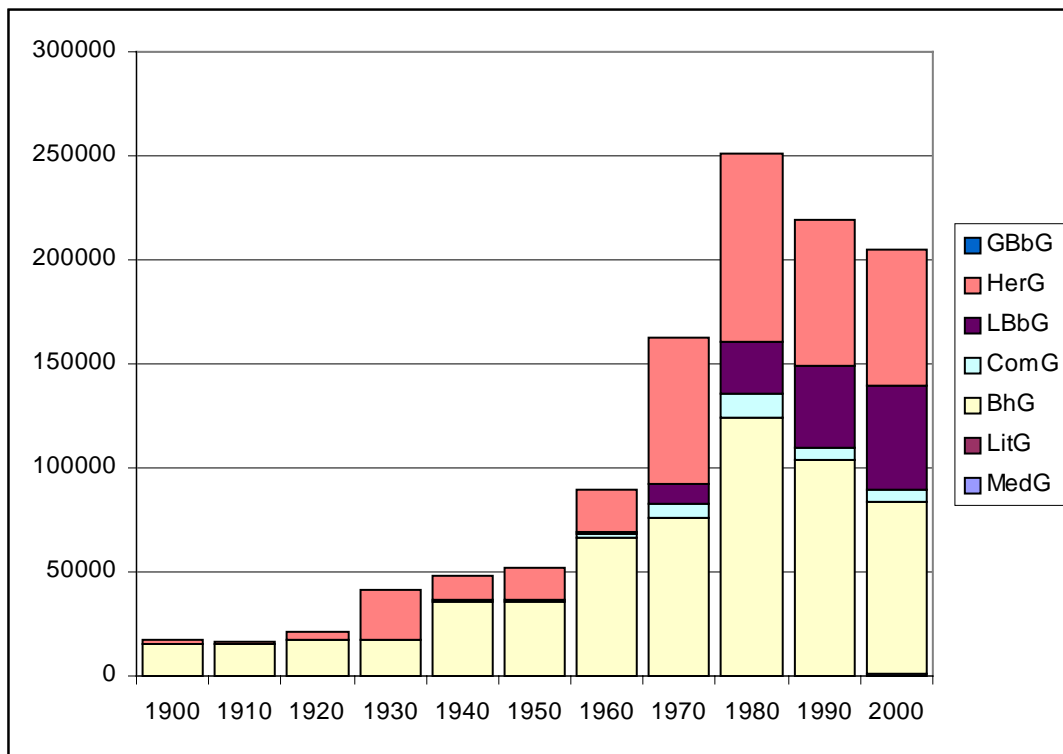
The overall population trends of gulls observed in Germany and The Netherlands do in fact match up quite well with this pattern, although there are differences between species that require further explanation (Figures 3.2–3.5). Black-headed and herring gulls have dominated the area during most of the 20<sup>th</sup> century, with colonisation of new areas by common and lesser black-backed gulls and a very few great black-backed gulls in recent years.



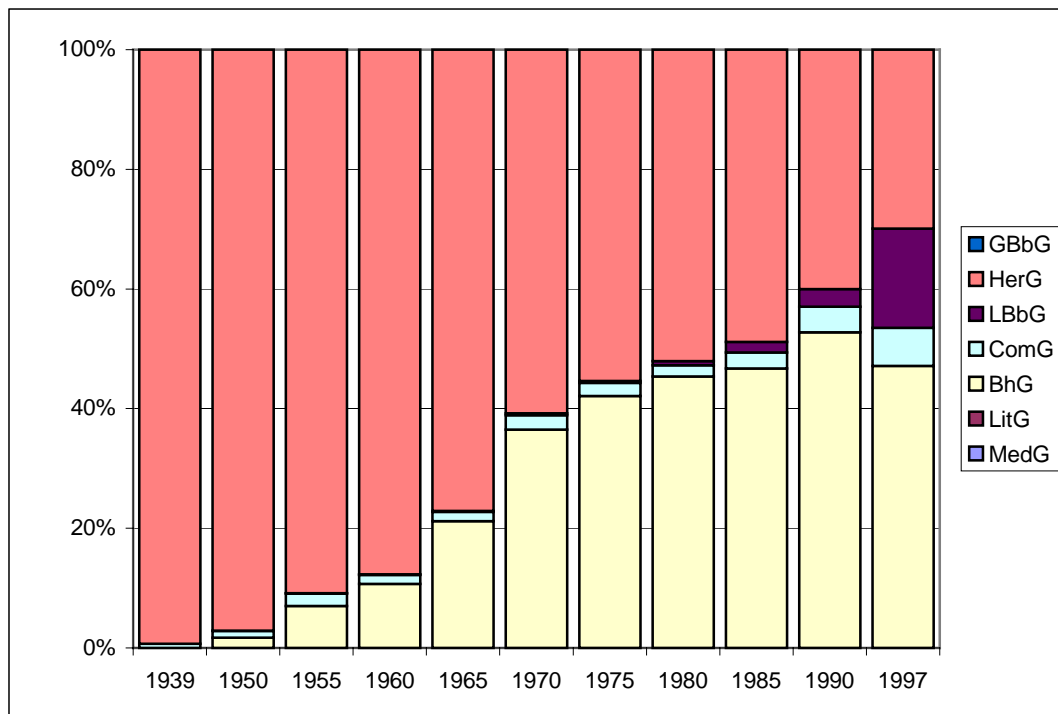
**Figure 3.2.** Population trend and species composition of gulls nesting in coastal areas of the North Sea in Germany (data after Schulz, 1947, and Garthe *et al.*, 2000). Y-axis represents numbers of breeding pairs.

**Table 3.2.** Possible impacts of factors listed in Table 3.1 on gulls in SE North Sea.

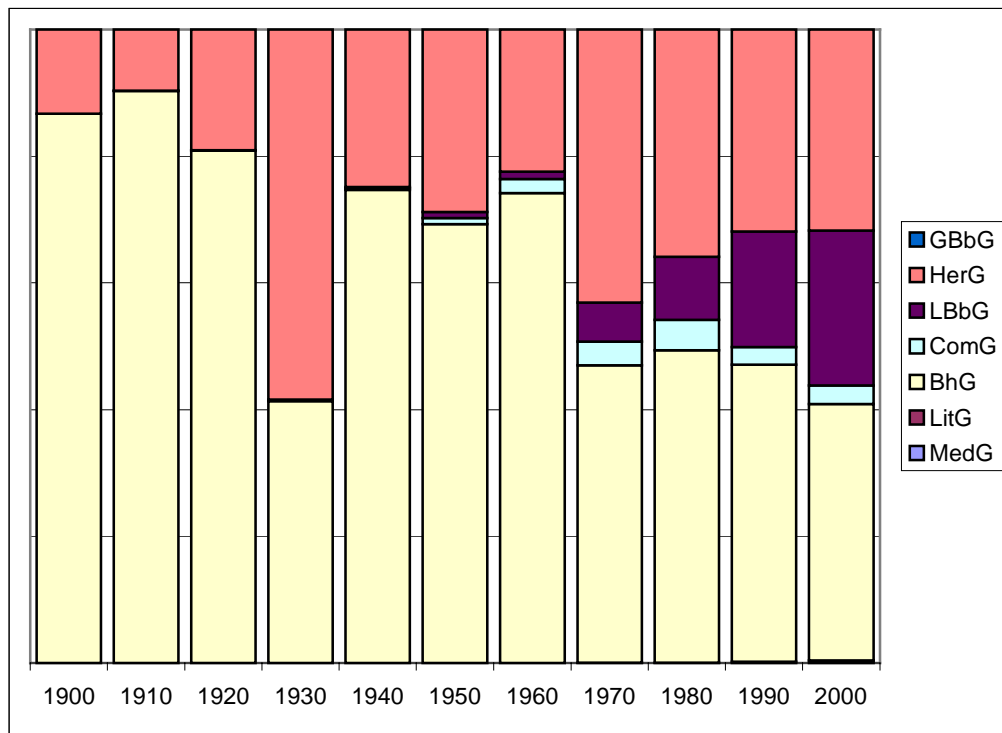
| Decade | Exploitation |         |                | Persecution |        | Predation    |                  | Prey availability |                |              |                             |                | Breeding grounds |                |           |      | Overall trend |
|--------|--------------|---------|----------------|-------------|--------|--------------|------------------|-------------------|----------------|--------------|-----------------------------|----------------|------------------|----------------|-----------|------|---------------|
|        | Egging       | Culling | Killing adults | Eggs Chicks | Adults | Rubbish tips | Littered Beaches | Discards          | Eutrophication | Agri-culture | Overfishing<br>Prey species | Predatory fish | Disturbance      | Nature Reserve | Pollution |      |               |
| 1900   | -            | --      |                |             |        |              |                  |                   |                |              | -                           |                |                  |                |           | ---  |               |
| 1910   | -            | --      |                |             |        |              |                  |                   |                |              | -                           | +              |                  |                |           | ---  |               |
| 1920   | -            | --      |                |             |        |              |                  |                   |                |              | -                           | +              |                  |                |           | ---  |               |
| 1930   | -            | --      | -              |             |        |              |                  |                   |                | +            | -                           | +              |                  |                |           | ---  |               |
| 1940   | --           | --      | -              |             |        |              |                  |                   | +              | +            | -                           | +              |                  |                | -         | ---- |               |
| 1950   |              | --      | -              |             |        |              |                  | +                 | +              | +            |                             |                |                  |                | -         | -    |               |
| 1960   |              | --      | -              |             |        | ++           | +                | +                 | +              | +            | --                          | ++             | -                |                | --        | +    |               |
| 1970   |              | -       | -              | -           | -      | ++           | +                | ++                | ++             | ++           | --                          | ++             | -                |                | -         | ++   |               |
| 1980   |              | -       |                | --          | -      | +            | +                | ++                | ++             | ++           | --                          | ++             | -                | +              | -         | ++   |               |
| 1990   |              |         |                | --          | -      |              | +                | ++                | ++             | ++           | -                           | +              | -                | +              |           | +    |               |



**Figure 3.3.** Population trends and species composition of gulls nesting in coastal areas in the Netherlands (data after Meininger and Flamant, 1998, Koks, 1998, van Dijk, 1998, Keijl and Arts, 1998, Spaans, 1998 a and b). Y-axis represents numbers of breeding pairs.



**Figure 3.4.** Species composition (% of all coastal nesting individuals) of gull at the North Sea coast of Germany (references as in Figure 3.2.).



**Figure 3.5.** Species composition (% of all coastal nesting individuals) of gull in The Netherlands (references as in Figure 3.3.)

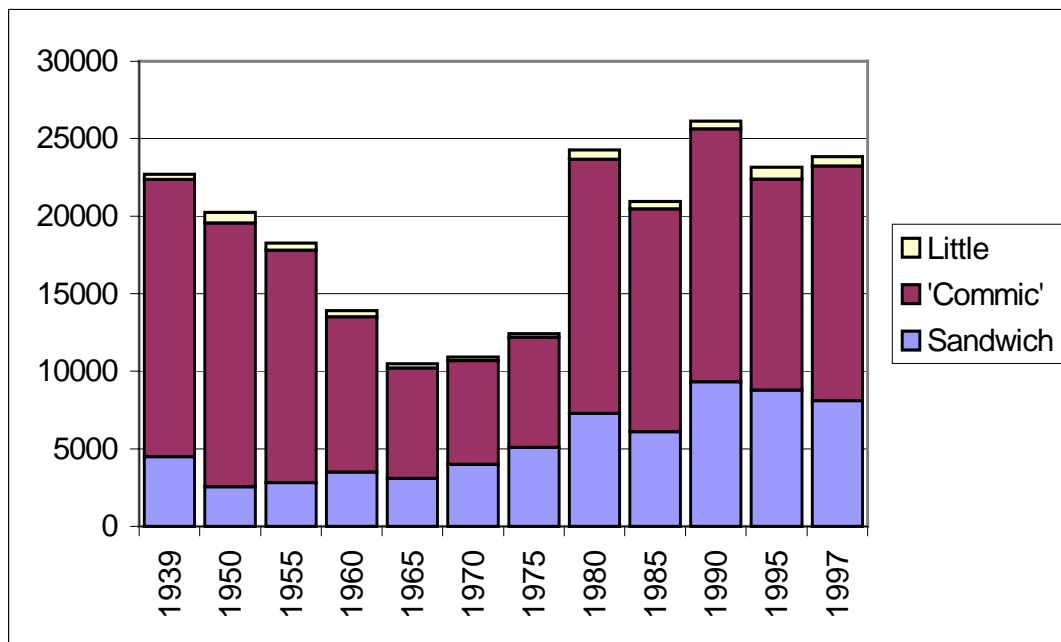
Perhaps the most important fishery induced impact on gull populations has been caused by the production of discards from commercial fisheries. The amounts of discards and offal in the North Sea offshore fisheries were estimated by Garthe *et al.* (1996) from published data and from unpublished statistics. In addition, Garthe *et al.* (1999) quantified discards in the coastal shrimp fisheries on the basis of calculations by Walter (1997). In total, approximately 1 million tonnes of biota is discarded every year by commercial fisheries in the North Sea. The fisheries in which discards are discharged at the highest rate are beam trawl fisheries (Camphuysen *et al.*, 1995; Garthe and Damm, 1997). The species of seabirds profiting most from discards and offal of these beamtrawl fisheries are several species of gull, most notably herring and lesser black-backed gulls (Camphuysen *et al.*, 1995). Several of the smaller species such as black-headed and common gulls are more numerous in inshore waters, notably in shallow areas such as the Wadden Sea (Garthe, 1997). Most of these gulls, however, produce more offspring in seasons when their natural prey is available and are consumed in abundance than in years when discards form the greater part of their diet (e.g., Spaans *et al.* 1994).

Reducing the amount of discards available to scavenging seabirds might increase the predation pressure on other, non-scavenging, seabird species (Furness, 1992). On the island of Trischen (Germany) the predation and kleptoparasitism by black-headed gulls on terns is considerably higher in times when discards from the local shrimp fishery are not available (Hälterlein, 1996). Substantial effects of discard availability were observed at least in herring and great black-backed gulls wintering on the island of Helgoland. When cod fishery discards were available close to the island, 83 to 87% of the gulls' pellets contained discard remains (70 to 73% of all pellets consisted even exclusively of these). At times when no nearby trawling took place, numbers of herring gulls dropped by up to 86% and numbers of great black-backed gulls by up to 80%. Adults of both gull species had a significantly lower body mass during periods of no fishing around the island (13 and 24% less, respectively). Effects on gull winter mortality and thus on population dynamics can be assumed (Hüppop and Wurm 2000).

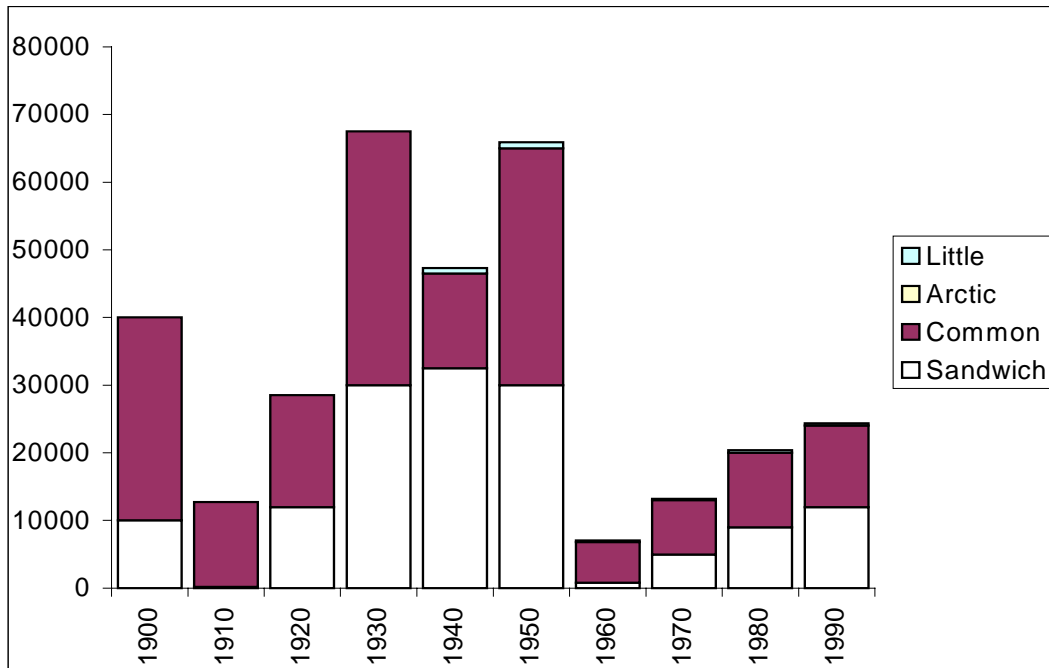
In conclusion, gulls in the south-eastern North Sea have obviously benefited considerably from fishery induced changes in food supply, but the effects coincided with several important aspects either stimulating or suppressing further growth of the population. In the absence of detailed studies and with the impracticability of controlled experiments, the extent to which fishing activity has contributed to these trends are very difficult to judge. The species composition in the south-eastern North Sea gull breeding community has changed considerably over time, with a tendency to much higher numbers and increased diversity in the last decades. During the 1990s in The Netherlands, numbers reached a plateau in some species, and levelled off in others, while new species colonised the country and lesser black-backed gulls were still increasing rapidly (Spaans 1998a,b). In Germany, there have so far been only signs of such a levelling off in the

population of herring gulls in Niedersachsen (bordering The Netherlands; 13% decline between 1993 and 1997; Garthe *et al.* 2000). It is important to note that the increase in some species of gull is certainly not due to fisheries. This is best illustrated by the increase in Western Europe of Mediterranean gulls *Larus melanocephalus*, a species with strictly terrestrial feeding habits, certainly in the breeding season, and which spends the winter in areas away from the main fisheries in south-western Europe (Meininger and Flamant 1998). Furthermore, most waders breeding in the Wadden Sea have increased in numbers simultaneously (e.g., Hälterlein, 1996), although they do not feed on fish and discards.

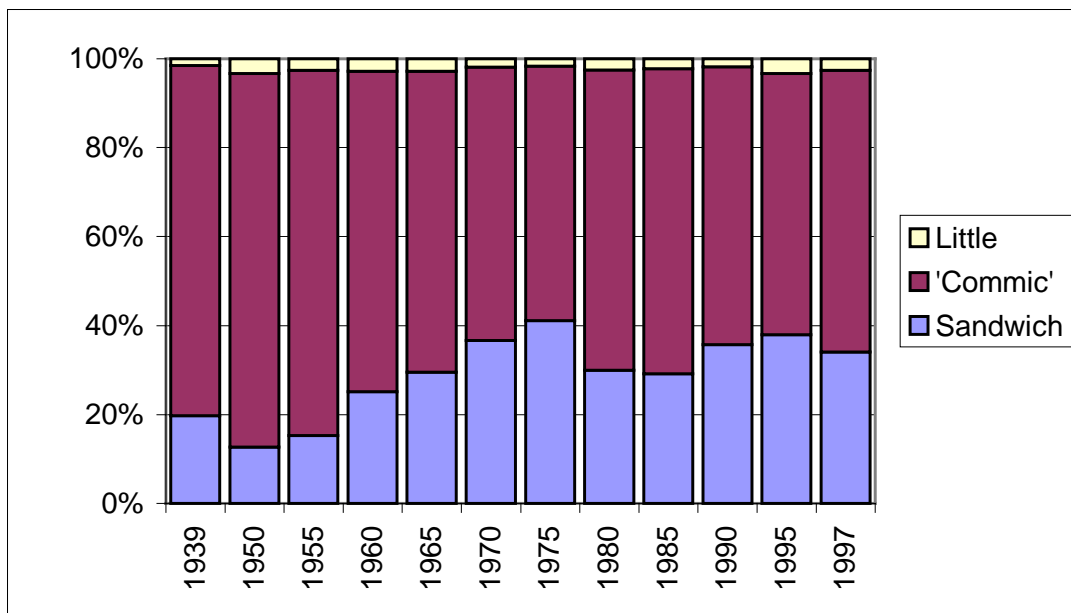
Since the tern species breeding on the Wadden Sea coast are very different in their food and foraging habits, they might offer an opportunity to use their breeding numbers as indicators of food availability. However, as with gulls, their population development is influenced by a variety of factors at a time. Both in The Netherlands and in Germany, numbers of common and Arctic terns decreased considerably in the 1950s and 1960s (Figs. 3.6.-3.9.). The same holds true for the Sandwich tern in The Netherlands, whereas its numbers at the German North Sea even increased throughout this period (e.g., Glutz von Blotzheim and Bauer, 1982, Becker and Erdelen, 1987). The dramatic decrease in the 1950s and 1960s was most probably caused by contamination of the southern North Sea by chlorinated hydrocarbons from a Dutch factory (Becker and Erdelen 1987, Südbeck *et al.* 1998). Although the populations of common and Arctic terns recovered quickly in the early 1980s, numbers did not reach the level before World War II. In contrast, the numbers of breeding Sandwich terns in Germany did not show the pollution related decrease but instead doubled from 1939 to the late 1990s.



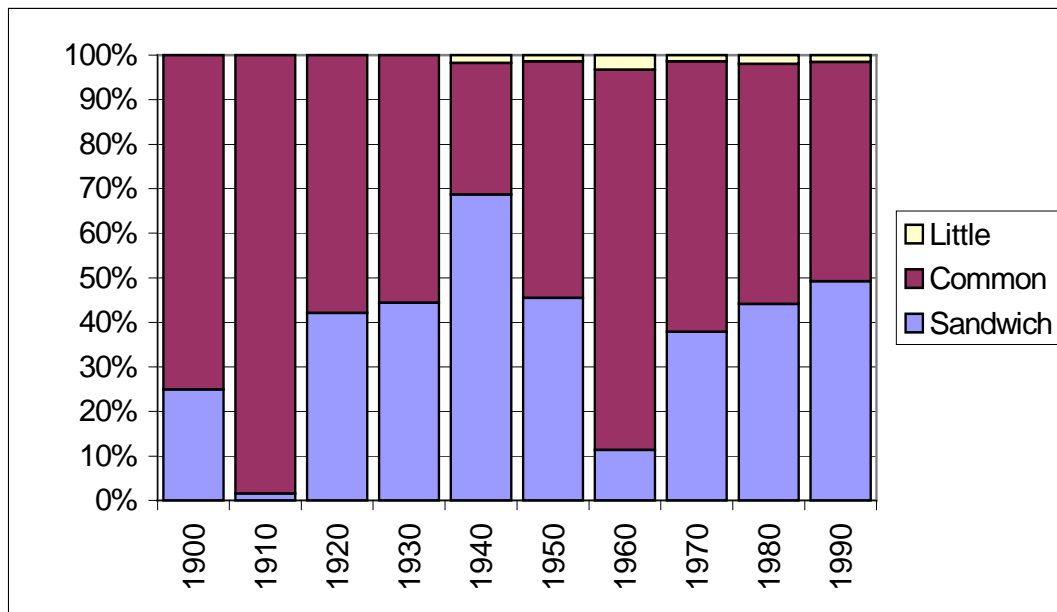
**Figure 3.6.** Population trends and species composition of terns nesting in coastal areas of the North Sea in Germany (data after Schulz, 1947, Becker and Erdelen, 1987, Behm-Berkelmann and Heckenroth, 1991, Hälterlein, 1996, Südbeck and Hälterlein, 1997 and 1999, Südbeck *et al.* 1998). (Commic = common/Arctic).



**Figure 3.7.** Population trends and species composition of terns nesting in coastal areas of the Netherlands (data after Brenninkmeijer and Stienen., 1992, and Stienen and Brenninkmeijer, 1992). Y-axis represents numbers of breeding pairs.



**Figure 3.8.** Species composition (% of all coastal nesting individuals) of tern at the North Sea coast of Germany (references as in Figure 3.6.). Y-axis represents numbers of breeding pairs. (Commic = common/Arctic).



**Figure 3.9.** Species composition (% of all coastal nesting individuals) of tern in coastal areas of The Netherlands (references as in Figure 3.7.).

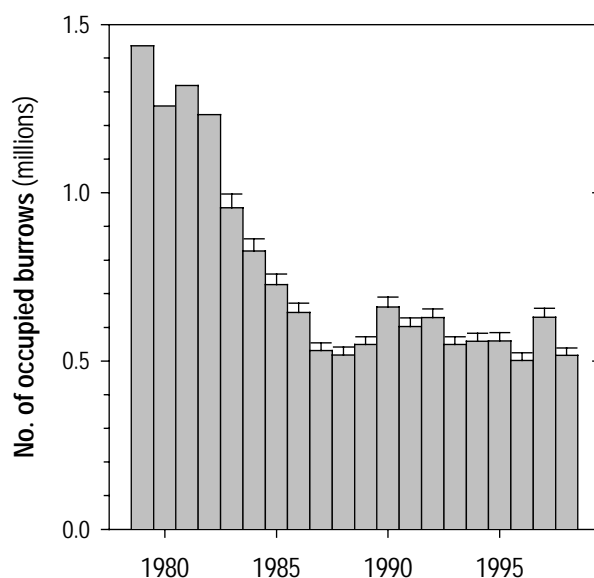
The steep increase in numbers of the common/Arctic terns at the beginning of the 1980s coincides with the rehabilitation of herring stocks in the North Sea (Dornheim and Wegner 1998). Despite a continued improvement in herring stocks and despite the fact that the IBTS herring index is correlated with the nesting success of common terns in the German Wadden Sea (Greenstreet *et al.*, 1999), surprisingly the common/Arctic terns showed no further increase. However, the decrease in the herring index in the early 1990s was followed by a slight decrease in numbers of nesting of common terns. This supports the assumption that a reduction in food availability is responsible for the slight recent decrease (Südbeck *et al.* 1998). In contrast, the numbers of Arctic terns breeding on the German North Sea coast remained fairly stable. This tern species has a broader food spectrum, namely it takes more crustaceans (Glutz von Blotzheim and Bauer, 1982, Niedernostheide, 1996). Thus it is likely that it was less affected by a decreasing availability of herring.

In contrast to common and Arctic terns, the German North Sea population of the Sandwich tern was virtually unaffected by changes in the herring stock, since the massive increase in Sandwich terns started about 10 years earlier than the recovering of the herring (e.g., Südbeck and Hälterlein, 1997). In the southern North Sea, this tern species almost exclusively preys on clupeids and sandeels (e.g., Glutz von Blotzheim and Bauer 1982, Garthe and Kubetzki 1998). Hence, the increase in numbers could be related to an possible increase in sandeel stocks in the south-eastern North Sea that might be caused by e.g., a reduction of the predatory fish species or by eutrophication. Once again it is impossible to prove any effects of fisheries on community structure.

### 3.5.2 Prey stock depletion

More than one million pairs of Atlantic puffins breed in the Lofoten area (NW Norway) and along the coast adjacent to the Norwegian coastal current north of the main spawning areas of the Norwegian spring-spawning herring stock. First-year herring was an important food for these birds in the 1950s (Myrberget 1962). In the late 1960s, this herring stock collapsed completely, as a combined effect of overfishing and poor recruitment (Jakobsson, 1985). For the next twenty years, the stock remained at a very low level. Although the very strong year class of 1983 led to a substantial increase in 1988 (Hamre 1994), the stock was not fully recovered until the late 1990s when several good year classes recruited into the spawning population (Röttingen 1998). During the first three decades following the collapse, the breeding success of puffins in the large colonies at Røst in the Lofoten Islands was successful in seven season only, while in the other years most or all nestlings died from starvation (Lid, 1981; Anker-Nilssen 1987, 1992, 1998). Puffins, as with most other seabirds, are long-lived and adapted to withstand years with poor feeding conditions, however, it is not surprising

that this exceptional series of production failures have affected the number of breeding birds in the area. During the 1980s, the population of breeding puffins at Røst declined at 13.7% per annum and levelled off at only about 35% of its previous level and although it has since remained relatively stable, a further decrease is now expected due to the annual breeding failures in 1993–98 (Anker-Nilssen 1998).



**Figure 3.10.** Population development (number of apparently occupied nest burrows  $\pm$  1 SE) of Atlantic puffins at Røst, N Norway in 1979–1998. Anker-Nilssen (1998).

Jensen *et al.* (1994) studied the overlaps between the distributions of fish (sandeel and sprat), three auk species (common guillemot, razorbill, puffin) and the fisheries for these fish at a relatively large scale in the North Sea. There were significant positive correlations between bird and fish distribution in the third quarter of the year, with most of the association being in the north-western North Sea. There were some associations between birds and the fisheries, that indicated that at a large scale some fisheries and some birds were exploiting the same fish species in the same place, but at different times of year. An example of this was that fisheries for sprat in the southern North Sea took place mostly in the autumn, but there was greater spatial overlap between the two in winter. This study illustrated also the difficulty of comparing data collected at different scales for different purposes, and therefore highlighted a problem in demonstrating the competitive impact of fisheries on seabirds. However, fishery impacts at these harvest levels could be cumulative, and potential effects on seabird populations might be lagged in time.

In the most intensively studied seabird-sandeel interaction, certain seabirds, particularly surface feeding Arctic terns and black-legged kittiwakes, suffered a series of years with very poor breeding in Shetland in the 1980s. Birds in this area are entirely reliant on sandeels during the breeding season. This decline was again coincident with an increase in catch from local sandeel grounds. Research however indicated that fisheries were unlikely to be the cause of the decline in sandeel abundance. There was considerable fluctuation in recruitment of sandeels following a closure of the local fishery. A more likely candidate in this case was connected with the recruitment mechanisms of sandeels occurring in the area (Wright and Bailey, 1993; Wright, 1996). This case highlighted the importance of fluctuations in year class strength and in understanding the prey population structure in an area before any potential effects of fisheries can be understood.

### 3.5.3 Depletion of shellfish stocks

In the early 1990s, the Dutch sector of the Wadden Sea was cleared of old mussel banks and 100% of the high-density cockle banks were removed (Beukema and Cadée, 1996). Common eiders and oyster catchers suffered extra mortality in 1991, due to acute food shortages (Camphuysen, 1997). Wintering eiders have sought refuge in later years in the coastal North Sea waters, mixing with common scoters over *Spisula* banks and competing for prey in these waters (Leopold and Dankers, 1997). Oyster catcher populations in the eastern Wadden Sea declined, largely as a result of recruitment failures of post-1990 cohorts into the breeding population (D. Heg, personal communication).

### 3.5.4 Increases in prey stocks as a consequence of depletion of stocks of larger fish and marine mammals

An effect of the reduction in stocks of large fish by fisheries has been to reduce competition for the prey of some seabirds. Populations of diving seabirds in the North Sea and around the United Kingdom and Ireland increased dramatically during the 20th century (Lloyd *et al.* 1991; Table 3.3). Some of this, as mentioned before, may have been a response to the cessation of seabird hunting at the end of the 19<sup>th</sup> century, but the duration of this increase indicates other causes. The increased proportion of small fish in the North Sea in comparison with the Faroe Bank (Pope and Knights 1982) and Georges Bank (Pope *et al.* 1988) was attributed to a possible direct consequence of the more intense harvesting in the North Sea. Sherman *et al.* (1981) considered that sandeel stocks had increased in the North Sea and in the western Atlantic shelf seas as a response to reduced competition with herring and mackerel. In the Barents Sea, an increase in capelin may have occurred through over-fishing of their main predator, herring (Hamre 1988, 1991, Gjøsæther 1998). It is possible that the increases in kittiwakes and guillemots in the southern Barents Sea between 1960 and 1990 can be attributed to this superabundance of capelin in the region (Figs. 3.1 and 3.11, Krasnov and Barrett 1995). However, there is no compelling evidence for this relationship in the northwest Atlantic (Carscadden and Nakashima 1997), perhaps due to the complexity of direct and indirect effects in marine food webs (Lavigne 1996) or to oceanographic effects (Frank *et al.* 1996).

**Table 3.3.** Changes in numbers and relative abundance of seabirds breeding in the United Kingdom and Ireland between the early 1970s and the mid 1980s. Only those species with relatively reliable census figures are included.

| Species                  | 1969–71<br>population | 1969–71 % of<br>all birds | 1985–87<br>population | 1985–87 % of<br>all birds | population<br>change |
|--------------------------|-----------------------|---------------------------|-----------------------|---------------------------|----------------------|
| Northern fulmar          | 309 000               | 14.2                      | 571 000               | 20.5                      | +                    |
| Northern gannet          | 138 000               | 6.3                       | 188 000               | 6.8                       | +                    |
| Great cormorant          | 8 000                 | 0.4                       | 10 000                | 0.4                       | +                    |
| European shag            | 34 000                | 1.6                       | 47 000                | 1.7                       | +                    |
| Arctic skua              | 1 000                 | >0.1                      | 3 000                 | 0.1                       | +                    |
| Great skua               | 3 000                 | 0.1                       | 8 000                 | 0.2                       | +                    |
| Black-headed gull        | 75 000                | 3.4                       | 84 000                | 3.0                       | +                    |
| Common gull              | 13 000                | 0.6                       | 16 000                | 0.6                       | +                    |
| Lesser black-backed gull | 50 000                | 2.3                       | 64 000                | 2.3                       | +                    |
| Herring gull             | 335 000               | 15.4                      | 191 000               | 6.9                       | -                    |
| Great black-backed gull  | 23 000                | 1.0                       | 23 000                | 0.8                       | ±                    |
| Kittiwake                | 447 000               | 20.6                      | 544 000               | 19.6                      | +                    |
| Sandwich tern            | 12 000                | 0.5                       | 18 000                | 0.7                       | +                    |
| Roseate tern             | 2 500                 | 0.1                       | 500                   | 0.0                       | -                    |
| Common tern              | 15 000                | 0.7                       | 15 000                | 0.5                       | ±                    |
| Arctic tern              | 52 000                | 2.4                       | 80 000                | 2.9                       | +                    |
| Little tern              | 2 000                 | 0.1                       | 3 000                 | 0.1                       | +                    |
| Guillemot                | 550 000               | 25.3                      | 806 000               | 29.0                      | +                    |
| Razorbill                | 103 000               | 4.7                       | 182 000               | 4.4                       | +                    |

Figure 3.11.

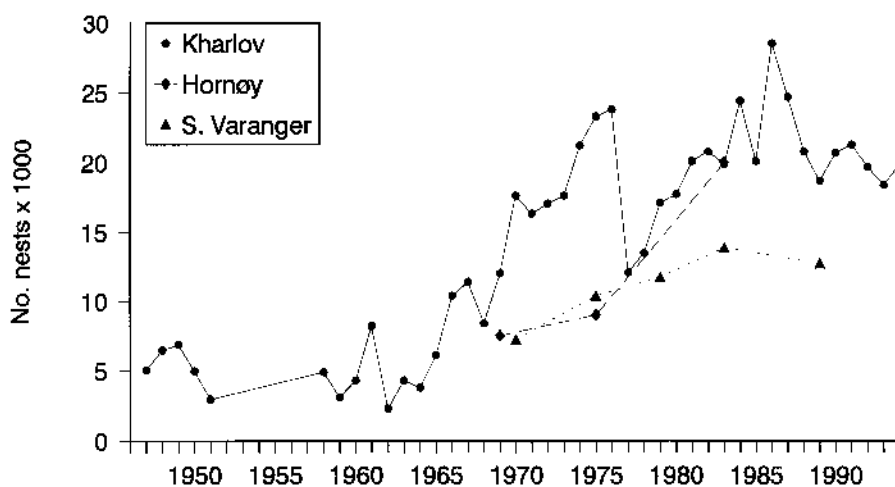


Fig. 6. Changes in the total numbers of breeding Kittiwakes *Rissa tridactyla* (apparently occupied nests) on Hornøy, Kharlov and on 35 colonies in Sør Varanger.

### 3.5.5 Discussion

Both negative and positive impacts of fisheries on seabirds can occur at multiple spatial and temporal scales. Commonly, effects on population abundance are difficult to demonstrate, even if they are very likely to exist. To make things more complicated, a single fishery can potentially have simultaneous positive and negative impacts on a species of seabird. The potential effects of shifts in age and size-structure of fish in the North Sea as a result of overfishing large predatory fish are very difficult to quantify, but are likely to be or have been substantial. Discards and offal as an extra source of food were probably most significantly positive effects for birds like the northern fulmar and several species of gulls.

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## 4 FURTHER ASSESSMENTS OF FOOD CONSUMPTION BY SEABIRDS IN THE ICES AREA

### 4.1 Introduction

Building on its efforts in 1999, the Working Group refined its models of seabird consumption in areas away from the North Sea (see Tasker and Furness, 1996). The specific regions included are the Gulf of St. Lawrence (NAFO Areas TSR), the Northwest Atlantic (NAFO Areas 2J3KLNOPs), the Barents Sea (ICES Area I and eastern parts of IIa and IIb), the Norwegian Sea (ICES Area IIa) and the Baltic (ICES Area III minus Skagerrak). Efforts were made to integrate models from the different regions into a single compatible one to facilitate comparative analyses and communication. The aim is to eventually compare seabird consumption in all ICES and NAFO areas.

The models integrated data on i) populations, including breeders, chicks, nonbreeders and migrants that breed outside but spend considerable periods of time within these ICES and NAFO areas, ii) estimated daily field metabolic rates (FMR), iii) occupancy dates and iv) diets. Many of these data inputs, such as those involving populations and diets are constantly being revised, and diets are often quite incompletely known outside breeding seasons.

### 4.2 Model inputs

#### 4.2.1 Numbers of birds

To estimate numbers of nestlings and pre-breeders, the species were classified according to whether they lay single or multiple egg clutches, and empirical calculations based on breeding pairs (bp) (single-egg species =  $(bp \times 0.6) + (bp \times 0.7)$ ; multi-egg species =  $(bp \times 0.6) + (bp \times 1)$ ) were adopted. These calculations assume that numbers of non-breeders (immatures or deferred breeders) are equivalent to 30% of the breeding population and that the fledging success of single-egg and multi-egg clutch species is 0.7 and 1.0 chicks/pair respectively. Approximate occupation dates for breeding and non-resident populations in each area were estimated for each species.

#### 4.2.2 Energy expenditure

Values for body mass for Norwegian seabirds were taken from Barrett (unpubl., northern gannet, shag, black-legged kittiwake, razorbill, common and Brünnich's guillemot, and Atlantic puffin), Barrett and Anker-Nilssen (1997, black guillemot), Cramp and Simmons (1977, great cormorant) and from the 1999 ICES Seabird Ecology Group Report. For Canadian birds, values were taken from last year's report, and for the Baltic Sea from Bezzel (1985).

Basal metabolic rate was estimated using Gabrielsen's (1994) allometric equations for Procellariiformes ( $BMR=377.9m^{0.705}$ , m in kg) and for seabirds using flapping flight in cold waters (the rest,  $BMR=455.1m^{0.746}$ , m in kg). Field metabolic rate within the breeding season was estimated for Procellariiformes using Nagy *et al.*'s (1999) allometric equation ( $FMR=18.4m^{0.599}$ , m in g) and for the remaining species using Birt-Friesen *et al.*'s (1989) allometric equations for seabirds using flapping flight in cold waters ( $FMR=11.455m^{0.727}$ , m in g). The length of the breeding season was estimated as incubation period + fledging period (as given in Cramp and Simmons, 1977, 1983; Cramp, 1985) + 20 days. Outside the breeding season FMR was estimated as 2.5 x BMR. The overall energy-expenditure for breeding seabirds in each area was thus calculated separately within the breeding season (using the largest FMR values) and outside the breeding season, and for non-breeding birds throughout the period they occupied the area in question using the reduced FMR values. These were summed to give the overall energy-expenditure for all seabirds in each region during the year.

#### 4.2.3 Food consumption

To calculate the overall food consumption, we used published information on diet composition of each species in each region. Most studies have been at breeding colonies during summer and little is known of the diets outside this period. Estimates of food consumption should thus be interpreted cautiously when applied to the complete period in which the species occupies the area. The assessment of seabird diet by numbers of prey items or by frequency of occurrence, as is common in dietary papers makes it difficult to estimate the biomass of prey consumed by seabirds (Tasker and Furness, 1996). We tried to avoid such information in the model but in some cases this was the only information available. The input parameters to the model and their sources and assumptions for each region are given in Tables 4.3, 4.5 and 4.9. For each region, the diet was divided into three categories, fatty fish (e.g., capelin, herring, sandeels, mackerel, etc.), lean fish (cod, saithe, etc.) and invertebrates. The mean energy density values applied to each of these categories varied from region to region, and are summarised in Table 4.1. An assimilation efficiency of 75% was also assumed (Brekke and Gabrielsen, 1994, Tasker and Furness, 1996). The output of the model includes only prey items taken from the sea, and none of the terrestrial prey.

**Table 4.1.** Values of energy densities of food items used in the consumption models for each region.

| Region               | Fatty fish | Other fish | Invertebrates |
|----------------------|------------|------------|---------------|
| Barents Sea          | 6          | 5          | 4.5           |
| Norwegian Sea        | 6          | 5*         | 4.5           |
| Gulf of St. Lawrence | 7          | 3          | 3             |
| Northwest Atlantic   | 4.5        | 3          | 3             |
| Baltic Sea           | 6          | 5          | 4.5           |

\*For puffins a value of 4 was used due to the small size of their main prey in this region, 0-group herring.

### 4.3 Studies off eastern Canada

Previous models of energy use by seabirds in eastern and Arctic Canada (Cairns *et al.* 1991; Diamond *et al.* 1993) permitted estimation of energy requirements in different oceanographic areas and comparison between these areas. For example, Diamond *et al.*'s (1993) model demonstrated that year-round energy demand by seabirds in the Northwest Atlantic (NWA) was mainly from non-breeding birds, especially populations breeding in the Northeast Atlantic and in the southern hemisphere. However, in the Gulf of St. Lawrence the year-round energy consumption was close to an estimate already based on breeding birds alone (Cairns *et al.*, 1991), illustrating the relatively small impact of the few number of trans-oceanic and trans-equatorial migrants in this area (Brown, 1986).

In this section, the breeding populations of the seabird species in the Gulf of St. Lawrence and Northwest Atlantic (NWA), together with data on energy expenditure, occupancy dates and diet, provide the basis for estimating food consumption by these populations. For the NWA, trans-oceanic and trans-equatorial migrants are also considered in the estimate of energy demands. The estimates include many assumptions and uncertainties regarding the sizes of the breeding populations, particularly for gull species in the Gulf and NWA, winter diets, etc.

#### 4.3.1 Gulf of St. Lawrence (NAFO Areas TSR)

The Gulf of St. Lawrence is 214 000 km<sup>2</sup> in extent (Steven, 1975). The breeding populations were taken from BIOMQ (Banque Informatisée des Oiseaux Marins du Québec) and from Chapdelaine and Brousseau (1992), Lock *et al.* (1994) and Chapdelaine (1995, 1996). We estimated that 30 % of the numbers of breeding birds were pre-breeders and nonbreeders, and we estimated that production for species producing 1-egg clutches was 0.7 fledglings per pair and that production for species producing clutches of 2+ eggs was 1.0 fledgling per pair (Cairns *et al.*, 1986). Estimates of seabird biomass were based on the body masses in Birt-Friesen *et al.* (1989) and Cairns *et al.* (1990). Approximate occupation dates, population estimates in pairs and number of birds (breeders, nestlings and nonbreeders) identified as total population using the breeding areas (TPA) are presented in Table 4.2.

**Table 4.2.** Estimated prey consumption by seabirds in NAFO Areas 4RST, Gulf of St. Lawrence.

| Species                  | Body mass<br><i>g</i> | Total population |                     |             | Period present | Breed. season<br><i>days</i> | FMR ( <i>kJ/d</i> ) |            | Diet (%)    |               |                    | Total consumption ( <i>tonnes</i> ) |               |                    | Sum          | %          |
|--------------------------|-----------------------|------------------|---------------------|-------------|----------------|------------------------------|---------------------|------------|-------------|---------------|--------------------|-------------------------------------|---------------|--------------------|--------------|------------|
|                          |                       | <i>indivs.</i>   | % by<br><i>nos.</i> | <i>mass</i> |                |                              | bree-<br>ding       | or<br>else | fat<br>fish | other<br>fish | inverte-<br>brates | fat<br>fish                         | other<br>fish | inverte-<br>brates |              |            |
| Leach's storm-petrel     | 50                    | 1709             | 0.1                 | 0.0         | 0.5            | 130                          | 192                 | 114        | 0           | 0             | 100                | 0                                   | 0             | 20                 | 20           | 0.0        |
| Northern gannet          | 3200                  | 178200           | 12.9                | 38.6        | 0.58           | 150                          | 4048                | 2709       | 94          | 6             | 0                  | 22184                               | 3304          | 0                  | 25488        | 25.5       |
| Great cormorant          | 2250                  | 8942             | 0.6                 | 1.4         | 0.58           | 100                          | 3134                | 2083       | 20          | 80            | 20                 | 170                                 | 1588          | 397                | 2155         | 2.2        |
| Double-crested cormorant | 1670                  | 140400           | 10.2                | 15.9        | 0.58           | 100                          | 2523                | 1668       | 49          | 51            | 10                 | 5250                                | 12749         | 2500               | 20498        | 20.5       |
| Black-headed gull        | 500                   | 36               | 0.0                 | 0.0         | 0.58           | 80                           | 1050                | 678        | 0           | 10            | 0                  | 0                                   | 0             | 0                  | 0            | 0.0        |
| Ring-billed gull         | 280                   | 120211           | 8.7                 | 2.3         | 0.58           | 100                          | 689                 | 440        | 50          | 50            | 0                  | 1225                                | 2858          | 0                  | 4083         | 4.1        |
| Herring gull             | 1120                  | 172393           | 12.5                | 13.1        | 0.83           | 90                           | 1887                | 1238       | 62          | 29            | 9                  | 8297                                | 9055          | 2810               | 20162        | 20.2       |
| Great black-backed gull  | 680                   | 35050            | 2.5                 | 1.6         | 0.83           | 100                          | 1313                | 853        | 77          | 22            | 1                  | 1460                                | 973           | 44                 | 2478         | 2.5        |
| Black-legged kittiwake   | 440                   | 303754           | 22.1                | 9.1         | 0.58           | 90                           | 957                 | 617        | 93          | 0             | 7                  | 7940                                | 0             | 1394               | 9334         | 9.3        |
| Caspian tern             | 610                   | 40               | 0.0                 | 0.0         | 0.41           | 70                           | 1213                | 787        | 50          | 50            | 10                 | 1                                   | 1             | 0                  | 2            | 0.0        |
| Common tern              | 120                   | 94565            | 6.9                 | 0.8         | 0.41           | 70                           | 372                 | 234        | 64          | 31            | 5                  | 465                                 | 526           | 85                 | 1076         | 1.1        |
| Arctic tern              | 110                   | 3618             | 0.3                 | 0.0         | 0.41           | 70                           | 349                 | 219        | 90          | 10            | 0                  | 23                                  | 6             | 0                  | 30           | 0.0        |
| Common guillemot         | 990                   | 181500           | 13.2                | 12.2        | 0.58           | 70                           | 1725                | 1129       | 100         | 0             | 0                  | 9139                                | 0             | 0                  | 9139         | 9.1        |
| Brünnich's guillemot     | 930                   | 40               | 0.0                 | 0.0         | 0.58           | 70                           | 1648                | 1078       | 97          | 2             | 1                  | 2                                   | 0             | 0                  | 2            | 0.0        |
| Razorbill                | 720                   | 52800            | 3.8                 | 2.6         | 0.58           | 70                           | 1369                | 890        | 100         | 0             | 0                  | 2100                                | 0             | 0                  | 2100         | 2.1        |
| Black guillemot          | 400                   | 17143            | 1.2                 | 0.5         | 1              | 90                           | 893                 | 574        | 36          | 63            | 1                  | 265                                 | 1083          | 17                 | 1365         | 1.4        |
| Atlantic puffin          | 460                   | 66000            | 4.8                 | 2.1         | 0.58           | 110                          | 988                 | 637        | 100         | 0             | 0                  | 1990                                | 0             | 0                  | 1990         | 2.0        |
| <b>Total</b>             |                       | <b>1376401</b>   | <b>100</b>          | <b>100</b>  |                |                              |                     |            |             |               |                    | <b>60511</b>                        | <b>32144</b>  | <b>7268</b>        | <b>99923</b> | <b>100</b> |

**Table 4.3.** Summary of diets (% mass) for seabirds in the Gulf of St. Lawrence.

| Species                  | Diets assumed for the model  | References |
|--------------------------|--|------------|
| Leach's storm-petrel     | 100% invertebrates   | 1          |
| Northern gannet          | 58% mackerel, 4% herring, 10% capelin, 22% sandeel, 6% others                            | 2, 3, 4    |
| Great cormorant          | 20% sandeel, 40% flatfish, 30% cunner, 7% sculpins, 3% others                            | 5          |
| Double-crested cormorant | 6% herring, 18% capelin, 25% sandeel, 15% flatfish, 11% cunner, 10% sculpins, 15% others | 5, 6, 7, 8 |
| Black-headed gull        | n.a.   | n.a.       |
| Ring-billed gull         | 50% capelin, 50% other   | 10         |
| Herring gull             | 1% herring, 58% capelin, 3% sandeel, 9% invertebrates, 29% others                        | 2, 9       |
| Great black-backed gull  | 19% herring, 57% capelin, 1% sandeel, 1% invertebrates, 1% sculpins, 21% others          | 2, 10      |
| Black-legged kittiwake   | 27% capelin, 66% sandeel, 7% invertebrates   | 10, 11     |
| Caspian tern             | n.a.   | n.a.       |
| Common tern              | 33% capelin, 31% sandeel, 5% invertebrates, 31% others                                   | 12, 13     |
| Arctic tern              | 17% capelin, 73% sandeel, 10% invertebrates  | 12         |
| Guillemot                | 97% capelin, 3% sandeel  | 10         |
| Brünnich's guillemot     | n.a.   | n.a.       |
| Razorbill                | 58% capelin, 42% sandeel   | 10, 14     |
| Black guillemot          | 8% sandeel, 1% invertebrates, 33% gadidae, 28% daubed shanny, 30% others                 | 15         |
| Atlantic puffin          | 37% capelin, 63% sandeel   | 10         |

(1) Montevocchi *et al.* (1992); (2) Rail *et al.* 1996; (3) Burton and Pilon (1978); (4) Taylor and Nettleship (1974); (5) Pilon *et al.* (1983); (6) Rail and Chapdelaine (1998); (7) Gallant (1988); (8) Léger and Burton (1979); (9) Rail *et al.* (in prep.); (10) Chapdelaine and Rail (unpubl.); (11) Chapdelaine and Brousseau (1989); (12) Chapdelaine *et al.* (1985); (13) Chalifour (1982); (14) Chapdelaine and Brousseau (1996); (15) Cairns (1981)

#### 4.3.1.1 Seabird populations

The estimate of the total number of seabird breeding pairs in the Gulf of St. Lawrence is about 394 000 and we estimated at  $1.38 \times 10^6$  individuals as the total population of birds using the area. The seabird guild is dominated by black-legged kittiwake (22.1% of total TPA) but their total biomass represents only 9.1%. The northern gannet dominates the seabird biomass with 38.6% and represents 12.9% of total TPA. Common guillemots, herring gulls and double-crested cormorants are the next most important consumers with 13.2%, 12.5% and 10.2% of total TPA and represent 12.2%, 12.1% and 15.9% of the total seabird biomass, respectively.

#### 4.3.1.2 Consumption of food and energy uptake

The northern gannet is the major seabird consumer among the species in the Gulf of St. Lawrence, taking 25.5% of the food biomass (Table 4.2). The double-crested cormorant, herring gull, and black-legged kittiwake follow with 20.5%, 20.2% and 9.3% of the food biomass consumed annually by all seabirds. The annual total prey biomass consumed by the TPA is estimated at 100 000 tonnes. This is the equivalent of  $4.0 \times 10^5$  GJ of energy required by seabirds in the Gulf or  $0.47 \text{ g/m}^2$  ( $1 \text{ g/m}^2 = 1 \text{ t/km}^2$  and entire area is 214 000  $\text{km}^2$ ). Because marine birds are not evenly distributed at sea, the value given for average prey consumption per unit area is not representative of every sector of the Gulf. Cairns *et al.*'s (1991) bioenergetics model subdivided prey type harvest by NAFO Unit Area for the Gulf of St. Lawrence and showed that in general the spatial distribution of seabird consumption followed the pattern of breeding colonies.

#### 4.3.1.3 Estimated prey harvest

Fish accounted for 97.6% of the prey consumption of this community. Capelin and sandeel are consumed by all seabirds and represent the largest prey components, comprising 30.5% (33 000 tonnes) and 21.5% (23 300 tonnes) respectively of the total consumption (Table 4.4). Larid and alcid species are the most important consumers of these small pelagic and schooling fish. Mackerel are preyed only by northern gannet and account for 13.6% (14 500 tonnes). The total benthic and estuarine fish (mainly represented by flatfish, cunners, sculpins) are consumed mostly by great and double-crested cormorant and comprise 8.4% of the annual prey consumption by seabirds.

**Table 4.4.** Estimated prey harvest by seabirds in the Gulf of St. Lawrence.

| Species                  | Pelagic fish |         |         |         | Invertebrates | Benthic and estuarine fish |          |         |          |               | Others  |
|--------------------------|--------------|---------|---------|---------|---------------|----------------------------|----------|---------|----------|---------------|---------|
|                          | Mackerel     | Herring | Capelin | Sandeel |               | Cunner                     | Sculpins | Gadidae | Flatfish | Daubed Shanny |         |
| Leach's storm-petrel     |              |         |         |         | 21.0          |                            |          |         |          |               |         |
| Northern gannet          | 14783.0      | 1019.5  | 2548.8  | 5607.4  |               |                            |          |         |          |               | 1529.3  |
| Great cormorant          |              |         |         | 431.0   |               | 646.5                      | 150.9    |         | 862.0    |               | 64.7    |
| Double-crested cormorant |              | 1229.9  | 3689.6  | 5124.5  |               | 2254.8                     | 2049.8   |         | 3074.7   |               | 3024.7  |
| Black-headed gull        | -----        |         |         |         |               | n.a.                       |          |         |          |               |         |
| Ring-billed gull         |              |         |         | 2041.5  |               |                            |          |         |          |               | 2041.5  |
| Herring gull             |              | 201.6   | 11694.0 | 604.9   | 1814.6        |                            |          |         |          |               | 5847.0  |
| Great black-backed gull  |              | 470.8   | 1412.5  | 24.8    | 24.8          |                            | 24.8     |         |          |               | 520.4   |
| Black-legged kittiwake   |              |         | 2520.2  | 6160.4  | 653.4         |                            |          |         |          |               |         |
| Caspian tern             | -----        |         |         |         |               | n.a.                       |          |         |          |               |         |
| Common tern              |              |         | 355.1   | 333.6   | 53.3          |                            |          |         |          |               | 333.6   |
| Arctic tern              |              |         | 5.1     | 21.9    | 3.0           |                            |          |         |          |               |         |
| Guillemot                |              |         | 8864.8  | 2241.7  |               |                            |          |         |          |               |         |
| Brünnich's guillemot     | -----        |         |         |         |               | n.a.                       |          |         |          |               |         |
| Razorbill                |              |         | 1218.0  | 882.0   |               |                            |          |         |          |               |         |
| Black guillemot          |              |         |         | 109.2   | 13.7          |                            |          | 450.5   |          | 382.2         | 409.5   |
| Atlantic puffin          |              |         | 736.3   | 1253.7  |               |                            |          |         |          |               |         |
| Total prey harvest       | 14783.0      | 5323.3  | 33044.4 | 23295.0 | 2584.2        | 2901.3                     | 2225.0   | 450.5   | 3936.7   | 382.2         | 13820.6 |
| % of tonnes/year         | 14.8         | 5.0     | 33.1    | 20.8    | 2.6           | 3.9                        | 2.2      | 0.4     | 3.9      | 0.4           | 11.1    |

### 4.3.2 Northwest Atlantic (NAFO Areas 2J3KLNOPs)

The area of the Northwest Atlantic considered in this section is estimated at 470 000 km<sup>2</sup> (Lilly and Shelton 2000). For breeding populations of NWA, most information is provided by Nettleship and Evans (1985), Montevecchi and Tuck (1987), Nettleship and Chapdelaine (1988; unpubl.), Cairns *et al.* (1989), Lock *et al.* (1994), Diamond *et al.* (1993), Sklepkovych and Montevecchi (1989), Storey and Lien (1985), Stenhouse and Montevecchi (1999), Chapdelaine and Chardine (unpubl.). Estimates of the proportions of different prey consumed by seabird species are given in Table 4.5. The NWA is frequented by large numbers of migrants so an estimate of energy use by this group of seabirds was done separately.

**Table 4.5.** Summary of diets (% mass) for seabirds in the Northwest Atlantic.

| Species                  | Diets assumed for the model  | References   |
|--------------------------|--|--------------|
| Northern fulmar          | 50% capelin, 20% squid, 10% discards   | 18           |
| Manx shearwater          | n.a.   | n.a.         |
| Leach's storm-petrel     | 55% myctophid, 30% amphipods, 10% euphausiid, 5% other   | 1            |
| Northern gannet          | 35% mackerel, 35% capelin, 15% herring, 10% saury, 3% squid, 2% sandeel, 2% Atlantic salmon, 1% gadoids, 1% others | 2, 19        |
| Great cormorant          | 53% cunner, 16% sculpins, 12% sculpins, 5% flatfish, 2% invertebrates, 1% gadoids, 27% other                       | 3, 4         |
| Double-crested cormorant | 27% cunner, 10% flatfish, , 6% sandeel, 41% other  | 3, 4, 5      |
| Black-headed gull        | n.a.   | n.a.         |
| Ring-billed gull         | 50% capelin, 50% other   | 18           |
| Herring gull             | 51% capelin, 9% invertebrates, 2% gadoids, 1% squid, 37% others  | 6, 7, 8, 9   |
| Great black-backed gull  | 50% capelin, 10% seabirds, 40% other   | 18           |
| Black-legged kittiwake   | 75% capelin, 25% others  | 6, 10        |
| Caspian tern             | n.a.   | n.a.         |
| Common tern              | 33% capelin, 31% sandeel, 5% invertebrates, 31% other  | 11           |
| Arctic tern              | 73% sandeel, 17% capelin, 10% invertebrates  | 11           |
| Guillemot                | 86% capelin, 5% sandeel, 5% daubed shanny, 2% gadoids, 2% others   | 12, 13, 14   |
| Brünnich's guillemot     | 66% daubed shanny, 29% capelin, 2% sandeel, 2% gadoids, 1% other   | 14           |
| Razorbill                | 62% capelin, 33% sandeel, 5% other   | 13, 15       |
| Black guillemot          | 33% gadoids, 28% daubed shanny, 8% sandeel, 1% invertebrates, 30% other  | 16           |
| Atlantic puffin          | 80% capelin, 15% sandeel, 3% gadoids, 12% other  | 9, 13, 17,18 |

(1) Montevecchi *et al.* (1992); (2) Montevecchi and Myers (1997); (3) Milton and Austin-Smith (1983); (4) Ross (1976); (5) Lewis (1957); (6) Threlfall (1968); (7) Haycock and Threlfall (1975); (8) Pierotti (1983); (9) Brown and Nettleship (1984); (10) Regehr (1994); (11) Chapdelaine *et al.* (1985); (12) Cairns *et al.* (1990); (13) Birkhead and Nettleship (1983); (14) Birkhead and Nettleship (1987); (15) Chapdelaine and Brousseau (1996); (16) Cairns (1981); (17) Rodway and Montevecchi (1996); (18) Montevecchi unpubl.; (19) Montevecchi *et al.* submitted.

#### 4.3.2.1 Seabird populations

The 18 nesting seabird species within the NAFO Unit Areas 2J3KLNOPs number about 5.6 million of pairs (Table 4.6). We estimated the total population at  $3.27 \times 10^7$  individual seabirds. Most are Leach's storm-petrels (81%), common guillemots (10%) and Atlantic puffins (5.4%) breeding at colonies on Baccalieu Island, Funk Island and Witless Bay Islands (Montevecchi and Tuck 1987; Cairns *et al.* 1989; Lock *et al.* 1994). Gulls and terns (2.8%), northern gannet (0.4%), black guillemot, Brünnich's guillemot, razorbill (0.8%), double-crested cormorant, great cormorant, Manx shearwater and northern fulmar (<0.1%) comprise the remainder. Biomass densities of nesting seabirds in this area represent 7.8 kg km<sup>-2</sup> during the breeding season.

In contrast to the Gulf of St. Lawrence, this area supports large numbers of migrant seabirds that breed outside the region. Their population sizes are poorly known but the migrants probably number about 75% the breeding species (Brown, 1986; Diamond *et al.*, 1993; Lock *et al.*, 1994). Nine species are considered as occurring within and breeding mostly or completely outside of NAFO Areas 2J3KLNOPs. The offshore banks of Newfoundland are the chief wintering area for little auks that represent about 70% of the migrant group estimated at  $14.3 \times 10^6$  of birds (Table 4.6). Brünnich's guillemot (10.5%), great shearwater (10.5%), black-legged kittiwake (3.5%), northern fulmar (2.1%), sooty shearwater (2.1%), Iceland gull, glaucous gull and Wilson's storm-petrel (1.3%) complete the list. Biomass densities of these migrants represent a potential of 10.7 kg km<sup>-2</sup> through the year. Thus, in contrast to the seabird numbers the biomass of migrants exceeds that of the breeders.

**Table 4.6.** Estimated prey consumption by seabirds in NAFO Areas 2J3KLMNOPs, Northwest Atlantic (NWA).

| Species                           | Body mass<br>g | Total population |           |      | Period present | Breed. season days | FMR (kJ/d) |         | Diet (%) |            |               | Total consumption (tonnes) |            |               |         |      |
|-----------------------------------|----------------|------------------|-----------|------|----------------|--------------------|------------|---------|----------|------------|---------------|----------------------------|------------|---------------|---------|------|
|                                   |                | indivs.          | % by nos. | mass |                |                    | breeding   | or else | fat fish | other fish | invertebrates | fat fish                   | other fish | invertebrates | Sum     | %    |
| Northern fulmar (natives)         | 800            | 175              | 0.0       | 0.0  | 1              | 140                | 1009       | 807     | 70       | 10         | 20            | 11                         | 2          | 5             | 19      | 0.0  |
| Northern fulmar (visitors)        | 800            | 300000           | 0.9       | 3.8  | 1              | 0                  |            | 807     | 70       | 10         | 20            | 18333                      | 3929       | 7857          | 30119   | 2.9  |
| Manx shearwater                   | 480            | 330              | 0.0       | 0.0  | 0.75           | 140                | 743        | 563     | 25       | 25         | 50            | 4                          | 6          | 12            | 23      | 0.0  |
| Greater shearwater (visitors)     | 890            | 1500000          | 4.6       | 21.3 | 0.58           | 0                  |            | 870     | 25       | 25         | 50            | 20470                      | 30705      | 61410         | 112584  | 10.8 |
| Sooty shearwater (visitors)       | 790            | 300000           | 0.9       | 3.8  | 0.58           | 0                  |            | 800     | 25       | 25         | 50            | 3764                       | 5646       | 11292         | 20702   | 2.0  |
| Wilson's storm-petrel (visitors)  | 40             | 50000            | 0.2       | 0.0  | 0.58           | 0                  |            | 98      | 20       | 0          | 80            | 61                         | 0          | 368           | 429     | 0.0  |
| Leach's storm-petrel              | 50             | 14889442         | 45.4      | 11.9 | 0.58           | 130                | 192        | 114     | 20       | 0          | 80            | 26728                      | 0          | 160371        | 187099  | 18.0 |
| Northern gannet                   | 3200           | 80850            | 0.2       | 4.1  | 0.58           | 150                | 4048       | 2709    | 95       | 2          | 3             | 15823                      | 500        | 750           | 17072   | 1.6  |
| Great cormorant                   | 2250           | 601              | 0.0       | 0.0  | 0.75           | 100                | 3134       | 2083    | 0        | 98         | 2             | 0                          | 165        | 3             | 168     | 0.0  |
| Double-crested cormorant          | 1670           | 1048             | 0.0       | 0.0  | 0.75           | 100                | 2523       | 1668    | 6        | 94         | 0             | 9                          | 221        | 0             | 230     | 0.0  |
| Black-headed gulls                | 280            | 25               | 0.0       | 0.0  | 1              | 80                 | 689        | 440     | 0        | 10         | 0             | 0                          | 0          | 0             | 0       | 0.0  |
| Ring-billed gulls                 | 500            | 23062            | 0.1       | 0.2  | 0.58           | 100                | 1050       | 678     | 50       | 50         | 0             | 561                        | 842        | 0             | 1403    | 0.1  |
| Herring gull                      | 1120           | 151787           | 0.5       | 2.7  | 1              | 90                 | 1887       | 1238    | 51       | 39         | 10            | 11110                      | 12743      | 3268          | 27120   | 2.6  |
| Great black-backed gull           | 680            | 12460            | 0.0       | 0.1  | 1              | 100                | 1313       | 853     | 50       | 40         | 0             | 622                        | 746        | 0             | 1368    | 0.1  |
| Iceland gull (visitors)           | 860            | 100000           | 0.3       | 1.4  | 0.58           | 0                  |            | 1017    | 50       | 50         | 0             | 3189                       | 4783       | 0             | 7971    | 0.8  |
| Glaucous gull (visitors)          | 1700           | 50000            | 0.2       | 1.4  | 0.58           | 0                  |            | 1690    | 50       | 50         | 0             | 2651                       | 3976       | 0             | 6627    | 0.6  |
| Black-legged kittiwake (natives)  | 440            | 293821           | 0.9       | 2.1  | 1              | 90                 | 957        | 617     | 75       | 0          | 25            | 15807                      | 0          | 7904          | 23711   | 2.3  |
| Black-legged kittiwake (visitors) | 440            | 500000           | 1.5       | 3.5  | 0.58           | 0                  |            | 617     | 75       | 0          | 25            | 14506                      | 0          | 7253          | 21759   | 2.1  |
| Caspian tern                      | 610            | 108              | 0.0       | 0.0  | 0.5            | 70                 | 1213       | 787     | 50       | 50         | 0             | 3                          | 4          | 0             | 6       | 0.0  |
| Common tern                       | 120            | 11128            | 0.0       | 0.0  | 1              | 70                 | 372        | 234     | 64       | 31         | 5             | 192                        | 139        | 22            | 353     | 0.0  |
| Arctic tern                       | 110            | 16358            | 0.0       | 0.0  | 0.5            | 70                 | 349        | 219     | 90       | 0          | 10            | 197                        | 0          | 33            | 229     | 0.0  |
| Common guillemot                  | 990            | 1856597          | 5.7       | 29.3 | 1              | 70                 | 1725       | 1129    | 95       | 5          | 0             | 228614                     | 18048      | 0             | 246662  | 23.7 |
| Brünnich's guillemot (natives)    | 930            | 39600            | 0.1       | 0.6  | 1              | 70                 | 1648       | 1078    | 97       | 2          | 1             | 4753                       | 147        | 73            | 4973    | 0.5  |
| Brünnich's guillemot (visitors)   | 440            | 1500000          | 4.6       | 10.5 | 0.58           | 0                  |            | 617     | 97       | 2          | 1             | 56282                      | 1741       | 870           | 58893   | 5.7  |
| Razorbill                         | 720            | 49500            | 0.2       | 0.6  | 1              | 70                 | 1369       | 890     | 95       | 5          | 0             | 4811                       | 380        | 0             | 5191    | 0.5  |
| Black guillemot                   | 400            | 54000            | 0.2       | 0.3  | 1              | 90                 | 893        | 574     | 36       | 63         | 1             | 1299                       | 3410       | 54            | 4764    | 0.5  |
| Atlantic puffin                   | 460            | 1002213          | 3.1       | 7.3  | 1              | 110                | 988        | 637     | 95       | 5          | 0             | 72235                      | 5703       | 0             | 77937   | 7.5  |
| Little auk (visitors)             | 150            | 10000000         | 30.5      | 23.9 | 0.41           | 0                  |            | 276     | 0        | 0          | 100           | 0                          | 0          | 183783        | 183783  | 17.7 |
| Total                             |                | 32783104         | 100       | 100  |                |                    |            |         |          |            |               | 502034                     | 93836      | 445327        | 1041197 | 100  |

#### 4.3.2.2 Consumption of food and energy uptake

The total biomass consumed annually by breeders (including nestlings and non-breeders) is estimated at 666 000 tonnes. This is the equivalent to energy consumption of  $2.0 \text{ GJ} \times 10^6$  and corresponds to  $1.4 \text{ g/m}^2$  (entire area is 477 000  $\text{km}^2$ ). This estimate, however, excludes populations breeding in other oceanographic regions present through the year. Common guillemots dominate consumption by breeders, with 23.6% of the total biomass taken during a year. Leach's storm-petrels, Atlantic puffins and black-legged kittiwakes consume 18.2%, 7.5% and 2.3% of the total respectively (Table 4.7).

The bioenergetics model estimates that the migrants remove about 385 000 tonnes/year of living prey from Northwest Atlantic (Table 2.4). Little auk, greater shearwater, Brünnich's guillemot, northern fulmar and black-legged kittiwake take 77%, while sooty shearwater, Iceland and glaucous gull and Wilson's storm-petrel are consuming 33%. The annual energy consumption requirement for migrants is  $0.9 \text{ GJ} \times 10^6$  or  $0.8 \text{ g/m}^2$ .

Combining the annual consumption of breeders and migrants gives 1 043 241 tonnes of fish and invertebrates consumed by seabirds in the Northwest Atlantic. This is equivalent to  $2.9 \text{ GJ} \times 10^6$  or  $2.2 \text{ g/m}^2$ .

#### 4.3.2.3 Estimated prey harvest

The partitioning of consumption by prey type shows that capelin is the most important prey consumed by breeders in NWA with 318 000 tonnes. It represents 53% of the total annual prey type harvested by seabirds. Common guillemot is the most important predator with 247 000 tonnes or 55.8% of capelin taken annually by seabirds. Sandeel represent the second most important type of prey fish but yields only 4.4% (26 700 tonnes) of total annual consumption. It is mainly consumed by common guillemot and Atlantic puffin but its availability appears, as in the Gulf of St. Lawrence, to be less than in the North Sea where sandeel constitute the staple food of most of the seabird community (Tasker and Furness, 1996). Mackerel and herring are consumed only by northern gannets and represent a mere 1.4% of the total biomass consumed. Invertebrates are mostly consumed by the abundant Leach's storm-petrel whose global distribution is concentrated in the NWA (Montevecchi *et al.* 1992). More specifically, myctophids, amphipods, euphausiids as well as decapods, copepods and isopods constitute their diet but owing to small body size and metabolic efficiency, they account for comparatively little of the energy that flows through the avian assemblage of the NWA.

Migrants certainly have an important impact on pelagic fish species as removals by northern fulmars, greater and sooty shearwaters, kittiwakes, Brünnich's guillemots and little auk represent 73.7% of the total seabird removal. We know that these species consume capelin but having few details of the proportions of prey types in information we cannot speculate beyond this.

**Table 4.7.** Estimated prey consumption (tonnes) by seabirds that breed in the Northwest Atlantic.

| Species                  | Pelagic fish and squid |         |          |         |                |       | Benthic and estuarine fish |          |        |          |         |               |         |
|--------------------------|------------------------|---------|----------|---------|----------------|-------|----------------------------|----------|--------|----------|---------|---------------|---------|
|                          | Mackerel               | Herring | Capelin  | Sandeel | Atlantic Saury | Squid | Invertebrates              | Flatfish | Cunner | Sculpins | Salmon  | Daubed Shanny | Others  |
| Northern fulmar          |                        |         | 13.3     |         |                | 3.8   |                            |          |        |          |         |               | 1.9     |
| Manx shearwater          | -----n. a.-----        |         |          |         |                |       |                            |          |        |          |         |               |         |
| Leach's storm-petrel     |                        |         |          |         |                |       | 151707.3                   |          |        |          |         |               | 37926.8 |
| Northern gannet          | 5804.5                 | 2560.8  | 5925.2   | 170.7   | 1707.2         | 512.2 |                            |          |        |          | 189.3   |               | 170.7   |
| Great cormorant          |                        |         |          |         |                |       | 3.4                        | 8.4      | 89.0   | 20.2     |         |               | 47.0    |
| Double-crested cormorant |                        |         |          | 13.8    |                |       |                            | 23.0     | 62.1   | 36.8     |         |               | 94.3    |
| Black-headed gull        | -----n. a.-----        |         |          |         |                |       |                            |          |        |          |         |               |         |
| Ring-billed gull         |                        |         | 457.0    |         |                |       |                            |          |        |          |         |               | 457.0   |
| Herring gull             |                        |         | 13831.2  |         |                | 271.2 | 2440.8                     |          |        |          |         |               | 10526.8 |
| Great black-backed gull  |                        |         | 684.0    |         |                |       |                            |          |        |          |         |               | 684.0   |
| Black-legged Kittiwake   |                        |         | 17783.3  |         |                |       |                            |          |        |          |         |               | 5927.0  |
| Caspian tern             | -----n. a.-----        |         |          |         |                |       |                            |          |        |          |         |               |         |
| Common tern              |                        |         | 116.5    | 109.4   |                |       | 17.7                       |          |        |          |         |               | 109.4   |
| Arctic tern              |                        |         | 38.9     | 167.2   |                |       | 22.9                       |          |        |          |         |               |         |
| Guillemot                |                        |         | 212129.3 | 12333.1 |                |       |                            |          |        |          | 12333.1 |               | 9856.5  |
| Brünnich guillemot       |                        |         | 1442.2   | 99.5    |                |       |                            |          |        |          | 3282.2  |               | 49.7    |
| Razorbill                |                        |         | 3218.4   | 1713.0  |                |       |                            |          |        |          |         |               | 259.6   |
| Black guillemot          |                        |         |          | 381.1   |                |       | 47.6                       |          |        |          | 1333.9  |               | 3001.3  |
| Atlantic puffin          |                        |         | 62349.6  | 11690.6 |                |       |                            |          |        |          |         |               | 3896.9  |
| Total prey harvest       | 5804.5                 | 2560.8  | 318025.6 | 26678.4 | 1707.2         | 783.4 | 154239.6                   | 31.4     | 151.1  | 57.0     | 189.7   | 16949.2       | 73067.8 |
| % tonnes/year            | 1.0                    | 0.4     | 53.0     | 4.4     | 0.3            | 0.1   | 25.7                       | 0.0      | 0.0    | 0.0      | 0.0     | 2.8           | 12.2    |

#### 4.4 Icelandic waters (ICES Area Va)

Last year's efforts include some initial calculations of prey consumption by seabirds in Icelandic waters. During future efforts by the Working Group on Seabird Ecology, we will apply the newly developed consumption model applied to the areas addressed in this report to Icelandic seabird populations.

#### 4.5 Barents Sea (ICES Area I and eastern parts of IIa,b)

Mehlum and Gabrielsen (1995) describe the breeding populations of the major seabird species in the Barents Sea region, together with estimates of energy expenditure and food consumption. This study expands on their estimation of food consumption through an update of the population numbers (from Anker-Nilssen *et al.* in press) including the addition of the very large Svalbard populations of fulmars and little auks and the application of more recent equations to estimate metabolic rates. Population numbers were taken from Anker-Nilssen *et al.* (in press) having subtracted the numbers of birds breeding along the coasts of northern Nordland and Troms and the White Sea. In the Barents Sea there are few birds which breed elsewhere and visit the region such that the year-round energy consumption by seabirds is close to an estimate based on breeding birds alone.

The estimate of total number of seabirds breeding in the Barents Sea region is about 5.4 million pairs. The commonest are the Brünnich's guillemot and the little auk (35% and 25% by number respectively of the 17 million individuals, Table 4.8). By biomass, the Brünnich's guillemot dominated the guild (55%), with the fulmar and kittiwake as the next most important species (13% and 8% respectively). Their main diets are given in Table 4.9.

The annual total prey biomass consumed by the marine birds in the entire Barents Sea is estimated at 1.0 million tonnes (Table 4.8). The Brünnich's guillemot is the major consumer taking 55% of the food biomass. The other major consumers are the fulmar (15%), kittiwake (8%), little auk (8%), and puffin (6%).

Of the ca. one million tonnes of food consumed by marine birds, ca. 482 000 tonnes (48%) constitute fatty fish and 466,000 tonnes (46 %) invertebrates. Brünnich's Guillemots account for 61% of the fatty fish and 56% of the invertebrates consumed. Fulmars take 23% of the invertebrates, while kittiwakes and puffins take 15% and 13% respectively of the fatty fish. The second largest invertebrate consumer is the little auk (15%).

The estimated food consumption using the present model was similar to the 1.1 million tonnes estimated by Mehlum and Gabrielsen (1995) using a smaller number of fulmars (27 100 pairs as opposed to 500 000 pairs in this model) and little auks (580 000 pairs/1.3 million pairs). If Mehlum and Gabrielsen's figures for fulmars and little auks are applied to the present model, the total consumption drops to 0.83 million tonnes, and the fulmar outtake from 14% to 1% of the total. That of the Brünnich's guillemot rises correspondingly to 67%, slightly more than Mehlum and Gabrielsen's 63%.

The present model also assumes that fulmars and kittiwakes consume only live prey, an assumption that may be incorrect. A considerable proportion of the diet of fulmars (60–75%) and kittiwakes (50%) in the North Sea is offal and discards from the fishing fleet (Garthe *et al.* 1996), and it is thus reasonable to suppose that the large cod-fishing fleet in the Barents Sea is also a significant food source for both these species in the region. If 50% of their diet was offal and/or discards, the total consumption of live prey by all seabirds from the Barents Sea is reduced by ca. 75 000 tonnes (7%).

The similarity of outtake compared to Mehlum and Gabrielsen (1995) despite the large difference in number of fulmars used may be explained by the present model's allowance made for a ca. 34% reduction in FMR for all species outside the breeding season. Mehlum and Gabrielsen did not take this into consideration. Similarly they used a flat rate of 5 kJ/g as a mean energy density of food, irrespective of choice of diet. Applying this figure for energy density to the present model, however, increases the consumption by only ca. 50 000 tonnes.

**Table 4.8.** Estimated prey consumption by seabirds in ICES area I and parts of IIa and IIb, the Barents Sea.

| Species                  | Body mass<br>g | Total population |            | Period present | Breed. season days | FMR (kJ/d) |          | Diet (%) |          |            | Total consumption (tonnes) |               |              |               |                |            |
|--------------------------|----------------|------------------|------------|----------------|--------------------|------------|----------|----------|----------|------------|----------------------------|---------------|--------------|---------------|----------------|------------|
|                          |                | indivs.          | % by nos.  |                |                    | mass       | breeding | or else  | fat fish | other fish | invertebrates              | fat fish      | other fish   | invertebrates | Sum            | %          |
| Northern fulmar          | 820            | 1650000          | 9.7        | 12.6           | Jan-Dec            | 120        | 1024     | 821      | 0        | 30         | 70                         | 0             | 41518        | 107638        | 149156         | 14.8       |
| Northern gannet          | 3204           | 4950             | 0.0        | 0.1            | Mar-Oct            | 150        | 4052     | 2712     | 100      | 0          | 0                          | 865           | 0            | 0             | 865            | 0.1        |
| Great cormorant          | 3250           | 13000            | 0.1        | 0.4            | Mar-Oct            | 100        | 4094     | 2741     | 40       | 50         | 10                         | 896           | 1344         | 299           | 2539           | 0.3        |
| Shag                     | 1836           | 15600            | 0.1        | 0.3            | Mar-Oct            | 100        | 2703     | 1790     | 50       | 50         | 0                          | 882           | 1058         | 0             | 1940           | 0.2        |
| Great skua               | 1400           | 780              | 0.0        | 0.0            | Apr-Sep            | 100        | 2219     | 1462     | 0        | 10         | 0                          | 0             | 7            | 0             | 7              | 0.0        |
| Arctic skua              | 350            | 15600            | 0.1        | 0.1            | May-Sep            | 80         | 810      | 520      | 40       | 0          | 0                          | 135           | 0            | 0             | 135            | 0.0        |
| Mew gull                 | 380            | 52000            | 0.3        | 0.2            | Apr-Sep            | 80         | 860      | 553      | 0        | 30         | 40                         | 0             | 499          | 740           | 1239           | 0.1        |
| Herring gull             | 1000           | 260000           | 1.5        | 2.4            | Mar-Oct            | 90         | 1738     | 1138     | 0        | 60         | 40                         | 0             | 11999        | 8888          | 20887          | 2.1        |
| Lesser black-backed gull | 800            | 1300             | 0.0        | 0.0            | Apr-Sep            | 90         | 1478     | 963      | 0        | 30         | 0                          | 0             | 22           | 0             | 22             | 0.0        |
| Great black-backed gull  | 1680           | 65000            | 0.4        | 1.0            | Mar-Oct            | 100        | 2534     | 1675     | 50       | 40         | 0                          | 3103          | 2979         | 0             | 6081           | 0.6        |
| Glaucous gull            | 1800           | 31200            | 0.2        | 0.5            | Apr-Sep            | 100        | 2664     | 1764     | 0        | 10         | 10                         | 0             | 326          | 362           | 689            | 0.1        |
| Black-legged kittiwake   | 409            | 2210000          | 13.1       | 8.4            | Mar-Oct            | 90         | 907      | 584      | 90       | 0          | 10                         | 73130         | 0            | 10834         | 83964          | 8.3        |
| Common tern              | 125            | 2600             | 0.0        | 0.0            | May-Aug            | 70         | 383      | 241      | 0        | 100        | 0                          | 0             | 26           | 0             | 26             | 0.0        |
| Arctic tern              | 110            | 130000           | 0.8        | 0.1            | May-Aug            | 70         | 349      | 219      | 0        | 50         | 50                         | 0             | 589          | 654           | 1243           | 0.1        |
| Razorbill                | 711            | 66000            | 0.4        | 0.4            | Mar-Oct            | 70         | 1356     | 882      | 100      | 0          | 0                          | 3465          | 0            | 0             | 3465           | 0.3        |
| Common guillemot         | 1028           | 396000           | 2.3        | 3.8            | Feb-Nov            | 70         | 1773     | 1161     | 100      | 0          | 0                          | 33354         | 0            | 0             | 33354          | 3.3        |
| Brünnich's guillemot     | 998            | 5940000          | 35.1       | 55.3           | Feb-Nov            | 70         | 1735     | 1136     | 60       | 0          | 40                         | 293658        | 0            | 261029        | 554688         | 55.0       |
| Black guillemot          | 410            | 130000           | 0.8        | 0.5            | Jan-Dec            | 90         | 909      | 585      | 40       | 0          | 60                         | 2727          | 0            | 5453          | 8180           | 0.8        |
| Atlantic puffin          | 480            | 1650000          | 9.7        | 7.4            | Mar-Oct            | 110        | 848      | 658      | 100      | 0          | 0                          | 63757         | 0            | 0             | 63757          | 6.3        |
| Little auk               | 160            | 4290000          | 25.3       | 6.4            | Apr-Sep            | 80         | 459      | 290      | 10       | 0          | 90                         | 5838          | 0            | 70053         | 75891          | 7.5        |
| <b>Total</b>             |                | <b>16924030</b>  | <b>100</b> | <b>100</b>     |                    |            |          |          |          |            |                            | <b>481810</b> | <b>60367</b> | <b>465952</b> | <b>1008128</b> | <b>100</b> |

**Table 4.9.** The main constituents of the diet made up of fish or marine invertebrates of seabirds breeding in the Barents and Norwegian Seas. Data from Anker-Nilssen *et al.* (in press) unless otherwise indicated.

| Species           | Barents Sea  | Norwegian Sea   | Refs. |
|-------------------|--|---|-------|
| Northern fulmar   | Invertebrates 70%, fish 30%                              |   |       |
| Northern gannet   | Herring, capelin   | Herring, mackerel, saithe, sandeels                       |       |
| Great cormorant   | Gadids 50%, sandeels and capelin 40%, invertebrates 10%  | Gadids (cod, saithe) 80%, invertebrates 20%               | 1,2   |
| Shag              | Gadids 50%, sandeels 50%                                 | Gadids (cod, saithe) 70%, sandeels 15%, invertebrates 10% | 1     |
| Great skua        | Fish 10%   |   |       |
| Arctic skua       | Fish (capelin, herring, sandeels) 100%                   |   |       |
| Common gull       | Fish 30%, invertebrates 40%                              | Fish 30%, invertebrates 40%, plant material 30%           |       |
| Herring gull      | Fish 30%, offal 30%, invertebrates 40%                   |   |       |
| LBB gull          | Fish 30%   |   |       |
| GBB gull          | Fish (herring, cod, capelin, sandeels) 90%,              |   |       |
| Glaucous gull     | Fish 10%, invertebrates 10%,                             |   |       |
| Kittiwake         | Fish (capelin, polar cod) 90%                            | Fish (80%), euphausiids (20%)                             |       |
| Common tern       |  |   |       |
| Arctic tern       | Fish 50%   |   |       |
| Razorbill         | Fish (capelin, sandeels, herring) 100%                   | Capelin, sandeels   |       |
| Common guill.     | Capelin 50%, herring 20%, sandeels 10%                   | Capelin, sandeels, herring, saithe                        |       |
| Brünnich's guill. | Fish (polar cod, capelin, gadid) 60%, invertebrates 40%  | -   |       |
| Black guillemot   | Fish (sandeels, capelin, sculpin) 20%, invertebrates 80% | Butterfish 50%, sculpins                                  |       |
| Puffin            | Capelin 50%, sandeels 30%, herring 10%                   | Herring 30%, saithe 25%, sandeels 15%, gadids 10%         |       |
| Little auk        | Invertebrates 100%                                       | -   |       |

(1) Barrett *et al.* 1990, (2) Johansen *et al.* 1999.

#### 4.6 Norwegian Sea (part of IIa)

Estimates of the populations of seabirds breeding along the Norwegian coast of the Norwegian Sea south to and including Møre and Romsdal (Figure 4.3) were taken from Anker-Nilssen (unpubl.) and the Norwegian Seabird Registry at the Norwegian Institute for Nature Research (NINA). Their main diets are given in Table 4.9.

The number of seabirds breeding along the Norwegian coast of the Norwegian Sea was estimated to be ca. two million pairs, or nearly seven million individuals. The breeding population is dominated by the puffin, which constitutes ca. 79% by number and 72% by total biomass of the numbers. The kittiwake is the next most common species, 9% by number and 7% by biomass.

All the breeding seabirds in the Norwegian Sea consumed the order of 400 000 tonnes of food of which 63 000 tonnes (16%) are fatty fish, 310 000 tonnes (79%) are lean fish and 18 000 tonnes (5%) are invertebrates. Puffins account for ca. 240 000 tonnes (77%) of the total consumption while kittiwakes are the second largest consumers with ca. 25 000 tonnes (6%). In these calculations, we have treated the 0-group herring taken by puffins as a medium quality prey with an energy density of 4 kJ/g as opposed to 6 kJ/g for fatty fish used for all the other species (Anker-Nilssen and Øyan 1995).

These estimates do not, however, include the very large but unknown number of fulmars that are spread over most of the area throughout the year. In addition an unknown, but similarly very large, number of little auks from the Barents Sea spend the winter in the Norwegian Sea. If figures for both these populations are set at 2 million individuals, the total consumption by all the birds in the Norwegian sea increases by ca. 50% to ca. 600 000 tonnes (Table 4.10). Of this ca. 430 000 tonnes are fish and the remainder invertebrates. Puffins account for approximately half of this consumption, and fulmars ca. 30%. These figures are, however, very uncertain due to the unknown numbers of fulmars and little auks in the area. It should also be noted that the model does not include the large numbers of seabirds which breed on Shetland or the Faeroe Islands, many of which probably also forage in the Norwegian Sea during a large part of the year.

**Table 4.10.** Estimated prey consumption by seabirds in part of ICES area IIa, the Norwegian Sea.

| Species                    | Body mass g | Total population |            |            | Period present | Breed. season days | FMR (kJ/d) |         | Diet (%) |            |               | Total consumption (tonnes) |               |               |               |            |
|----------------------------|-------------|------------------|------------|------------|----------------|--------------------|------------|---------|----------|------------|---------------|----------------------------|---------------|---------------|---------------|------------|
|                            |             | indivs.          | % by nos.  | mass       |                |                    | breeding   | or else | fat fish | other fish | invertebrates | fat fish                   | other fish    | invertebrates | Sum           | %          |
| Northern fulmar (natives)  | 810         | 24750            | 0.2        | 0.4        | Jan-Dec        | 120                | 1016       | 814     | 0        | 30         | 70            | 0                          | 618           | 1601          | 2219          | 0.4        |
| Northern fulmar (visitors) | 810         | 2000000          | 18.6       | 32.0       | Jan-Dec        | 0                  |            | 814     | 0        | 30         | 70            | 0                          | 47557         | 123295        | 170852        | 28.8       |
| European storm-petrel      | 24          | 16500            | 0.2        | 0.0        | Jun-Dec        | 130                | 115        | 70      | 0        | 0          | 100           | 0                          | 0             | 91            | 91            | 0.0        |
| Leach's storm-petrel       | 42          | 1650             | 0.0        | 0.0        | Jun-Dec        | 130                | 173        | 107     | 0        | 0          | 100           | 0                          | 0             | 14            | 14            | 0.0        |
| Northern gannet            | 3204        | 7425             | 0.1        | 0.5        | Mar-Oct        | 150                | 4052       | 2712    | 100      | 0          | 0             | 1297                       | 0             | 0             | 1297          | 0.2        |
| Great cormorant            | 3250        | 54000            | 0.5        | 3.5        | Jan-Dec        | 100                | 4094       | 2741    | 80       | 0          | 20            | 10326                      | 0             | 3442          | 13768         | 2.3        |
| Shag                       | 1836        | 45000            | 0.4        | 1.6        | Jan-Dec        | 100                | 2703       | 1790    | 15       | 70         | 10            | 1056                       | 5915          | 939           | 7910          | 1.3        |
| Great skua                 | 1400        | 90               | 0.0        | 0.0        | Apr-Sep        | 100                | 2219       | 1462    | 0        | 10         | 0             | 0                          | 1             | 0             | 1             | 0.0        |
| Arctic skua                | 350         | 18000            | 0.2        | 0.1        | May-Sep        | 80                 | 810        | 520     | 40       | 0          | 0             | 148                        | 0             | 0             | 148           | 0.0        |
| Common gull                | 380         | 270000           | 2.5        | 2.0        | Mar-Sep        | 80                 | 860        | 553     | 0        | 30         | 40            | 0                          | 2850          | 4222          | 7073          | 1.2        |
| Herring gull               | 1000        | 45000            | 0.4        | 0.9        | Jan-Dec        | 90                 | 1738       | 1138    | 0        | 60         | 40            | 0                          | 3206          | 2375          | 5581          | 0.9        |
| Lesser black-backed gull   | 800         | 6300             | 0.1        | 0.1        | Apr-Sep        | 90                 | 1478       | 963     | 0        | 30         | 0             | 0                          | 102           | 0             | 102           | 0.0        |
| Great black-backed gull    | 1680        | 117000           | 1.1        | 3.9        | Jan-Dec        | 100                | 2534       | 1675    | 50       | 40         | 0             | 8570                       | 8227          | 0             | 16797         | 2.8        |
| Black-legged kittiwake     | 409         | 585000           | 5.4        | 4.7        | Mar-Oct        | 90                 | 907        | 584     | 0        | 80         | 20            | 0                          | 19873         | 5520          | 25393         | 4.3        |
| Common tern                | 125         | 10800            | 0.1        | 0.0        | May-Aug        | 70                 | 383        | 241     | 90       | 0          | 10            | 76                         | 0             | 11            | 87            | 0.0        |
| Arctic tern                | 110         | 90000            | 0.8        | 0.2        | May-Aug        | 70                 | 349        | 219     | 0        | 100        | 0             | 0                          | 769           | 0             | 769           | 0.1        |
| Razorbill                  | 711         | 49500            | 0.5        | 0.7        | Feb-Oct        | 70                 | 1356       | 882     | 100      | 0          | 0             | 2870                       | 0             | 0             | 2870          | 0.5        |
| Common guillemot           | 1028        | 16500            | 0.2        | 0.3        | Feb-Nov        | 70                 | 1773       | 1161    | 100      | 0          | 0             | 1385                       | 0             | 0             | 1385          | 0.2        |
| Black guillemot            | 390         | 54000            | 0.5        | 0.4        | Jan-Dec        | 90                 | 876        | 564     | 45       | 55         | 0             | 1195                       | 1753          | 0             | 2948          | 0.5        |
| Atlantic puffin            | 460         | 5362500          | 49.8       | 48.7       | Mar-Oct        | 110                | 988        | 637     | 17       | 83         | 0             | 36376                      | 266399        | 0             | 302775        | 51.1       |
| Little auk (visitors)      | 160         | 2000000          | 18.6       | 6.3        | Oct-Mar        | 0                  |            | 290     | 0        | 30         | 70            | 0                          | 8443          | 21890         | 30333         | 5.1        |
| <b>Total</b>               |             | <b>10774015</b>  | <b>100</b> | <b>100</b> |                |                    |            |         |          |            |               | <b>63300</b>               | <b>365711</b> | <b>163401</b> | <b>592412</b> | <b>100</b> |

#### 4.7 Baltic Sea (IIIb,c,d and southern part of IIIa)

The estimates of population size used in the calculations were taken from Durinck *et al.* (1994), while the dietary information is given in section 7 of this report. Due to the large numbers of waterfowl in the Baltic as opposed to the other regions considered in this report, we included common eiders, which are truly marine birds throughout the year, and a group collectively termed “other waterfowl”. The latter is comprised mainly of wintering congregations of seaducks, primarily long-tailed ducks (ca. 4.3 million), common scoters (ca. 0.8 million), velvet scoters (ca. 0.9 million), goosanders (ca. 73 000) and red-breasted mergansers (ca. 44 000), as well as coots (ca. 212 000) and red- and black-throated divers (ca. 56 000). With exception for the relatively few red-breasted mergansers, these species only stay in marine areas of the Baltic Sea during the non-breeding season, which for our purpose is defined as 1 October - 31 March. For most species we calculated an approximate body mass from ranges given by Bezzel (1985). For the waterfowl group we used an average of the estimates for the species included, being weighted according to the number of birds of each species.

The population of marine birds in the Baltic Sea totals approximately 13 million individuals, of which ca. 1.7 million pairs breed in marine areas (Table 4.11). The most numerous breeder is the black-headed gull (0.6 million pairs), but this species constitutes only 6% of the total biomass and feeds almost exclusively in terrestrial and freshwater areas. In contrast, the estimated 450 000 pairs of common eiders represent 12% by numbers and 23% by biomass. However, 52% of the individuals belong to the non-breeding waterfowl group, which amounts to 55% of the bird biomass in the consumption model. Adding the ca. 720 000 wintering common eiders, these figures rise to 57% and 65%, respectively.

The total mass of seafood consumed by marine birds in the Baltic was estimated at 762 000 tonnes, of which 615 000 tonnes (81%) were invertebrates and only 147 000 tonnes (19%) were fish (Table 4.11). The waterfowl (including the eiders) account for as much as 673 000 tonnes (88%) of the total, taking practically all the invertebrates and 40% (59 000 tonnes) of the fish, followed by herring gulls (4%) and great cormorants (2%).

#### 4.8 Discussion

The food consumption estimates presented in this report are preliminary and do not cover all areas of interest for ICES, for instance waters west of the British Isles, waters off Greenland and the Bay of Biscay. Also, the consumption model we have applied will need future refinement of many of the parameters. In general, information on the distribution, diets and energy budgets of seabird outside the breeding season are scarce and new data could easily alter our assessments considerably. Nevertheless, the results illustrate the magnitude of seabird consumption, which is above one million tonnes per year in Canadian waters and in the range of 0.6–1.0 million tonnes per year in each of the Barents, Norwegian and Baltic Seas. Furthermore, they demonstrate some important differences and similarities between the different areas considered.

Most striking, perhaps, is the very similar consumption estimates (1.0 million tonnes per year) for the NW Atlantic area and the Barents Sea, despite seabird numbers in the Canadian region being estimated at twice those of the Barents Sea (Table 4.12). The difference in numbers is largely explained by the huge numbers of small-sized seabirds, mainly Leach’s storm-petrels and visiting little auks appearing in Canadian waters. The two regions are also amazingly similar with respect to the balance between fish and invertebrate prey with a slightly higher consumption (almost 50% of the total) of fatty fish species (the most important being capelin, herring and sandeels) while fish species with lower energy content constitutes less than 10% of the total consumption.

In the Norwegian Sea, fatty fish is seemingly less important than in Canada and the Barents Sea, but this is mainly due to the lower energy quality of herring in their first summer than later in life. First-year herring are the staple food of Atlantic puffins, which constitute the bulk of seabirds breeding in this region. The consumption of invertebrate prey in the Norwegian Sea is probably significantly lower than that in the Barents Sea, but the estimate is highly susceptible to changes in the very uncertain number of visiting fulmars that was entered into the model.

In contrast to the other areas, fish is by far the most important in the Gulf of St. Lawrence, with fatty fish comprising twice as much of the total than other fish, while invertebrate prey is relatively insignificant. For the Baltic, however, the situation is very different due to the large number of seaducks, and the consumption of invertebrate prey is there five times higher than that of fish.

**Table 4.11.** Estimated prey consumption by seabirds in ICES areas IIIb,c,d and part of IIIa, the Baltic Sea.

| Species                           | Body mass g | Total population |            |            | Period present | Breed. season days | FMR (kJ/d) |         | Diet (%) |            |               | Total consumption (tonnes) |              |               |               |            |
|-----------------------------------|-------------|------------------|------------|------------|----------------|--------------------|------------|---------|----------|------------|---------------|----------------------------|--------------|---------------|---------------|------------|
|                                   |             | indivs.          | % by nos.  | mass       |                |                    | breeding   | or else | fat fish | other fish | invertebrates | fat fish                   | other fish   | invertebrates | Sum           | %          |
| Northern fulmar (visitors)        | 810         | 2700             | 0.0        | 0.0        | Jan-Dec        | 0                  | 814        |         | 0        | 30         | 70            | 0                          | 64           | 166           | 231           | 0.0        |
| Great cormorant                   | 2200        | 216000           | 1.7        | 4.2        | Jan-Dec        | 100                | 3083       | 2049    | 0        | 35         | 0             | 0                          | 16234        | 0             | 16234         | 2.1        |
| Arctic skua                       | 350         | 3600             | 0.0        | 0.0        | Apr-Sep        | 80                 | 810        | 520     | 0        | 10         | 0             | 0                          | 10           | 0             | 10            | 0.0        |
| Mediterranean gull                | 275         | 180              | 0.0        | 0.0        | Apr-Sep        | 80                 | 680        | 434     | 0        | 10         | 0             | 0                          | 0            | 0             | 0             | 0.0        |
| Little gull                       | 110         | 46800            | 0.4        | 0.0        | May-Sep        | 80                 | 349        | 219     | 0        | 8          | 0             | 0                          | 39           | 0             | 39            | 0.0        |
| Black-headed gull                 | 290         | 2160000          | 16.5       | 5.5        | Apr-Oct        | 80                 | 707        | 452     | 0        | 3          | 0             | 0                          | 1867         | 0             | 1867          | 0.2        |
| Common gull                       | 380         | 360000           | 2.8        | 1.2        | Jan-Dec        | 80                 | 860        | 553     | 0        | 17         | 0             | 0                          | 3516         | 0             | 3516          | 0.5        |
| Herring gull                      | 1000        | 720000           | 5.5        | 6.3        | Jan-Dec        | 90                 | 1738       | 1138    | 0        | 35         | 0             | 0                          | 29923        | 0             | 29923         | 3.9        |
| Lesser black-backed gull          | 800         | 108000           | 0.8        | 0.8        | Apr-Sep        | 90                 | 1478       | 963     | 30       | 60         | 0             | 1454                       | 3490         | 0             | 4945          | 0.6        |
| Great black-backed gull           | 1680        | 43200            | 0.3        | 0.6        | Jan-Dec        | 100                | 2534       | 1675    | 0        | 60         | 0             | 0                          | 4557         | 0             | 4557          | 0.6        |
| Black-legged kittiwake (natives)  | 350         | 360              | 0.0        | 0.0        | Jan-Dec        | 90                 | 810        | 520     | 80       | 0          | 0             | 13                         | 0            | 0             | 13            | 0.0        |
| Black-legged kittiwake (visitors) | 350         | 76000            | 0.6        | 0.2        | Oct-Mar        | 0                  |            | 520     | 0        | 50         | 50            | 0                          | 964          | 1071          | 2035          | 0.3        |
| Caspian tern                      | 650         | 6840             | 0.1        | 0.0        | Apr-Aug        | 80                 | 1271       | 825     | 25       | 25         | 0             | 55                         | 67           | 0             | 122           | 0.0        |
| Sandwich tern                     | 240         | 5400             | 0.0        | 0.0        | Apr-Sep        | 70                 | 616        | 392     | 50       | 50         | 0             | 48                         | 58           | 0             | 106           | 0.0        |
| Common tern                       | 110         | 252000           | 1.9        | 0.2        | Apr-Sep        | 70                 | 349        | 219     | 40       | 40         | 0             | 1012                       | 1214         | 0             | 2226          | 0.3        |
| Arctic tern                       | 120         | 288000           | 2.2        | 0.3        | Apr-Sep        | 70                 | 372        | 234     | 40       | 40         | 0             | 1233                       | 1480         | 0             | 2714          | 0.4        |
| Little tern                       | 50          | 7200             | 0.1        | 0.0        | May-Aug        | 70                 | 197        | 122     | 0        | 50         | 50            | 0                          | 17           | 19            | 36            | 0.0        |
| Razorbill (natives)               | 730         | 49500            | 0.4        | 0.3        | Jan-Dec        | 70                 | 1382       | 900     | 100      | 0          | 0             | 3837                       | 0            | 0             | 3837          | 0.5        |
| Razorbill (visitors)              | 730         | 136500           | 1.0        | 0.9        | Oct-Mar        | 0                  |            | 900     | 46       | 53         | 1             | 2297                       | 3176         | 67            | 5540          | 0.7        |
| Common guillemot (natives)        | 930         | 49500            | 0.4        | 0.4        | Jan-Dec        | 70                 | 1648       | 1078    | 100      | 0          | 0             | 4594                       | 0            | 0             | 4594          | 0.6        |
| Common guillemot (visitors)       | 930         | 66500            | 0.5        | 0.5        | Oct-Mar        | 0                  |            | 1078    | 46       | 53         | 1             | 1341                       | 1854         | 39            | 3233          | 0.4        |
| Black guillemot                   | 380         | 72000            | 0.6        | 0.2        | Jan-Dec        | 90                 | 860        | 553     | 45       | 45         | 10            | 1563                       | 1876         | 463           | 3903          | 0.5        |
| Common eider                      | 1630        | 1620000          | 12.4       | 23.2       | Jan-Dec        | 50                 | 2479       | 1638    | 0        | 0          | 100           | 0                          | 0            | 298205        | 298205        | 39.1       |
| Other waterfowl species           | 920         | 6800000          | 51.9       | 54.9       | Oct-Mar        | 0                  |            | 1069    | 20       | 0          | 80            | 59130                      | 0            | 315362        | 374492        | 49.1       |
| <b>Total</b>                      |             | <b>13090280</b>  | <b>100</b> | <b>100</b> |                |                    |            |         |          |            |               | <b>76579</b>               | <b>70406</b> | <b>615392</b> | <b>762377</b> | <b>100</b> |

**Table 4.12.** Estimated prey consumption by seabirds in different oceanographic areas.

| Region  | Total population |        | Total consumption (%) |       |          | Total consumption (tonnes) |        |          |         |
|---|------------------|--------|-----------------------|-------|----------|----------------------------|--------|----------|---------|
|   | individuals      | tonnes | fat                   | other | inverte- | fat                        | other  | inverte- | Sum     |
|   |                  |        | fish                  | fish  | brates   | fish                       | fish   | brates   |         |
| Gulf of St Lawrence (NAFO 4RST)                   | 1376401          | 1476   | 60.6                  | 32.2  | 7.3      | 60511                      | 32144  | 7268     | 99923   |
| NW Atlantic (NAFO 2J3KLNO)                        | 32783104         | 6273   | 48.2                  | 9.0   | 42.8     | 502034                     | 93836  | 445327   | 1041197 |
| Barents Sea (ICES Area I)                         | 16924030         | 10725  | 47.8                  | 6.0   | 46.2     | 481810                     | 60367  | 465952   | 1008128 |
| Norwegian Sea (ICES Area IIa)                     | 10774015         | 5069   | 10.7                  | 61.7  | 27.6     | 63300                      | 365711 | 163401   | 592412  |
| Baltic Sea (ICES Area IIIb,c,d and parts of IIIa) | 13090280         | 11389  | 10.0                  | 9.2   | 80.7     | 76579                      | 70406  | 615392   | 762377  |
| Total   | 74947829         | 34931  |                       |       |          | 1184234                    | 622465 | 1806699  | 3504038 |

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## **5 FURTHER REVIEW OF THE CONTENTS ON THE DATABASE ON SEABIRD DIET COMPOSITION**

### **5.1 Introduction**

The diet database resulted from a survey of 921 studies or datasets, providing detailed information of prey taken by 38 species of seabirds, divers (loons), grebes and seaduck in 20 ICES subregions and 4 NAFO areas (Table 5.1.1). The database is by no means complete and some predator species and ICES areas are covered better than others. Best covered to date are Atlantic puffin *Fratercula arctica* (155 studies), common guillemot *Uria aalge* (80), great skua *Stercorarius skua* (75), and northern fulmar *Fulmarus glacialis* (68). Some 161 studies were not assigned to any specific ICES or NAFO subregion, while 237 studies were in subregion IVa, 153 in IVb, 69 in I, 49 in IVc and VIa, and 47 in IIb. The data are also heavily biased to the breeding season (Tables 5.1.2, 5.1.3), with 534 out of 921 datasets referring to that period and a further 31 studies being related to the ‘summer’ period (covering 27 species in total). Some 65 datasets referred to the pre-nesting period (17 species), 90 to the post-breeding season (23 species), 120 to the winter period (21 species) and 81 studies were not assigned (20 species). A large update of the database, covering particularly the cormorant and gull families has been prepared, but has yet to be formally incorporated.

### **5.2 Database structure**

The information collected in the database is relatively simple. Two separate files hold information on the predator and on the type and source of data is provided (basetable) and on the frequency of occurrence and size of particular prey items encountered in samples (e.g., pellets, stomachs, dropping or regurgitated prey) taken during these study (diet data). Genus and species names or prey items are stored and prey identifications are included when possible on species level. Prey items taken for courtship display by predators are tagged and can be separated from prey delivered to chicks or taken by adults, whenever these data were provided by the source.

Prey items listed most often in the datasets surveyed were sandeels (264 studies referring to unidentified *Ammodytes*, a further 166 studies referring to *Ammodytes marinus*), capelin *Mallotus villosus* (175 datasets), discarded whiting *Merlangius merlangus* (153), discarded herring *Clupea harengus* (129), herring (123) and discarded offal (115). That same species and groups were indicated most often as ‘common’ prey or staple foods in seabirds.

If the database were to be included on the ICES website (see Section 8), it will need to be modified. Further updates would be required and a better link to a reference database would be required to further improve the database and to develop a valuable tool of reference. After reviewing the contents of the database (Tables 5.1.3) it has now become clear that the following field require urgent updating: all missing or poorly represented ICES and NAFO subregions (Table 5.1.4), the Manx shearwater *Puffinus puffinus*, the grebes Podicipedidae, most gulls Laridae and all species of seaduck Anatidae, offshore areas, and winter (or non-breeding) diets. Filling in these gaps is now the first priority, before the database can be released for successful use.

**Table 5.1.1.** Seabird diet studies surveyed for the Diet Database by NAFO area or ICES subregion.

| 5.2.1.1 Predator         | NAFO |    |   |   | ICES |     |      |      |     |     |    |     |     |     |     |   |      | n.s.  |       |      |      |      |     |    |    |     |     |
|--------------------------|------|----|---|---|------|-----|------|------|-----|-----|----|-----|-----|-----|-----|---|------|-------|-------|------|------|------|-----|----|----|-----|-----|
|                          | 0    | 3  | 4 | 5 | I    | III | IIIa | IIIb | IIa | IIb | IV | IVa | IVb | IVc | IXa | V | VIII | VIIIa | VIIIc | VIIe | VIIg | VIIj | VIa | Va |    |     |     |
| Red-throated diver       |      |    |   |   |      |     | 2    |      |     | 1   |    | 3   |     | 2   |     |   |      |       |       |      |      |      |     |    |    | 1   | 9   |
| Black-throated diver     |      |    |   |   |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 4   | 4   |
| Great northern diver     |      |    |   |   |      |     |      |      |     |     |    | 1   |     |     |     |   |      |       |       | 1    |      |      |     |    |    | 19  | 21  |
| White-billed diver       |      |    |   |   |      |     |      |      |     |     |    |     |     | 1   |     |   |      |       |       |      |      |      |     |    |    |     | 1   |
| Great crested grebe      |      |    |   |   |      |     |      |      |     |     |    | 1   |     |     |     |   |      |       |       |      |      |      |     |    |    |     | 1   |
| Fulmar                   | 1    |    |   |   | 3    |     | 2    |      |     | 12  | 1  | 17  | 12  | 6   |     |   |      |       |       |      |      |      | 5   | 6  | 3  | 68  |     |
| Cory's shearwater        |      |    |   |   |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    | 1  | 1   |     |
| Great shearwater         |      |    |   |   |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      | 1   |    |    | 1   |     |
| Sooty shearwater         |      |    |   |   |      |     |      |      |     |     | 1  |     | 1   |     |     |   |      |       |       |      |      |      | 1   |    | 1  | 4   |     |
| Gannet                   |      |    |   |   |      |     |      |      |     |     | 1  | 15  | 11  | 3   |     |   |      |       |       |      |      |      | 1   |    | 9  | 40  |     |
| Cormorant                |      |    |   |   |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 4   | 4   |
| Double-crested cormorant |      |    | 3 | 1 |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 19  | 23  |
| Shag                     |      |    |   |   |      |     |      |      |     |     |    | 6   |     |     |     |   |      |       |       |      |      |      | 1   |    |    |     | 7   |
| Cormorant sp.            |      |    |   |   |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 1   | 1   |
| Common eider             |      |    |   |   |      | 1   |      |      |     | 1   |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 3   | 5   |
| Common scoter            |      |    |   |   |      |     |      |      |     |     |    | 1   |     |     |     |   |      |       |       |      |      |      |     |    |    |     | 1   |
| Red-necked phalarope     |      |    |   |   |      |     |      |      |     | 1   |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    |     | 1   |
| Pomarine skua            |      |    |   |   |      |     |      |      |     |     |    |     | 1   |     |     |   |      |       |       |      |      |      |     |    |    | 1   | 2   |
| Arctic skua              |      |    |   |   |      |     |      |      |     | 1   |    | 3   |     |     |     |   |      |       |       |      |      |      | 1   |    |    |     | 5   |
| Great skua               |      |    |   |   |      |     |      |      |     |     | 1  | 61  | 5   |     |     |   |      |       |       |      |      |      |     | 8  |    |     | 75  |
| Little gull              |      |    |   |   |      |     |      |      |     |     |    |     | 1   |     |     |   |      |       |       |      |      |      |     |    |    |     | 1   |
| Bonaparte's gull         |      |    |   |   |      |     |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 1   | 1   |
| Black-headed gull        |      |    |   |   |      |     |      |      |     |     |    | 1   | 3   | 2   |     |   |      |       |       |      |      |      |     |    |    |     | 6   |
| Common gull              |      |    |   |   |      |     | 1    |      |     |     | 1  | 3   | 8   | 2   |     |   |      |       |       |      |      |      | 1   |    | 2  |     | 18  |
| Lesser black-backed gull |      |    |   |   |      |     | 2    |      |     |     |    | 6   | 10  | 6   |     |   |      |       |       |      |      |      | 1   |    |    |     | 25  |
| Herring gull             |      |    | 2 |   |      |     | 2    |      |     |     | 1  | 7   | 12  | 3   |     |   |      |       |       |      |      |      | 2   |    | 4  |     | 33  |
| Yellow-legged gull       |      |    |   |   |      |     | 1    |      |     |     |    |     | 2   |     |     |   |      |       |       |      |      |      |     |    |    |     | 3   |
| Glaucous gull            |      |    |   |   |      | 1   |      |      |     | 4   |    | 1   | 1   |     |     |   |      |       |       |      |      |      |     |    |    |     | 7   |
| Great black-backed gull  |      |    |   |   |      |     | 2    |      |     |     | 1  | 11  | 12  | 4   |     |   |      |       |       |      |      |      | 1   |    | 4  |     | 35  |
| Gull sp.                 |      |    |   |   |      |     |      |      |     |     |    | 2   | 1   |     |     |   |      |       |       |      |      |      |     |    |    |     | 3   |
| Kittiwake                |      |    |   |   |      | 4   |      |      |     | 3   | 1  | 12  | 15  | 4   |     |   |      |       |       |      |      |      | 1   | 5  | 4  |     | 49  |
| Ivory gull               |      |    |   |   |      | 1   |      |      |     |     |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    |     | 1   |
| Sandwich tern            |      |    |   |   |      |     |      |      |     |     |    |     | 1   | 5   |     |   |      |       |       |      |      |      |     |    |    |     | 6   |
| Common tern              |      |    |   |   |      | 2   |      |      |     | 3   |    |     | 16  | 1   |     |   |      |       |       |      |      |      |     |    | 3  |     | 25  |
| Arctic tern              |      |    |   |   |      |     |      |      |     | 1   |    | 10  | 6   | 1   |     |   |      |       |       |      |      |      |     |    |    | 1   | 19  |
| Common/Arctic tern       |      |    |   |   |      |     |      |      |     |     |    |     | 1   | 1   |     |   |      |       |       |      |      |      |     |    |    | 1   | 3   |
| Guillemot                |      |    |   |   |      | 8   | 3    | 1    | 3   | 5   |    | 10  | 11  | 5   |     |   | 2    |       |       |      | 1    |      | 1   | 5  | 25 | 80  |     |
| Brunnich's guillemot     | 1    | 12 | 1 |   |      | 9   |      |      | 1   | 6   |    |     |     |     |     |   |      |       |       |      |      |      |     |    | 4  | 12  | 46  |
| Razorbill                |      |    |   |   |      | 4   | 3    | 1    |     |     |    | 5   | 4   | 2   | 1   | 1 | 2    | 1     | 1     |      | 5    |      | 4   | 5  | 20 | 59  |     |
| Black guillemot          | 1    |    | 1 |   |      | 13  | 1    | 5    | 2   | 7   | 5  |     | 13  | 1   |     |   |      |       |       |      |      |      | 1   | 4  | 11 | 65  |     |
| Little auk               |      |    |   |   |      | 2   | 1    |      |     | 3   |    |     |     |     |     |   |      |       |       |      |      |      |     |    |    | 1   | 7   |
| Puffin                   |      |    |   |   |      | 21  |      |      | 29  | 1   |    | 48  | 18  | 1   |     |   |      |       |       |      | 5    | 1    | 19  | 6  | 6  | 155 |     |
|                          | 3    | 12 | 7 | 1 |      | 69  | 4    | 22   | 3   | 40  | 47 | 8   | 237 | 153 | 49  | 1 | 1    | 4     | 1     | 1    | 1    | 11   | 1   | 49 | 35 | 161 | 921 |

**Table 5.1.2** Seabird diet studies surveyed for the Diet Database by NAFO area or ICES subregion and season (pre-breeding, summer, breeding, post-breeding, winter and unassigned (n.s.)).

| NAFO/ICES | pre-breeding | summer | breeding | post-breeding | winter | n.s. | <b>Total</b> |
|-----------|--------------|--------|----------|---------------|--------|------|--------------|
| 0         |              | 2      | 1        |               |        |      | 3            |
| 3         | 3            |        |          |               | 9      |      | 12           |
| 4         |              | 1      | 4        |               | 1      | 1    | 7            |
| 5         |              |        | 1        |               |        |      | 1            |
| I         | 12           | 4      | 47       | 5             | 1      |      | 69           |
| IIa       |              |        | 36       | 2             | 2      |      | 40           |
| IIb       | 2            | 2      | 34       | 9             |        |      | 47           |
| III       |              | 1      | 1        |               | 2      |      | 4            |
| IIIa      | 6            |        | 10       |               | 6      |      | 22           |
| IIIb      |              | 2      | 1        |               |        |      | 3            |
| IV        |              |        |          | 8             |        |      | 8            |
| IVa       | 11           | 2      | 140      | 15            | 28     | 41   | 237          |
| IVb       | 19           |        | 69       | 37            | 26     | 2    | 153          |
| IVc       | 9            |        | 10       | 5             | 18     | 7    | 49           |
| V         |              |        | 1        |               |        |      | 1            |
| Va        |              | 2      | 32       |               | 1      |      | 35           |
| Vla       |              |        | 32       | 2             |        | 15   | 49           |
| VIIe      |              |        |          |               | 1      |      | 1            |
| VIIg      |              |        | 11       |               |        |      | 11           |
| VIIj      |              |        | 1        |               |        |      | 1            |
| VIII      |              |        |          |               | 4      |      | 4            |
| VIIIa     |              |        |          |               | 1      |      | 1            |
| VIIIc     |              |        |          |               | 1      |      | 1            |
| IXa       |              |        |          |               | 1      |      | 1            |
| n.s.      | 3            | 15     | 103      | 7             | 18     | 15   | 161          |
|           | 65           | 31     | 534      | 90            | 120    | 81   | 921          |

**Table 5.1.3** Seabird diet studies surveyed for the Diet Database by predator species and season (pre-breeding, summer, breeding, post-breeding, winter and unassigned (N.S.)).

| Predator                 | Pre-breeding | Summer | Breeding | Post-breeding | Winter | N.S. | Total |
|--------------------------|--------------|--------|----------|---------------|--------|------|-------|
| Red-throated diver       |              |        | 3        |               | 3      | 3    | 9     |
| Black-throated diver     | 1            |        | 2        |               | 1      |      | 4     |
| Great northern diver     |              |        | 10       | 1             | 4      | 6    | 21    |
| White-billed diver       | 1            |        |          |               |        |      | 1     |
| Great crested grebe      |              |        |          |               | 1      |      | 1     |
| Fulmar                   | 8            |        | 36       | 10            | 8      | 6    | 68    |
| Cory's shearwater        |              |        | 1        |               |        |      | 1     |
| Great shearwater         |              |        |          |               |        | 1    | 1     |
| Sooty shearwater         |              |        |          | 2             |        | 2    | 4     |
| Gannet                   | 5            |        | 20       | 6             | 7      | 2    | 40    |
| Cormorant                |              |        | 4        |               |        |      | 4     |
| Double-crested cormorant |              | 1      | 22       |               |        |      | 23    |
| Shag                     |              |        | 1        |               |        | 6    | 7     |
| Cormorant sp.            |              |        | 1        |               |        |      | 1     |
| Common eider             |              | 2      |          | 2             | 1      |      | 5     |
| Common scoter            |              |        |          |               | 1      |      | 1     |
| Red-necked phalarope     |              |        | 1        |               |        |      | 1     |
| Pomarine skua            |              |        |          | 2             |        |      | 2     |
| Arctic skua              |              |        | 1        |               |        | 4    | 5     |
| Great skua               |              |        | 62       | 6             |        | 7    | 75    |
| Little gull              |              |        | 1        |               |        |      | 1     |
| Bonaparte's gull         | 1            |        |          |               |        |      | 1     |
| Black-headed gull        | 1            |        |          | 4             |        | 1    | 6     |
| Common gull              | 3            |        | 2        | 7             | 5      | 1    | 18    |
| Lesser black-backed gull | 3            |        | 7        | 6             | 6      | 3    | 25    |
| Herring gull             | 7            |        | 11       | 6             | 6      | 3    | 33    |
| Yellow-legged gull       | 1            |        | 1        | 1             |        |      | 3     |
| Glaucous gull            | 1            |        | 2        | 2             | 2      |      | 7     |
| Great black-backed gull  | 7            |        | 10       | 7             | 6      | 5    | 35    |
| Gull sp.                 |              |        |          |               | 3      |      | 3     |
| Kittiwake                | 9            |        | 19       | 9             | 8      | 4    | 49    |
| Ivory gull               |              | 1      |          |               |        |      | 1     |
| Sandwich tern            |              |        | 6        |               |        |      | 6     |
| Common tern              | 2            |        | 21       | 2             |        |      | 25    |
| Arctic tern              |              |        | 14       | 2             |        | 3    | 19    |
| Common/Arctic tern       |              |        | 1        | 1             |        | 1    | 3     |
| Guillemot                | 7            | 4      | 37       | 7             | 18     | 7    | 80    |
| Brunnich's guillemot     | 6            | 7      | 17       | 1             | 15     |      | 46    |
| Razorbill                |              |        | 39       | 2             | 13     | 5    | 59    |
| Black guillemot          | 2            | 16     | 35       | 1             | 6      | 5    | 65    |
| Little auk               |              |        | 3        | 2             | 2      |      | 7     |
| Puffin                   |              |        | 144      | 1             | 4      | 6    | 155   |
|                          | 65           | 31     | 534      | 90            | 120    | 81   | 921   |

**Table 5.1.4** Poorly represented areas and species groups in the 1.0 version of the diet database

| ICES/NAFO region | updates required              | area                |
|------------------|-------------------------------|---------------------|
| 0                | all species                   | Baffin Island       |
| 1                | all species                   | West Greenland      |
| 2                | all species                   | East Labrador       |
| 3                | Gannet, seaduck, gulls, terns | Newfoundland        |
| 4                | Gannet, seaduck, gulls terns  | Nova Scotia         |
| 5                | Gannets, gulls, terns         | Maine               |
| I                |                               | Barents Sea         |
| II               |                               | Norw/Greenl Sea     |
| III              | seaduck                       | Baltic Sea          |
| IV               | seaduck                       | North Sea           |
| V                | all species                   | Iceland/Faeroe      |
| VI               | all species                   | off NW Scotland     |
| VII              | all species                   | off SW Ireland      |
| VIII             | all species                   | Bay of Biscay       |
| IX               | all species                   | Atlantic off Iberia |
| X                | all species                   | Azores, open ocean  |
| XII              | all species                   | C North Atlantic    |
| XIV              | all species                   | East Greenland      |

## **6 HOW CAN WE DEVELOP AWARENESS OF THE RELEVANCE OF SEABIRD ECOLOGY TO ICES SCIENCE AND ADVICE?**

### **6.1 Introduction**

We feel that knowledge of seabird ecology can offer a great deal in enhancing ICES science and advice. Studies of seabirds have been underway for more than a century, and in some cases there are datasets that extend throughout this period. Long runs of data are generally rare. These seabird data show some strong trends, which may well be related to human use of, or “natural” changes in, the marine environment and therefore should be of direct interest to ICES. Seabirds are at the top of the food chain, and as such consume quantities of organisms that are the focus of other areas of ICES science and advice. In addition, contaminants within the food organisms are ingested and may be accumulated. Top predators can act as a remarkably sensitive indication of the state of contamination or pollution of the marine environment.

### **6.2 Suggestions**

The core of developing awareness must be further integration of our work with that of the “mainstream” of ICES. Encouraging the participation of marine scientists who would not normally consider their knowledge of being useful to WGSE in working group meetings would be particularly valuable. This would be facilitated by holding concurrent meetings, or by holding meetings in “non ornithological” institutes.

Greater integration with the wider scientific community will be furthered through the participation in and or organisation of scientific meetings. Members of WGSE will offer papers to the Theme session on Trophic Dynamics of Top Predators: Foraging Strategies and Requirements, and Consumption Models to be held at the 2000 ASM. However, greater integration will be achieved if members offered to a much wider range of theme sessions.

Greater awareness can also be achieved through publication. WGSE has succeeded in preparing two ICES CRR during its existence, and certainly intends to continue to do this. Publication on the ICES website (see Section 8) will further develop awareness.

### **6.3 Limitations**

In making these suggestions, WGSE would like to point out that it is reliant on the participation of a range of scientists from a number of institutions. Many of these institutions are not funded directly by the Governments of Member Countries, or are not funded for participation in the work of ICES. The capacity of the Group (and therefore of ICES) would be considerably enhanced if further Member Governments could find ways of providing funding for participation in the Group. We note also that there will be a need to work closely with scientists from other specialisms/Working Groups in order to undertake many of these tasks. Both Member Governments and ICES will need to examine ways by which this integration may be achieved.

As a further tactic to ensure the integration of ICES advice, we will examine ways of holding joint meetings with other Groups within ICES in order that we might benefit from interdisciplinary working. The proposal for concurrent meetings with other Groups working under the Oceanography Committee is greeted with enthusiasm by WGSE (see Section 9). We think that meetings concurrent with other Working Groups under, for instance the Living Resources Committee, ACME or ACFM would enhance knowledge and use of seabird information.

Much of the above also relies on the support and vision of the senior bodies within ICES. If integration is not seen as essential at this level, it will not happen. We were disappointed, for instance that the Study Group on Discard and By-catch Information (SGDBI), established at the 1999 Statutory meeting, has no term of reference or objective that would take account of the usefulness of this information to those concerned with the wider ecosystems effects of discards and bycatch. Seabirds are major consumers of discards and, as pointed out previously by the Working Group on Ecosystem Effects of Fishing Activities (WGECO), collection of discard information needs to take account of the needs of those looking at ecosystem effects as well as those using it in improving fisheries management advice.

## 7 COLLATION OF INFORMATION ON THE DISTRIBUTION AND POSSIBLE CONSUMPTION OF FISH OFFAL AND DISCARDS BY SEABIRDS IN THE BALTIC SEA

There has, as far as we know, been no research on the importance of discards or offal in the diets of seabirds in the Baltic Sea. However, we have been able to make a preliminary assessment of the likely consumption of discards and offal by scavenging seabirds in the Baltic Sea. This has been achieved by examining seabird numbers and distribution, knowledge of their diet composition, data on consumption of experimentally discarded fish in two areas of the southern Baltic, and newly available data on quantities of discards and offal discharged by Baltic fisheries.

### 7.1 Breeding populations of seabirds in the Baltic (ICES Area III)

Numbers of pairs of seabirds breeding on Baltic Sea coasts were taken from Hagemeyer and Blair (1997). The data in that volume are presented by country and by distribution maps with varying sizes of symbols. As a result there is no explicit information on the proportions of the national totals that nest on the coasts, and therefore that may feed in the Baltic Sea rather than in freshwater or terrestrial habitats. We have therefore used the following procedures to convert national totals to totals for the Baltic Sea: we assumed that:

- all Arctic skuas, lesser black-backed gulls, herring gulls, great black-backed gulls, Caspian terns, Sandwich terns, common terns, Arctic terns little terns, guillemots, razorbills and black guillemots breeding in each country bordering the Baltic Sea fed in marine environments;
- that half of the breeding cormorants, little and common gulls
- that 20% of breeding Mediterranean and black-headed gulls fed in marine environments (Table 7.1).

In that table, we also present a summary of the importance and types of fish in the diet of each species using only dietary data collected from breeding colonies in the Baltic since diet composition varies between populations in different geographical regions. Similar data for wintering populations are given in Table 7.2.

It is evident from the data in Tables 7.1 and 7.2 that the terns and auks are unlikely to take discards from Baltic Sea fisheries as they feed predominantly on very small fish, with a tendency to select lipid-rich fish such as clupeids. There is only slight evidence from existing dietary studies for breeding large gulls to take discards as a part of their breeding season diet, but this has not been studied in detail in the Baltic area and there have been few recent studies of gull diet, and none specifically investigating the occurrence of discards in breeding Baltic gull diets. In winter, it seems likely that herring gulls will predominate as scavengers of discards in the Baltic given their numerical abundance (Table 7.2), with fulmars, common gulls, and kittiwakes competing for offal and taking small discards, and great black-backed gulls taking large fish discards. Sea ducks are extremely abundant in the Baltic in winter, and there is some evidence to indicate that they can deplete their bivalve food resources through the winter and that they switch increasingly to feeding on fish (especially sandeels) and fish eggs during spring (Stempniewicz and Meissner 1999). Eider ducks do feed on discarded fish and offal beside small fishing boats in harbours, and can become very tame when regularly given fish scraps (R.W. Furness pers. obs.). It is possible that sea ducks, particularly eiders, may consume some discards and offal from Baltic fisheries, but this has not been reported or investigated. The ability of eiders to dive (though rarely to depths greater than 30m) could permit them access to sinking discards and offal out of the reach of surface-feeding gulls and fulmars.

In the case of the herring gull in the Baltic during winter, Durinck *et al.* (1994) state 'more than half occur in Bornholms Deep, where intensive fishing activities are carried out'. Most of the other herring gulls are found in sub-areas 21–23, corresponding to the sub-areas identified by ICES SGDIB as the Sub-areas where the vast majority of discards and majority of offal are produced. According to Durinck *et al.* (1994) 'outside the breeding season, herring gulls frequently eat fish waste from trawlers, and their winter distribution in the offshore parts of the Baltic Sea seems to depend on commercial fishing activities'. Total counts of wintering herring gulls in the Baltic do not include birds in harbours, on coastlines, estuaries or in terrestrial habitats, although birds may move between these habitats. Durinck *et al.* (1994) state of other gulls that might feed on discards or offal 'new gulls [=common gulls] may also feed on fisheries waste', of great black-backed gulls 'this species is a common scavenger behind trawlers, where it feeds mainly on discarded fish' and of kittiwakes 'fish waste from fishing vessels is also an important food resource'.

Therefore, we can surmise that these gull are important scavengers of discards and offal from the Baltic Sea fisheries. Next we develop a more quantitative assessment of this feeding activity.

**Table 7.1.** Breeding numbers of seabirds in countries bordering the Baltic Sea and estimates of the numbers of pairs of breeding seabirds that feed in Baltic Sea marine environments during summer, and summary of importance of fish in the diet. Census data from Hagemeyer and Blair (1997).

| Seabird species          | Breeding pairs in countries bordering the Baltic Sea | Estimated number of breeding pairs feeding in Baltic Sea during summer | Fish in breeding season diet at Baltic Sea colonies                                       | References for diet composition data |
|--------------------------|--|--|---|--------------------------------------|
| Great cormorant          | 60,000   | 30,000   | 100% fish, of a wide range of species and sizes   | Cramp and Simmons 1977               |
| Arctic skua              | 1,000  | 1,000  | Mostly small fish stolen from terns and gulls   | Cramp and Simmons 1983               |
| Mediterranean gull       | 50   | 10   | Some marine fish including discards but mainly outside breeding season                    | Cramp and Simmons 1983               |
| Little gull              | 13,000   | 6,500  | Mostly insects but some fish  | Cramp and Simmons 1983               |
| Black-headed gull        | 600,000  | 120,000  | 14% fish  | Götmark 1984                         |
| Common gull              | 100,000  | 50,000   | 17–49% fish   | Götmark 1984                         |
| Lesser black-backed gull | 30,000   | 30,000   | 87–92% fish (herring, sandeels, plaice, gadoids), including discards up to 31cm length.   | Götmark 1984, Hario 1990             |
| Herring gull             | 200,000  | 200,000  | 21–60% fish, including discards   | Götmark 1984                         |
| Great black-backed gull  | 12,000   | 12,000   | 41–82% fish, including discards   | Götmark 1984                         |
| Kittiwake                | 100  | 100  | Mostly sprats   | Cramp 1985                           |
| Caspian tern             | 1,900  | 1,900  | Fish, especially roach, perch and clupeids, 15–20cm                                       | Cramp 1985                           |
| Sandwich tern            | 1,500  | 1,500  | Marine fish ca 12cm   | Cramp 1985                           |
| Common tern              | 70,000   | 70,000   | Small marine and brackish fish, ca 6cm  | Cramp 1985                           |
| Arctic tern              | 80,000   | 80,000   | Small marine and brackish fish, ca 6 cm   | Cramp 1985                           |
| Little tern              | 2,000  | 2,000  | Marine invertebrates and small fish, ca 4 cm  | Cramp 1985                           |
| Common guillemot         | 15,000   | 15,000   | Mostly sprats   | Lyngs and Durinck 1998               |
| Razorbill                | 15,000   | 15,000   | Mostly clupeids   | Cramp 1985                           |
| Black guillemot          | 20,000   | 20,000   | Littoral and sublittoral fish and crustacea, especially butterfish, sandeels and blennies | Cramp 1985                           |

**Table 7.2.** Numbers of seabirds in Baltic Sea marine environments outside of the breeding season, with a summary of the importance of fish in the diet, and assessment of the likely importance of discards and/or offal in their diet.

| Seabird species                                       | Number of individuals in Baltic Sea in winter | Fish in diet outside of the breeding period, using Baltic Sea data where possible                                 | Reference for diet composition data relating to non-breeding seasons | Likely importance of discards/offal in diet outside breeding season                   |
|---|---|---|--|---|
| Great cormorant                                       | 19,400  | 100% fish, of a wide range of species and sizes   | Cramp and Simmons 1977   | Probably not, though there are a few records of cormorants taking discards            |
| Northern fulmar                                       | 2,700   | No Baltic data? Diet in Atlantic and North Sea includes offal and discards, as well as zooplankton and small fish | Cramp and Simmons 1977, Tasker and Furness 1996                      | Yes. Fulmars often obtain high proportions of offal and some discards                 |
| Sea ducks (mostly eiders, scoters, long-tailed ducks) | 7,500,000                                     | 0–40% fish (mainly sandeels and fish eggs), fish consumption increasing from winter to spring                     | Stempniewicz and Meissner 1999                                       | Probably not, though sea ducks, especially eiders, might take some discards and offal |
| Little gull   | 2,250   | Probably chiefly fish and marine invertebrates  | Cramp and Simmons 1983   | Not known. Due to small size may not be able to compete with larger gulls             |
| Common gull   | 72,000  | Some fish, including clupeids   | Cramp and Simmons 1983   | Yes? However, may be competed out by larger gulls                                     |
| Herring gull  | 310,000                                       | 5–30% gadoid discards; highest in winter and higher off Rostock than off Kiel                                     | Garthe <i>et al.</i> In prep; Garthe and Scherp in prep; Scherp 1999 | Yes. Takes discards and where possible offal  |
| Great black-backed gull                               | 21,000  | Mainly fish   | Cramp and Simmons 1983   | Yes. Takes discards and can swallow fish up to 35cm length                            |
| Kittiwake   | 76,000  | Mainly marine fish and invertebrates  | Cramp and Simmons 1983   | Yes. However, may be outcompeted by larger gulls                                      |
| Common guillemot                                      | 86,000  | 46% clupeids (mean length 13cm), 51% gadoids (mean length 10cm, max 21cm)   | Lorentsen and Anker-Nilssen 1999                                     | No  |
| Razorbill   | 156,000                                       | Similar to common guillemot   | Cramp 1985   | No  |
| Black guillemot                                       | 50,000  | Marine inshore fish   | Cramp 1985   | No  |

## 7.2 Discard and offal quantities produced by Baltic fisheries

The ICES Study Group on Estimation of the Annual Amount of Discards and Fish Offal in the Baltic Sea (SGDIB) reported in February 2000. Their report only reached our Working Group half way through our meeting in March 2000 and so we have had only a short time to explore the implications of their data for seabirds. However, we extracted from their report the following summary data. The SGDIB concluded that in 1998 (assumed to be typical of recent years) about 11,000 t of fish was discarded in the Baltic, with 4432 t in Sub-area 22, 2058 t in Sub-area 24, 3598 t in Sub-area 25, 786 t in Sub-area 26 and only 125 t in all the Sub-areas of the Baltic further to the north (Sub-areas 27–32). No data on sizes of fish discarded were available but species composition was predominantly cod (6573 t), flounder (2089 t), sprat (909 t), plaice (515 t), dab (390 t), scorpion fish (217 t), turbot (68 t) and whiting (52 t). The total discard mass represented 1.4% of total Baltic fish catch in 1998, or 3.8% of catch if industrial fish catch is excluded. This is a remarkably low discard fraction by comparison with fisheries in the North Sea and other areas. The estimate of offal discharge at sea was 18,400 t, mostly discharged in Sub-areas 22–26, with similar quantities produced in each of the four quarters of the year.

### 7.3 Estimates of fish consumption by seabirds in the Baltic

Elsewhere in this Report (Section 4), the food requirements of seabirds in the Baltic were estimated. The fish consumption by seabirds of species that can be expected to feed extensively on discards or offal were estimated as in Table 7.3. The result suggests that the seabirds likely to feed on discards and offal have a total fish consumption in the Baltic Sea that is considerably greater than the estimated quantity of discards and offal being produced there. This is not necessarily a contradiction, since it is known that several of these seabirds catch fish such as herring, sprats, and sandeels (Tables 7.1 and 7.2) as well as feeding on discards and offal.

**Table 7.3.** Estimates (from Section 4 of this report) of the quantities of fish (including discards and offal) consumed in the Baltic Sea by seabirds of the species likely to take some discards and/or offal

| Seabird species          | Estimated fish consumption (including discards and offal) (tonnes) | Time of year when most of this is consumed |
|--------------------------|--|--|
| Northern fulmar          | 64   | Winter                                     |
| Black-headed gull        | 1,867  | All year                                   |
| Common gull              | 3,516  | All year                                   |
| Herring gull             | 29,923   | Winter                                     |
| Lesser black-backed gull | 4,944  | Summer                                     |
| Great black-backed gull  | 4,557  | Winter                                     |
| Black-legged kittiwake   | 977  | Winter                                     |
| Total                    | 45,848   | Mainly in winter                           |

### 7.4 Consumption of discards and offal by seabirds at fishing vessels in the southern Baltic

Discard and offal consumption was investigated by so-called discard experiments (Table 7.4, 7.5, 7.6) from commercial fish trawlers and fishery research vessels (Scherp 1999). The study was conducted between June and December 1998, following the general methodology described e.g., by Hudson and Furness (1988) and Camphuysen *et al.* (1995). Studies concentrated on the areas off Kiel and Rostock but took also place until Poland. Table 7.4 shows that the proportions of experimentally discarded fish from commercial and research vessels that were consumed by gulls was high for roundfish, but lower for flatfish. For roundfish, over 80% of discards were taken by gulls up to lengths of 27cm, but larger cod were often too big for gulls to swallow. By species of fish (Table 7.5), consumption rates by gulls were similar to results obtained previously in studies in the North Sea (Camphuysen *et al.* 1995). Consumption was predominantly by herring gulls, which took over 90% of discards consumed by seabirds both in studies in ICES IIIc and in ICES III d (Table 7.6). These data are based on relatively small numbers of cruises and there is a need for further studies of discard consumption by seabirds in the Baltic, but the patterns reported here are as would be anticipated and are unlikely to be altered by more detailed study.

### 7.5 Ship-following seabirds

Birds attending commercial trawlers and fishery research vessels were counted throughout the study period. Following Garthe and Hüppop (1994), the maximum number per bird species attracted by the fishing vessels was taken. From that, mean numbers of ship-followers as well as their relative proportion were calculated (Table 7.7). Herring gulls predominated behind fishing vessels, forming 90–96% of the total flock of scavenging seabirds in the Baltic, both in summer and in winter. These results are entirely consistent with expectations based on the total numbers and the feeding habits of the seabirds to be found in the Baltic (Tables 7.1 and 7.2).

### 7.6 Estimated quantities of discards and offal consumed by Baltic seabirds

Discard and offal quantities consumed by seabirds in the Baltic (Table 7.8) were calculated on the basis of the data on discards and offal estimates provided by ICES (2000). These values were multiplied by the relative proportions of discards and offal so that a total of 7,100 t of discards and 17,800 t of offal resulted. According to ICES (2000), discards represent only 3.8 % of the total catch (with industrial catch totals excluded) which is remarkably low compared to all studies in the North Sea (e.g., Garthe *et al.* 1996). The discard and offal utilization by birds, on the other hand, might be somewhat overestimated due to a bias by conducting the discard experiments (Garthe and Hüppop 1998). Further studies and the application of correction figures (Garthe and Hüppop 1998) are certainly needed to refine the estimates on discard and offal consumption by seabirds, but it can be seen that gulls take a very high proportion of the discards and offal produced by fisheries in the Baltic Sea, with the herring gull being the main consumer at all times of year.

**Table 7.4:** Proportion of discarded fish (by length) consumed by scavenging seabirds in the Baltic Sea. ICES Sub-areas IIIc and IIId are combined as are seasons. Data are calculated from Scherp (1999) and Garthe and Scherp (in prep.). PDC = proportion of discards consumed

| Length (cm) | Cod    |     | Dab    |     | Sprat  |     | Herring |     | Whiting |     |
|-------------|--------|-----|--------|-----|--------|-----|---------|-----|---------|-----|
|             | sample | PDC | sample | PDC | Sample | PDC | sample  | PDC | Sample  | PDC |
| 7           | 1      | 0   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 8           | 0      | -   | 0      | -   | 5      | 60  | 1       | 0   | 0       | -   |
| 9           | 1      | 100 | 0      | -   | 4      | 100 | 0       | -   | 3       | 100 |
| 10          | 8      | 75  | 4      | 50  | 27     | 93  | 1       | 0   | 12      | 100 |
| 11          | 5      | 80  | 4      | 50  | 203    | 99  | 2       | 100 | 16      | 94  |
| 12          | 23     | 87  | 5      | 80  | 274    | 98  | 7       | 71  | 23      | 87  |
| 13          | 19     | 89  | 5      | 0   | 90     | 96  | 10      | 100 | 40      | 80  |
| 14          | 26     | 96  | 4      | 25  | 36     | 94  | 7       | 86  | 60      | 93  |
| 15          | 31     | 100 | 4      | 50  | 0      | -   | 15      | 93  | 91      | 98  |
| 16          | 26     | 96  | 4      | 0   | 0      | -   | 59      | 97  | 79      | 92  |
| 17          | 33     | 94  | 10     | 20  | 0      | -   | 67      | 97  | 40      | 98  |
| 18          | 33     | 85  | 11     | 27  | 0      | -   | 50      | 96  | 24      | 88  |
| 19          | 41     | 95  | 6      | 0   | 0      | -   | 35      | 97  | 22      | 100 |
| 20          | 81     | 95  | 28     | 21  | 0      | -   | 3       | 100 | 37      | 86  |
| 21          | 75     | 92  | 31     | 3   | 0      | -   | 0       | -   | 14      | 100 |
| 22          | 89     | 84  | 16     | 25  | 0      | -   | 0       | -   | 27      | 93  |
| 23          | 88     | 95  | 19     | 16  | 0      | -   | 0       | -   | 14      | 100 |
| 24          | 93     | 86  | 9      | 44  | 0      | -   | 0       | -   | 7       | 100 |
| 25          | 171    | 83  | 14     | 29  | 0      | -   | 0       | -   | 19      | 89  |
| 26          | 78     | 83  | 11     | 36  | 0      | -   | 0       | -   | 8       | 88  |
| 27          | 60     | 73  | 4      | 25  | 0      | -   | 1       | 100 | 8       | 88  |
| 28          | 57     | 72  | 0      | -   | 0      | -   | 0       | -   | 5       | 100 |
| 29          | 46     | 67  | 1      | 0   | 0      | -   | 0       | -   | 5       | 60  |
| 30          | 40     | 65  | 1      | 100 | 0      | -   | 0       | -   | 4       | 100 |
| 31          | 18     | 39  | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 32          | 21     | 48  | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 33          | 10     | 70  | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 34          | 9      | 22  | 0      | -   | 0      | -   | 0       | -   | 1       | 100 |
| 35          | 5      | 20  | 0      | -   | 0      | -   | 0       | -   | 1       | 0   |
| 36          | 5      | 20  | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 37          | 0      | -   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 38          | 2      | 50  | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 39          | 2      | 100 | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 40          | 1      | 0   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 41          | 0      | -   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 42          | 0      | -   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 43          | 0      | -   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 44          | 0      | -   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 45          | 0      | -   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |
| 46          | 2      | 0   | 0      | -   | 0      | -   | 0       | -   | 0       | -   |

**Table 7.5:** Consumption of different discard species by seabirds. Calculations are given for ICES Sub-areas IIIc and IIId but seasons are combined due to sample sizes. Data are calculated from Scherp (1999) and Garthe and Scherp (in prep.).

|                       | ICES Sub-area IIIc |                     | ICES Sub-area IIId |                     |
|-----------------------|--------------------|---------------------|--------------------|---------------------|
|                       | sample             | proportion consumed | sample             | proportion consumed |
| Cod                   | 1119               | 85 %                | 1183               | 84 %                |
| Dab                   | 191                | 23 %                | -                  | -                   |
| Herring               | 46                 | 78 %                | 828                | 89 %                |
| Plaice                | 11                 | 0 %                 | -                  | -                   |
| Four-bearded rockling | 16                 | 94 %                | 18                 | 61 %                |
| Sprat                 | 15                 | 73 %                | 935                | 89 %                |
| Scad                  | 6                  | 83 %                | -                  | -                   |
| Whiting               | 580                | 93 %                | 40                 | 83 %                |

**Table 7.6:** Consumption of three types of discards by seabirds. Calculations are given for ICES Sub-areas IIIc and IIId but seasons are combined due to sample sizes. Data are calculated from Scherp (1999) and Garthe and Scherp (in prep.).

|                     | Sample |              | Proportion consumed by species: |          |             |               |
|---------------------|--------|--------------|---------------------------------|----------|-------------|---------------|
|                     | Size   | Herring Gull | GBB Gull                        | LBB Gull | Common Gull | Black-h. Gull |
| ICES Sub-area IIIc: |        |              |                                 |          |             |               |
| gadids              | 1485   | 95 %         | 5 %                             | 0 %      | 0 %         | 0 %           |
| clupeids            | 47     | 91 %         | 0 %                             | 0 %      | 9 %         | 0 %           |
| flatfish            | 44     | 91 %         | 9 %                             | 0 %      | 0 %         | 0 %           |
| ICES Sub-area IIId: |        |              |                                 |          |             |               |
| gadids              | 1023   | 93 %         | 6 %                             | 0 %      | 1 %         | 0 %           |
| clupeids            | 1573   | 96 %         | 0 %                             | 2 %      | 1 %         | 0 %           |
| flatfish            | -      |              |                                 |          |             |               |

**Table 7.7:** Absolute and relative proportion of the seabirds attending fishing vessels in the Baltic Sea. Data are calculated from Scherp (1999) and Garthe and Scherp (in prep.). Great cormorant *Phalacrocorax carbo* and little gull *Larus minutus* were seen once and are not listed here.

|                     | Sample size (counts) | Species attending: |          |          |             |               |
|---------------------|----------------------|--------------------|----------|----------|-------------|---------------|
|                     |                      | Herring gull       | GBB gull | LBB gull | Common gull | Black-h. gull |
| summer:             |                      |                    |          |          |             |               |
| ICES Sub-area IIIc: | 11                   | 31 (96 %)          | 2 (3 %)  | 0        | < 1 (1 %)   | 0             |
| ICES Sub-area IIId: | 12                   | 129 (91 %)         | 4 (3 %)  | 7 (5 %)  | 1 (1 %)     | 1 (1 %)       |
| winter:             |                      |                    |          |          |             |               |
| ICES Sub-area IIIc: | 18                   | 117 (91 %)         | 5 (4 %)  | 0        | 6 (5 %)     | < 1 (0 %)     |
| ICES Sub-area IIId: | 22                   | 249 (90 %)         | 13 (5 %) | 0        | 16 (6 %)    | 0             |

**Table 7.8:** Quantities of discards and offal produced annually in the Baltic Sea and their consumption by seabirds. Data on discard and offal quantities taken from ICES (2000). Proportions consumed by seabirds were calculated as follows: for cod, sprat and whiting values were taken from Table 7.5, for flatfishes values were taken as an average for dab and plaice (see Table 7.5), for scorpion fish and "other fish" consumption percentages were set to 50 %. The value for offal was taken from Scherp (1999).

| Species              | Amount (in t) | Proportion consumed by seabirds | Amount consumed by seabirds (t) |
|----------------------|---------------|---------------------------------|---------------------------------|
| Cod                  | 6,573         | 85 %                            | 5,587                           |
| Flounder             | 2,089         | 12 %                            | 251                             |
| Sprat                | 909           | 81 %                            | 736                             |
| Plaice               | 390           | 12 %                            | 47                              |
| Scorpion fish        | 217           | 50 %                            | 109                             |
| Turbot               | 68            | 12 %                            | 8                               |
| Whiting              | 52            | 88 %                            | 46                              |
| other fish           | ca. 702       | 50 %                            | 351                             |
| <b>total discard</b> | <b>11,000</b> |                                 | <b>7,135</b>                    |
| <b>offal</b>         | <b>18,400</b> | 97 %                            | <b>17,848</b>                   |

## 7.7 Conclusions

Although there has been only a very limited amount of work on the consumption of discards by seabirds in the Baltic Sea, it is evident that herring gulls consume a high proportion of the offal and discard production in this area. A few discards are too large for gulls to swallow (predominantly cod over 27cm) but there is evidence of gulls selecting roundfish discards and not taking some flatfish discards. The data suggest that gulls consume considerably more than half of the discards and almost all of the offal discharged by Baltic fisheries. In addition, it appears that herring gull distribution in the Baltic in winter is determined to a considerable extent by the local distribution of discarding fishing vessels, which are concentrated in the southwest Baltic. Whether the provision of discards and offal from Baltic fisheries has affected the population trends of gulls in the Baltic is not known.

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## **8 WHAT INFORMATION CAN WE PLACE ON THE ICES WEBSITE?**

### **8.1 Introduction**

In considering this Term of Reference, it is important to assess what the “ICES community” actually is. We know that our reports have been used in considering the usefulness of seabirds in monitoring pollution levels in marine biota, in providing input to consumption models of North Sea fish (be these multi-species or otherwise) and in information provision for Quality Status Reports. It seems likely that potentially interested website viewers might wish to have more basic information on seabirds and their ecology. The suggestions below are made without full evaluation of the resource requirement: there is only a little experience in publishing to the web and it would seem logical that if ICES were to develop its website, the Secretariat (or a contractor) will need to provide some resources or assistance. This would also allow ICES to develop a consistency across the website.

### **8.2 Information**

This category includes basic information on seabirds occurring in the ICES area. Such information could include breeding distribution and numbers, at least by country, and possibly by ICES Sub-division, scientific names. Some basic population parameters might be published, e.g., number of eggs, longevity, survival rates, and productivity. Some of these parameters are relatively easily summarised, while it might be best to point at reviews in other cases. The dietary database developed by Group members could also be published on the web (see Section 5).

### **8.3 Reviews**

Much of the group’s work in recent years has been reviews of relevant topics. These could usefully be placed on the web for ready access. Reviews have included:

Seabirds as monitors of marine pollution,  
Food consumption, both fin- and shell-fish, and  
Use of seabird consumption as an indicator of fish stock health.

A contents list of all of the Group's products would probably be of use to many.

#### **8.4 Literature**

Beside the dietary database (which is underpinned with a literature review), key references to seabird biology in the ICES area could be included.

### **9 WHAT QUESTIONS CAN WE TRY TO ANSWER DURING CONCURRENT MEETINGS WITH OTHER OCEANOGRAPHY COMMITTEE WORKING GROUPS?**

The group considered that this initiative by the Oceanography Committee was very promising. While links with areas of marine science of some of our sister working groups might be viewed as esoteric, there was clear promise in working with WGSSO, WGOH, WGZE and WGCCC. WGSE can provide long-term datasets and insights on seabird abundance, seabird range changes, seabird breeding success and seabird diet. It would be interested in any other long-term datasets that might be of use in interpreting trends in these datasets.

In 1998, WGSE addressed a term of reference "review evidence for decadal scale variations in seabird distributions, populations sizes, reproduction and food habits and evaluate the extent to which these may be linked to the North Atlantic Oscillation and other physical cycles". When the 1998 report (ICES CM 1998/C:5) was under review, the relevant section of the report was (rightly, in hindsight) criticised as being naïve as it had little input from oceanographers. The concurrent meetings proposed for 2002 appear to be an ideal occasion to correct this fault, and we hope that oceanographic colleagues could help with this. The question might indeed be expanded to "Can linkages be found between time series of changes in seabird and oceanographic parameters?". From our review of the 2000 terms of reference to the Oceanography Committee groups it would appear that WGOH would be most relevant to this question.

There have been attempts to link at-sea distribution of seabirds with hydrographic features on the NW European shelf by several authors. It might prove instructive to review these attempts and consider whether there were any general findings, and to identify any areas for further research. It would appear that the expertise of WGSSO and WGOH would be most relevant.

### **10 RECOMMENDATIONS**

#### **10.1 Proposals**

The Working Group on Seabird Ecology makes the following proposals:

1. The **Working Group on Seabird Ecology** [WGSE] (Chair: Mark Tasker, UK) will meet at ICES Headquarters from 9–12 March 2001 to:
  - a) compile a first model of food consumption by seabirds for the entire ICES area;
  - b) examine the practicality and desirability of monitoring other aspects of seabird life history than those presently monitored;
  - c) assess the intersessional work of continuing to add to the database of seabird diet composition in the ICES area;
  - d) further develop ideas for meetings that might be held concurrently with other Working Groups in 2003.

WGSE will report to ACME before its May/June 2001 meeting and to the Oceanography and Marine Habitat Committees at the 90<sup>th</sup> Statutory Meeting.

## 10.2 Supporting information

|   |  |
|---|--|
| Priority:                               | This is the only work being carried out by ICES in relation to seabirds. If ICES wishes to maintain its profile in this area of work, then the above must be regarded as of high priority. Although none of the terms of reference currently result from a request from a client to ICES, the expertise currently present in the group is frequently called upon by the ICES advisory process (e.g., the discard issue). The advisory process may well add terms of reference for this meeting, and in this respect the group's existence should be regarded as having a very high priority.   |
| Scientific Justification:               | <p>a) The Working Group has been modelling consumption for a number of years, with a view to developing a model of the whole ICES area in due course. The group is now in a position to assemble this model. The information should be of interest to other ICES Working Groups, as well as to OSPAR and HELCOM.</p> <p>b) A start on this process was made in 2000 when the sensitivity of seabird population to changes in life history parameters was made. At present, parameters monitored include breeding numbers and success. The process in 2000 indicated that adult survival was particularly important for long-lived species dynamics, while age at first breeding was important for shorter-lived seabirds.</p> <p>c) This will be critical to the successful completion of term of reference a). The Working Group is keen to add information on energy density of prey species to its database and will be searching for this information (see 2) below).</p> <p>The Working Group is keen to continue the process of integration of seabird ecology into the workings of ICES. We look forward to possible concurrent working with sister Groups under the Oceanography Committee umbrella. WGSE thinks that a similar process would be productive for groups working under other committees.</p> |
| Relation to Strategic Plan:             | <p>The above will help achieve the following within the ICES strategic plan</p> <p>Goal 1. Develop a challenging core science programme to fulfil the ICES Mission.</p> <p>Goal 2. Provide sound, credible, timely, and understandable advice that is relevant to today's and future societal needs.</p> <p>Goal 5. Raise public understanding of marine ecosystems and their relevance to society.</p> <p>Objective 1. Understand the physical, chemical, and biological functioning of marine ecosystems.</p> <p>Objective 2. Understand and quantify human impacts on the marine environment, including living marine resources.</p> <p>Objective 3. Develop the scientific basis for sustainable use and protection of the marine environment, including living marine resources.</p> <p>Objective 4. Provide advice on the sustainable use and protection of the marine environment, including living marine resources.</p> <p>Objective 5. Co-ordinate and support interdisciplinary and international marine science programmes.</p> <p>Objective 6. Broaden the diversity of the scientists that participate in ICES activities.</p> <p>Objective 11. Make the scientific products of ICES more accessible to the public</p>   |
| Resource Requirements:                  | The ICES Headquarters is a good working environment. Since all active members of the group are at present funded outside core funding (some are privately funded) within the Member Countries, meeting over a weekend will minimise travel costs of members. If the meeting started on a Friday and finished on a Monday, beneficial interaction with the Secretariat would still be possible.   |
| Participants:                           | The current composition of the Group should be able to achieve the above objectives. However, some may not be able to attend through lack of funding. Funding from Member Countries for group members to attend would be very welcome. In particular, members with practical experience of consumption modelling or seabird monitoring would be useful.  |
| Secretariat Facilities:                 | The usual excellent support from the Secretariat will be appreciated.  |
| Financial:                              | No financial implications  |
| Linkages To Advisory Committees:        | Both ACFM/ACME would find the consumption model of use, either in assessing the environmental needs of seabirds or in estimating effects of seabirds on fish stocks. ACME should find work on seabird monitoring of particular use in devising wider marine environmental monitoring programmes.   |
| Linkages To other Committees or Groups: | The Working Group is keen to continue the process of integration of seabird ecology into the workings of ICES. We look forward to possible concurrent working with sister Groups under the Oceanography Committee umbrella. WGSE thinks that a similar process would be productive for groups working under other committee  |
| Linkages to other Organisations         | OSPAR and HELCOM may find work on seabird monitoring of use in the revised JAMP/equivalent.  |

2. The Working Group requests information on the energy density of seabird prey species from other ICES Working Groups. WGSE is further interested in variation in energy density including both temporal and geographic as well as such factors as length, age and stage. The Group noted that information on discarded fish was equally as important as naturally caught fish. A list of some of the more important prey species in which we are interested is included as Annex 3 to this report. Groups that may have members with relevant expertise or knowledge include: SGDEEP, SGBHSM, HAWG, SGDBI, WGBFAS, NWWG, WGNPBW, WWGNSDS, AFWG, WGEEL, WGSSDS, WGMHSA, WGNSSK, WGZE, WGCEPH, WGMMPD, SGNEPH, SGEF, WGCAN, SGCRA, and SBCAR. In addition, those Groups charged with planning surveys might consider whether it would be possible to gain information on energy density of marine species as an adjunct to the surveys.

The energy density of prey species is a key input parameter of the energetic models used by the group in calculating levels of prey consumption. WGSE has been aware that figures used in their models are frequently “best guesses”. The group is keen to improve this situation, and is thus searching for help in doing so. A compilation of such information on energy density would appear likely to be of use to other groups interested in energetic modelling, and thus WGSE could be of greater help to the ICES community.

**ANNEX 1 – NAMES AND ADDRESSES OF PARTICIPANTS**

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## ANNEX 2 – SCIENTIFIC NAMES OF SPECIES USED IN THIS REPORT

|                          |  |
|--------------------------|--|
| Red-throated diver       | <i>Gavia stellata</i>                    |
| Black-throated diver     | <i>Gavia arctica</i>                     |
| Great northern diver     | <i>Gavia immer</i>                       |
| White-billed diver       | <i>Gavia adamsii</i>                     |
| Great crested grebe      | <i>Podiceps griseigena</i>               |
| (Northern) fulmar        | <i>Fulmarus glacialis</i>                |
| Cory's shearwater        | <i>Calonectris diomedea</i>              |
| Great shearwater         | <i>Puffinus gravis</i>                   |
| Sooty shearwater         | <i>Puffinus griseus</i>                  |
| Wilson's storm-petrel    | <i>Oceanites oceanicus</i>               |
| Leach's storm-petrel     | <i>Oceanodroma leucorhoa</i>             |
| (Northern) gannet        | <i>Sula bassana</i>                      |
| (Great) cormorant        | <i>Phalacrocorax carbo</i>               |
| Double-crested cormorant | <i>Phalacrocorax auritus</i>             |
| Shag                     | <i>Phalacrocorax aristotelis</i>         |
| Cormorant sp.            | <i>Phalacrocorax spec.</i>               |
| Common eider             | <i>Somateria mollissima</i>              |
| Common scoter            | <i>Melanitta fusca</i>                   |
| Red-necked phalarope     | <i>Phalaropus fulicaria</i>              |
| Pomarine skua            | <i>Stercorarius pomarinus</i>            |
| Arctic skua              | <i>Stercorarius parasiticus</i>          |
| Great skua               | <i>Stercorarius skua</i>                 |
| Little gull              | <i>Larus minutus</i>                     |
| Bonaparte's gull         | <i>Larus philadelphia</i>                |
| Black-headed gull        | <i>Larus ridibundus</i>                  |
| Common gull              | <i>Larus canus</i>                       |
| Riung-billed gull        | <i>Larus delawarensis</i>                |
| Lesser black-backed gull | <i>Larus fuscus</i>                      |
| Herring gull             | <i>Larus argentatus</i>                  |
| Iceland gull             | <i>Larus glaucoides</i>                  |
| Yellow-legged gull       | <i>Larus michahellis</i>                 |
| Glaucous gull            | <i>Larus hyperboreus</i>                 |
| Great black-backed gull  | <i>Larus marinus</i>                     |
| Gull sp.                 | <i>Larus spec.</i>                       |
| Black-legged kittiwake   | <i>Rissa tridactyla</i>                  |
| Ivory gull               | <i>Pagophila eburnea</i>                 |
| Sandwich tern            | <i>Sterna sandvicensis</i>               |
| Caspian tern             | <i>Sterna caspia</i>                     |
| Roseate tern             | <i>Sterna dougallii</i>                  |
| Common tern              | <i>Sterna hirundo</i>                    |
| Arctic tern              | <i>Sterna paradisaea</i>                 |
| Common/Arctic tern       | <i>S. hirundo</i> / <i>S. paradisaea</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>                    |
| Little auk               | <i>Alle alle</i>                         |
| Puffin                   | <i>Fratercula arctica</i>                |

**ANNEX 3 – MAJOR PREY SPECIES OF SEABIRDS IN THE ICES AREA, IN ORDER OF NUMBER OF REFERENCES WITHIN THE PRESENT SEABIRD DIET DATABASE.**

|                                     |                                  |                                      |
|-------------------------------------|----------------------------------|--------------------------------------|
| <i>Ammodytes sp.</i>                | <i>Engraulis mordax</i>          | <i>Mysis sp.</i>                     |
| <i>Clupea harengus</i>              | <i>Gammarus wilkitzkii</i>       | <i>Nephrops norvegicus</i>           |
| <i>Merlangius merlangus</i>         | <i>Helicolenus dactylopterus</i> | <i>Pandalus sp.</i>                  |
| <i>Mallotus villosus</i>            | <i>Liparis sp.</i>               | <i>Pleuronectes platessa</i>         |
| <i>Ammodytes marinus</i>            | <i>Meganyctiphanes norvegica</i> | <i>Pomatoschistus minutus</i>        |
| <i>Gadus morhua</i>                 | <i>Mysis oculata</i>             | <i>Pseudopleuronectes americanus</i> |
| <i>Sprattus sprattus</i>            | <i>Ammodytes lancea</i>          | <i>Sebastes marinus</i>              |
| <i>Melanogrammus aeglefinus</i>     | <i>Ammodytes tobianus</i>        | <i>Spinachia spinachia</i>           |
| Offal                               | <i>Belone belone</i>             | <i>Spirinchus starksi</i>            |
| <i>Trisopterus esmarkii</i>         | <i>Buglossidium luteum</i>       | <i>Stichaeus punctatus</i>           |
| <i>Pollachius virens</i>            | <i>Ciliata mustela</i>           | <i>Syngnathus sp.</i>                |
| <i>Eutriglia gurnardus</i>          | <i>Gadiculus argenteus</i>       |                                      |
| <i>Boreogadus saida</i>             | <i>Liocarcinus holsatus</i>      |                                      |
| <i>Scomber scombrus</i>             | <i>Nereis irrorata</i>           |                                      |
| <i>Limanda limanda</i>              | <i>Pholis sp.</i>                |                                      |
| <i>Hippoglossoides platessoides</i> | <i>Pollachius pollachius</i>     |                                      |
| <i>Cephalopoda sp.</i>              | rockling sp.                     |                                      |
| <i>Euphausiacea sp.</i>             | <i>Calanus sp.</i>               |                                      |
| <i>Trisopterus minutus</i>          | <i>Echiichtys vipera</i>         |                                      |
| <i>Pholis gunnellus</i>             | <i>Leptoclinus maculatus</i>     |                                      |
| <i>Callionymus lyra</i>             | <i>Liparis liparis</i>           |                                      |
| <i>Trachurus trachurus</i>          | <i>Lumpenus sp.</i>              |                                      |
| <i>goby sp.</i>                     | <i>Myoxocephalus aeneus</i>      |                                      |
| <i>Decapoda sp.</i>                 | <i>Pandalus borealis</i>         |                                      |
| <i>Argentina sphyraena</i>          | <i>Thysanoessa raschii</i>       |                                      |
| <i>Gonatus fabricii</i>             | <i>Anarhichas lupus</i>          |                                      |
| <i>Trisopterus luscus</i>           | <i>Annelida sp.</i>              |                                      |
| <i>Hyperoplus lanceolatus</i>       | <i>Argentina sp.</i>             |                                      |
| <i>Micromesistius poutassou</i>     | <i>Cephalopod sp.</i>            |                                      |
| <i>Gasterosteus aculeatus</i>       | <i>Ctenolabrus rupestris</i>     |                                      |
| <i>Agonus cataphractus</i>          | <i>Engraulis encrasicolus</i>    |                                      |
| <i>Loligo sp.</i>                   | <i>Eupagarus sp.</i>             |                                      |
| <i>Trigla lucerna</i>               | <i>Gasterosteus sp.</i>          |                                      |
| <i>Osmerus eperlanus</i>            | <i>Hyas araneus</i>              |                                      |
| <i>Tautogolabrus adspersus</i>      | <i>Mytilus edulis</i>            |                                      |
| <i>Parathemisto libellula</i>       | <i>Parathemisto abyssorum</i>    |                                      |
| <i>Zoarces viviparus</i>            | <i>Scyliorhinus canicula</i>     |                                      |
| <i>Nereis sp.</i>                   | <i>Zoarces sp.</i>               |                                      |
| <i>Pleuronectes platessa</i>        | flatfish sp.                     |                                      |
| <i>Solea solea</i>                  | <i>Alosa pseudoharengus</i>      |                                      |
| <i>Asterias rubens</i>              | <i>Ammodytes hexapterus</i>      |                                      |
| <i>Thysanoessa inermis</i>          | <i>Arnoglossus laterna</i>       |                                      |
| <i>Ammodytes americanus</i>         | <i>Brachyura sp.</i>             |                                      |
| <i>Enchelyopus cimbricus</i>        | <i>Eumesogrammus praecisus</i>   |                                      |
| <i>Copepoda sp.</i>                 | <i>Galathea sp.</i>              |                                      |
| <i>Gammarillus homari</i>           | <i>Hyas sp.</i>                  |                                      |
| <i>Gobiusculus flavescens</i>       | <i>Hydrobates pelagicus</i>      |                                      |
| <i>Loligo opalescens</i>            | <i>Hyperia galba</i>             |                                      |
| <i>Lumpenus lampraeformis</i>       | <i>Insecta sp.</i>               |                                      |
| <i>Merluccius merluccius</i>        | <i>Lycodes sp.</i>               |                                      |
| <i>Microstomus kitt</i>             | <i>Maurolicus muelleri</i>       |                                      |
| <i>Myoxocephalus scorpius</i>       | <i>Microgadus tomcod</i>         |                                      |
| <i>Sardina pilchardus</i>           | Molluscs                         |                                      |
| <i>Anguilla rostrata</i>            | <i>Molva molva</i>               |                                      |
| <i>Crystallogobius linearis</i>     | <i>Myoxocephalus sp.</i>         |                                      |