Preponderance of mesopelagic fish in the diet of the Northern Fulmar *Fulmarus glacialis* around the Faroe Islands

Danielsen, J.[1*], van Franeker, J. A.[2], Olsen, B.[3] and Bengtson, S.-A.[4]

**Correspondence author. Email: johannisdanielsen@gmail.com*
[1] *Department of Ecology, Lund University, Sölvegatan 37, SE 223 62 Lund, Sweden;*
[2] *IMARES, PO Box 167, 1790 AB Den Burg, Texel, The Netherlands;*
[3] *Faroese Marine Research Institute, Nóatún, FO-100, Tórshavn, Faroe Islands;*
[4] *Museum of Zoology, Lund University, Helgonavägen 3, SE 223 62 Lund, Sweden.*

Abstract
The Northern Fulmar *Fulmarus glacialis* is the most abundant seabird species on the Faroe Islands and is a significant consumer of marine resources. This diet study over the period 1998–2004 showed that fish was their major food source, supplemented with squid (Teuthida), polychaetes (Polychaeta), crustaceans (Crustacea) and scavenged prey. Among the fish, the small, lipid-rich Myctophid Glacier Lanternfish *Benthosema glaciale* dominated in frequency of occurrence and number of otoliths. Other common fish species were Norway Pout *Trisopterus esmarkii*, Blue Whiting *Micromesistius poutassou*, and Gadidae. Myctophic fish mostly occur in deeper water layers, and their high abundance in a surface feeding seabird is remarkable. As *B. glaciale* is not commercially exploited around the Faroes, competition between fisheries and Northern Fulmars appears limited.

Introduction
The Northern Fulmar *Fulmarus glacialis* is known as a flexible feeder, utilising a wide range of fishes (Pisces), squid (Teuthida), macrozooplankton, scavenged prey discards and offal from commercial fisheries (Fisher 1952; Cramp & Simmons 1977; Camphuysen & van Franeker 1996, 1997; Camphuysen & Garthe 1997; Hamer *et al*. 1997; Phillips *et al*. 1999; Ojowski *et al*. 2001; Garthe *et al*. 2004; Harris *et al*. 2007; Lorenz & Seneveratne 2008).

The Northern Fulmar (hereafter 'Fulmar') is the most numerous seabird on the Faroes with an estimated breeding population of several 100,000 pairs (Bloch & Sørensen 1984), 16–26% of the northeast Atlantic population (Tasker 2004). Except for a short period in October, the species is present on the breeding cliffs all year around. The estimated number of birds around the Faroes was 1.3 million birds in April-June, 0.8 million in July-August, 0.9 million birds in September-November and 1.0 million in December-March; excluded in these estimates was an area to the west of the Faroes (Skov *et al.* 2002). Fulmars are believed to consume about half the food taken by the 21 seabird species occurring in Faroese waters (Olsen 2003; Gaard *et al*. 2002), potentially competing with local fisheries. At the same time, however, Fulmars themselves (adults, fledglings and eggs) are harvested for food by humans (Olsen & Nørrevang 2005), probably in the tens of thousands annually (B. Olsen pers. comm.).

In spite of their importance to the Faroese community, few data exist on the local diet of the Fulmar. Hagerup (1926) argued that planktonic crustaceans (especially copepods) predominated in importance on the Faroes, linked other diet components to foraging of Fulmars in association with whales or fishing vessels, and considered fish a minor part of the summer diet in this part of the Atlantic. Salomonsen (1935) probably relied on Hagerup in stating that the Fulmar diet chiefly consisted of pelagic crustaceans (Copepoda), small cephalopods, and offal from whaling and fisheries. There are no more recent data in the literature for Faroese Fulmar diet; this study surveyed stomach contents of Fulmars collected on the Faroe Islands during 1998–2004.

Material and methods

Fulmars were caught on land and at sea, mostly by means of a *fleyg*, a triangular net attached to a 3 m pole, the traditional method of catching Fulmars and other seabirds on the Faroes (Olsen & Nørrevang 2005). Birds from 1998–99 were collected by the Faroese Food and Environmental Agency for pollution studies, while those from 2002, 2003 and 2004 were mainly harvested for human consumption, with stomachs made available to the 'Save the North Sea' study on marine litter (van Franeker *et al.* 2005) and this diet research. For most birds from 2002 and 2003 only stomachs or stomachs plus heads were available; in those cases internal assessment of sex or age was lacking. Where complete corpses of birds could be examined, external and internal characters including details of sex and age were recorded according to the dissection methods described in van Franeker (2004). Since most of our birds lacked sex and age details, age distinction was largely limited to a simple separation between 'full-grown' birds and 'chicks plus fledglings' (chicks harvested from cliffs or collected from the sea surface directly after fledging).

Stomach contents (proventriculus plus gizzard) were rinsed in a sieve with a mesh size of 1 mm and marine litter and food components were separated. Food items were sorted into main categories of fish (number of otoliths, eye lenses and bones), squid (number of beaks), crustacean zooplankton, polychaete worms (jaws of *Nereis* spp.), scavenged prey (tissue or mostly feathers of other birds) or 'other'. Where possible, the number of prey individuals in each of those categories was estimated from e.g. the presence of pairs of eye lenses, otoliths, or squid beaks, or from identifiable characteristic bones. Where multiple indicators were available, e.g. fish eye lenses were often present as well as otolith pairs, the highest estimate was used.

Stomachs were considered to contain fisheries offal when remains of bivalves (Bivalvia) and gastropods (Gastropoda), sea urchins (Echinoidea), and/or crabs (Brachyura) were found. This was done since we assumed that if stomachs contained remains of benthic organisms, they would have originated from the consumption of discarded guts of larger bottom-dwelling fish thrown overboard from a fishing vessel. Although feeding on offal might be important to some Fulmar populations our attempt to identify offal-feeding individuals was only intended to exclude the possibility that specific hard prey remains (e.g. otoliths) were coming from fish guts, rather than from direct feeding. By following this method, the consumption of empty intestines and for example fish liver, a very important form of offal used by Fulmars scavenging at commercial fisheries, (Camphuysen *et al.* 1995), was overlooked.

Identification of squid beaks was based on Clarke (1986) while fish otoliths were identified using Härkönen (1986). Otolith length (OL) and width (OW) was measured to 0.1 mm. Although identification to species was still possible, many otoliths showed signs of wear from digestion. Lacking adequate data for corrections, wear was not included when using allometric formulae to calculate sizes and mass of fish from otoliths.

For Glacier Lanternfish *Benthosema glaciale*, calculations of size and mass were based on an indirect approach, because of incomplete data for this species on the Faroes. Firstly, total fish lengths (FL) for otoliths in our samples were estimated from regressions using OW by Breiby (1985). Next, a conversion from FL to standard length (SL) was calculated from fish collected during a fisheries cruise from 16 March to 13 April 2005 (SL = FL x 0.8646, n = 87). Finally weight was calculated from a power function between standard fish length and weight data ($FW = 4E^{-06} \times SL^{3.263}$, n = 130, $R^2 = 0.9442$) obtained from fish collected by a Faroese research vessel from 30 April to 15 May 2004 and on 5 April 2005.

For Blue Whiting *Micromesistius poutassou* and Norway Pout *Trisopterus esmarkii*, regression equations were derived from fresh fish collected from the shelf zone around the Faroes by a research vessel. Total length of fish (± 1 mm) and otolith (± 0.1 mm) and fish weight (± 0.1 g) were measured and the relationship between otolith size and fish size was calculated by fitting a linear least square regression to the log-transformed data.

The equations for the two species were: Blue Whiting FL = -17.520 + (23.581 x OL), n = 234, $r^2 = 0.97$ and FL range was 124–360 mm; $FW = 0.0269 \times OL^{3.29}$, n = 234, $r^2 = 0.96$ and FW range was 9.8–246.2 g; Norway Pout FL = -4.5321 + (23.116 x OL), n = 26, $r^2 = 0.976$ and FL range was 30–195 mm; $FW = 0.080 \times OL^{2.9709}$, n = 26, $r^2 = 0.970$ and FW range was 0.6–54.7 g. We tested the local formulae for Blue Whiting and Norway Pout FL and FW against those in Härkönen (1986). For Blue Whiting the formulae did not give significant differences in FL and FW, but for Norway Pout the local formulae gave significantly higher FL ($F_1 = 17.061$, $P < 0.001$) and FW ($F_1 = 7.073$, $P < 0.01$) than those in Härkönen. The local formulae for Norway Pout size resulted in about 5.8% larger FL and 68.3% higher FW than the Härkönen formula. Differences are possibly because the Härkönen formula was derived from a sample of fish that lacked the smaller size classes (Härkönen FL range 106–208 mm; FW range 5.7–69.6 g).

Using stomach contents to study seabird diet has limitations because of differential rates of digestion of different prey types (Gaston & Noble 1985; Jobling & Breiby 1986; Barrett *et al.* 2007). This is especially so when stomach contents include the material from the gizzard, where hard prey remains such as squid beaks may persist for longer periods of time than fragile otoliths. A bias towards hard prey remains can be aggravated by the fact that when Fulmars are captured with a *fleyg*, they often regurgitate fresh food from the proventriculus, further increasing the relative importance of older, hard prey remains in the gizzard (van Franeker *et al.* 2001). Hence, our analyses mainly focus on the use of frequency and numerical abundance data, rather than attempting to quantify proportions of the various prey groups in the diet.

To test for prey category differences in full-grown birds and in chicks, a One-way ANOVA was used in conjunction with a Welch Robust Test and Hochberg s GT2 post-hoc test to compensate for a lack of homogeneity and a large variation in sample sizes (Wright 2005). The same procedure was used to test for differences between the three most common fish species in the diet of full-grown birds and to compare local formulae with those from Härkönen (1986). SPSS version 17.0 for Windows was used for all statistical tests.

Results

Overall, 512 stomachs were available for analyses, spread unequally over the years 1998–2004 and over all months. Restricted sample sizes and their unequal temporal spread limited analyses to differences between the rough age classification of full-grown birds fully capable of flight, and flightless chicks and fledglings (Table 1).

Frequencies of occurrence and abundance of fish and squid prey were consistently high. Fish prey was relatively more abundant in full-grown birds than in chicks (F_1 = 109.139, $P < 0.001$). Squid beaks, however, were more abundant in chicks than in older birds (F_1 = 38.169, $P < 0.001$). Crustaceans were found in about one-third of the stomachs, but only in low numbers in both age groups and clearly represented no major component of the diet. Polychaete jaws were infrequent in full-grown birds, which differed significantly from their frequency and abundance in the stomachs of chicks (F_1 = 24.486, $P < 0.001$).

Most prey categories other than fish were difficult to identify. Squid beaks were mostly very worn and the only species identified was *Gonatus fabricius*. As far as could be determined, all jaws of polychaetes originated from the genus *Nereis*. Scavenged prey was mostly represented by bird feathers or bones; these were not

Table 1. Frequency of occurrence and abundance of the five main prey groups and offal in full-grown Northern Fulmars *Fulmarus glacialis* and chicks.

	All ages (n = 512)		Full grown (n = 393)		Chick/fledgling (n = 119)	
Prey type	Frequency of occurrence	Average number prey per stomach	Frequency of occurrence	Average number prey per stomach	Frequency of occurrence	Average number prey per stomach
Fish	96%	8.28	97%	9.77	92%	3.35
Squid	86%	3.32	83%	2.78	97%	5.13
Crustacea	31%	0.80	30%	0.89	36%	0.50
Polychaetes	22%	2.25	13%	0.60	52%	7.72
Scavenged prey	12%	0.14	7%	0.09	26%	0.29
Offal	21%		18%		29%	

identified in detail but contained a variety of remains of gulls (Laridae), auks (Alcidae), Fulmars and passeriform birds. The only prey group that can be considered in more detail are fish (Tables 2 & 3). There was an obvious difference in the condition of fish remains in full-grown birds compared to chicks. Stomach contents of chicks were extremely worn and contained few identifiable and measurable otoliths (Table 2). The focus is therefore on fish prey in the stomachs of the full-grown birds.

Glacier Lanternfish predominated among the otoliths in stomachs of full-grown birds, other frequent species being Norway Pout, Blue Whiting, and unidentified Gadidae (Table 3, Figure 1). Among these major fish prey, otolith sizes indicate maximum sizes of fish consumed to be below 25 cm FL and below 72 g FW, with average or modal sizes considerably below such values.

Table 2. Frequency of occurrence and abundance of fish prey found in full-grown Northern Fulmars *Fulmarus glacialis* and chicks.

	Full grown (n = 393)			**Chicks-fledglings (n = 119)**		
	Frequency of occurrence	**Average number otoliths ± SD**	**Max**	**Frequency of occurrence**	**Average number otoliths ± SD**	**Max**
Myctophidae						
Glacier Lanternfish						
Benthosema glaciale	35.0%	2.02 ± 6.43	53	6.0%	0.17 ± 2.12	6
Gadidae						
Norway Pout						
Trisopterus esmarkii	21.0%	0.81 ± 4.98	32	1.0%	0.02	2
Blue Whiting						
Micromesistius poutassou	10.0%	0.22 ± 1.21	6	4.0%	0.12 ± 1.30	4
Whiting						
Merlangius merlangus	1.5%	0.03 ± 0.41	2	0.8%	0.02	2
Silvery Pout						
Gadiculus argenteus	1.5%	0.03 ± 0.41	3	0.8%	0.01	1
unidentified Gadids	*22.0%*	*0.54 ± 2.12*	*12*	*6.0%*	*0.09 ± 0.79*	*3*
Ammodytidae						
unidentified Ammodytes	1.0%	0.03 ± 1.73	4	1.7%	0.02 ± 0.13	1
Clupeidae						
Herring						
Clupea harengus	0.5%	0.01 ± 0.71	2	0.0%		
Triglidae						
Grey Gurnard						
Eutrigla gurnardus	0.3%	0.01	2	0.0%		
Cyclopteridae						
Lumpsucker						
Cyclopterus lumpus	0.3%	0.01	2	0.0%		
Scorpaenidae						
Redfish						
Sebastes marinus	0.3%	0.01	2	0.0%		
Unidentified	*12.0%*	*0.23 ± 1.56*	*7*	*3.0%*	*0.06 ± 0.50*	*2*

Table 3. Number of otoliths from, and sizes of, main fish prey in full-grown Northern Fulmars *Fulmarus glacialis* (n = 393).

	Number of otoliths measured	Fish length (FL) Average (range) mm	Fish weight (FW) average (range) g
Glacier Lanternfish *Benthosema glaciale*	795	53 (25–95)	1.7 (0.2–12.0)
Norway Pout *Trisopterus esmarkii*	319	88 (38–179)	5.0 (0.5–35.8)
Blue Whiting *Micromesistius poutassou*	87	150 (30–242)	17.2 (0.3–71.8)

Discussion

Age group differences in stomach contents, as shown in Tables 1 & 2, are hard to interpret in terms of potentially differential food preferences in self-provisioning or chick-feeding birds. Overall, the chick stomach contents were more advanced in digestion than those of full-grown birds. We observed a significantly higher abundance of polychaetes in the chick diet; however, during July-September stomachs of full-grown birds contained significantly more polychaetes than during the rest of the year ($F_1 = 8.747$, $P < 0.01$) indicating a seasonal availability. This is in agreement with Phillips *et al.* (1999) who stated that polychaetes are caught at the surface during summer in their spawning phase.

The abundance of fish in the diet of Fulmars on the Faroes (Table 1) is consistent with many other dietary studies in the North Atlantic, but the dominant species differ (Table 2). In many areas, sandeels (*Ammodytes*) are a major prey fish for Fulmars, especially in the breeding season (Furness & Todd 1984; Fowler & Dye 1987; Thompson *et al.* 1995; Hamer *et al.* 1997; Phillips *et al.* 1999). In more northern locations during the breeding season, Capelin *Mallotus villosus* is often found to be a major fish prey (Camphuysen & van Franeker 1997; Cherel *et al.* 2001; Garthe *et al*. 2004). In the Barents Sea during winter, Cod *Gadus morhua* and Polar Cod *Boreogadus saida* were found to be important prey species (Erikstad 1990; Weslawski *et al*. 1994). This Faroese study showed Glacier Lanternfish, Norway Pout, Blue Whiting and Gadidae to be common prey species, in which the major role of Glacier Lanternfish is especially remarkable. Hamer *et al*. (1997) reported Glacier Lanternfish and two other mesopelagic fish species (*Scopelogadus beanie* and *Lampadena speculigera*) in 10% and 1% of Fulmar samples from St Kilda and Foula, respectively, but the high abundance of *Benthosema* in Fulmars on the Faroes is something that has not yet been reported from the North Atlantic. In the North Pacific, 86% of 29 Fulmars caught in drift nets between 40–44°N 171°E–172°W (500–700 km south of the Aleutian Islands) had consumed lanternfish of at least 10 different species (Gould *et al.* 1997).

The frequent occurrence of Glacier Lanternfish, in the diet of Faroese Fulmars is remarkable, given the depth range (150–500 m) where this prey species is thought to occur (Halliday 1970; Muus 1990). Fulmars are surface-feeding birds, with recorded diving depths normally of less than 1 m, with extremes probably up to c. 3 m (Hobson & Welch 1992; Garthe & Furness 2001). Cherel *et al.* (2001) suggest extremes of up to 4.7 m but used simple gauges intended for recording deeper dives and inaccurate

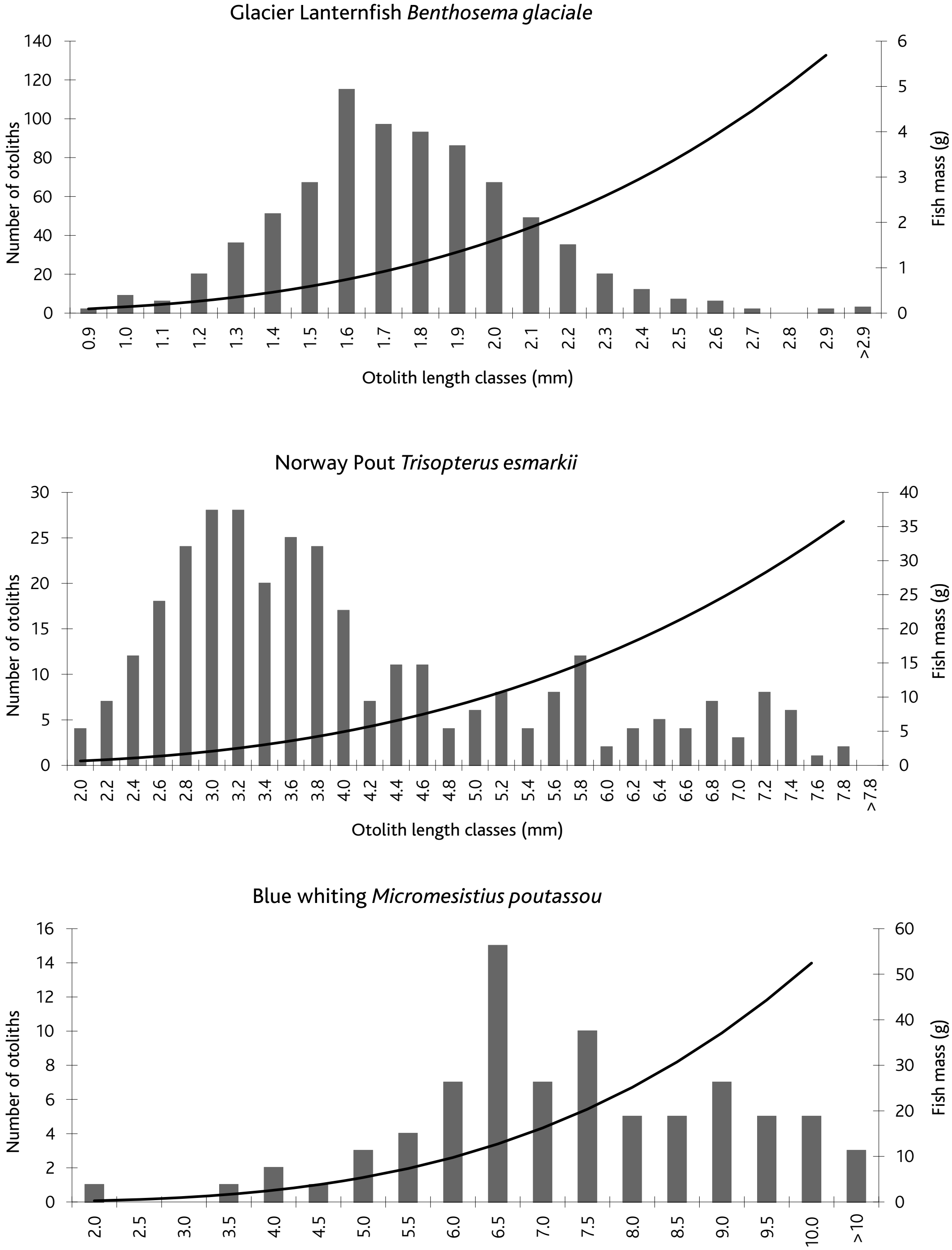

Figure 1. Number of otoliths (bars, left y-axis) from various otolith length classes (x-axis) and corresponding fish mass (line, right y-axis) for the three main fish prey species in full-grown Northern Fulmars *Fulmarus glacialis* (n = 393).

at repeated shallow depths (Burger & Wilson 1988). Studies in other regions, however, have shown that myctophids can be seized directly by surface-feeding fulmarines (Coria *et al*. 1997; Gould *et al*. 1997; Ferretti *et al*. 2001). Possibly, the nocturnal vertical migration of certain mesopelagic fish and zooplankton brings them closer to the surface, where Fulmars might have access to them (Furness & Todd 1984).

Quantitative roles of different prey species in the foraging ecology of Faroese Fulmars are hard to derive from frequencies of occurrence of prey items. Table 3 suggests that by mass the three major fish species would be of equal importance in Fulmar diet. However, different fish sizes may have different digestion rates, probably leading to underestimates of smaller fish and smaller otoliths, as is the case for the lanternfish in our study. Of crucial importance is the energy content of the prey and Myctophid fish are rich in energy (Sabate s *et al*. 2003; van de Putte *et al*. 2006). Our results suggest that the Glacier Lanternfish is an important prey for the Faroese Fulmar population, but in the absence of an adequate method to detect offal in stomach contents, the importance of commercial fisheries for Fulmars is not easy to establish.

Acknowledgements
The Save the North Sea Fulmar study group, Jens-Kjeld Jensen, Pól Jóhannis Simonsen and Maria Dam provided help in collecting the stomachs. Hjørdis Joensen, Sólveig Sørensen and Mardik Leopold assisted with the identification of otoliths and squid beaks. Part of the work for this study was funded by Amerada Hess, a PhD scholarship from Lunds University, Sweden and from a follow up Fulmar project supported by Chevron Upstream Europe.

References

Barrett, R. T., Camphuysen, C. J., Anker-Nilssen, T., Chardine, J. W., Furness, R. W., Garthe, S., Hüppop, O., Leopold, M. F., Montevecchi, W. A., & Veit, R. R. 2007. Diet studies of seabirds: a review and recommendations. *ICES Journal of Marine Science* 64: 1675–1691.

Bloch, D. & Sørensen, S. 1984. *Checklist of Faroese Birds*. Føroya Skúlabókagrunnur, Thorshavn.

Breiby, A. 1985. *Otolitter fra saltvandsfisker i Nord- Norge*. Tromura, naturvitenskap nr. 45. Universitetet i Tromsø, Instituttet for museumsvirksomhet, Tromsø Museum.

Burger, A. E. & Wilson, R. P. 1988. Capillary-tube depth gauges for diving animals: an assessment of their accuracy and applicability. *Journal of Field Ornithology* 59: 345–354.

Camphuysen, C. J., Calvo, B., Durinck, J., Ensor, K., Follestad, A., Furness, R. W., Garthe, S., Leaper, G., Skov, H., Tasker, M. L. & Winter, C. J. N. 1995. *Consumption of discards by seabirds in the North Sea. Final report EC DG XIV research contract BIOECO/93/10. NIOZ-Rapport 1995-5*. Netherlands Institute for Sea Research, Texel.

Camphuysen, C. J. & van Franeker, J. A. 1996. Jellyfish and fishery waste as food sources of Northern Fulmars *Fulmarus glacialis* feeding around St Kilda. *Sula* 10: 143–150.

Camphuysen, C. J. & van Franeker, J. A. 1997. Notes on the diet of Northern Fulmars *Fulmarus glacialis* from Bjørnøya (Bear Island). *Sula* 11: 1–10.

Camphuysen, C. J. & Garthe, S. 1997. An evaluation of the distribution and scavenging habits of northern fulmars *Fulmarus glacialis* in the North Sea. *ICES Journal of Marine Science* 54: 654–683.

Cherel, Y., Ridoux, V, Weimerskirch, H, Tveraa, T. & Chastel, O. 2001. Capelin *Mallotus villosus* as an important food source for northern fulmars *Fulmarus glacialis* breeding at Bjørnøya (Bear Island), Barents Sea. *ICES Journal of Marine Science* 58: 355–361.

Clarke, M. R. 1986. *A Handbook for the Identification of Cephalopod Beaks*. Clarendon Press, Oxford.

Coria, N. R., Soave, G. E. & Montalti, D. 1997. Diet of Cape Petrel *Daption capense* during the post-hatching period at Laurie Island, South Orkney Islands, Antarctica. *Polar Biology* 18: 236–239.

Cramp, S. & Simmons, K. E. L. (eds.) 1977. *The Birds of the Western Palearctic*. Vol. I. Oxford University Press, Oxford.

Erikstad, K. E. 1990. Winter diets of four seabird species in the Barents Sea after a crash in the Capelin stock. *Polar Biology* 10: 619–627.

Ferretti, V., Soave, G. E., Casaux, R. & Coria, N. R. 2001. Diet of the Snow Petrel *Pagodroma nivea* at Laurie Island, Antarctica, during the 1997/98 breeding season. *Marine Ornithology* 29: 71–73.

Fisher, J. 1952. *The Fulmar*. Collins, London.

Fowler, J. A. & Dye, A. P. 1987. Sandeels *Ammodytes marinus* in the diet of the Fulmar *Fulmarus glacialis* in Shetland, Scotland. *Seabird* 10: 71–74.

Furness, R. W. & Todd, C. M. 1984. Diets and feeding of Fulmars *Fulmarus glacialis* during the breeding season: a comparison between St Kilda and Shetland colonies. *Ibis* 126: 379–387.

Gaard, E., Hansen, B., Olsen, B. & Reinert, J. 2002. Ecological Features and Recent Trends in the Physical Environment, Plankton, Fish Stocks, and Seabirds in the Faroe Shelf Ecosystem. In: Sherman, K. & Skjoldal, H. R. (eds.). *Large Marine Ecosystems in the North Atlantic*: 245–265. ELSEVIER, Amsterdam.

Garthe, S. & Furness, R.W. 2001. Frequent shallow diving by a Northern Fulmar feeding at Shetland. *Waterbirds* 24: 287–289.

Garthe, S., Montevecchi, W.A., Ojowski, U. & Stenhouse, I. J. 2004. Diets of northern fulmar *Fulmarus glacialis* chicks in the northwest Atlantic Ocean. *Polar Biology* 27: 277–280.

Gaston, T. & Noble, D. G. 1985. The diet of Thick-billed Murres *Uria lomvia* in west Hudson Strait and northeast Hudson Bay. *Canadian Journal of Zoology* 63: 1148–1160.

Gould, P., Walker, W. & Ostrom, P. 1997. Foods of northern fulmars associated with high-seas drift nets in the transitional region of the North Pacific. *Northwestern Naturalist* 78: 57–61.

Hagerup, O. 1926. Communities of birds. Oecological Studies. *Videnskabelige Meddelelser fra Dansk naturhistorisk Forening* 82: 127–156.

Halliday, R. G. 1970. Growth and vertical distribution of the Glacier Lanternfish, *Benthosema glaciale*, in the northwestern Atlantic. *Journal of the Fisheries Research Board of Canada* 27: 105–116.

Hamer, K. C., Thompson, D. R. & Gray, C. M. 1997. Spatial variation in the feeding ecology, foraging ranges, and breeding energetics of northern fulmars in the north-east Atlantic Ocean. *ICES Journal of Marine Science* 54: 645–653.

Härkönen, T. 1986. *Guide to the otoliths of the bony fishes of the northeast Atlantic*. Danbiu ApS, Hellerup.

Harris, M. P., Beare, D., Toresen, R., Nottestad, L., Kloppmann, M., Dörner, H., Peach, K., Rushton, D. R. A., Foster-Smith, J. & Wanless, S. 2007. A major increase in snake pipefish *Entelurus aequoreus* in northern European seas since 2003: potential implications for seabird breeding success. *Marine Biology* 151: 973–983.

Hobson, K. A. & Welch, H. E. 1992. Observations of foraging Northern Fulmars (*Fulmarus glacialis*) in the Canadian high Arctic. *Arctic* 45: 150–153.

Jobling, M. & Breiby, A. 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. *Sarsia* 71: 265–274.

Lorenz, S. & Seneveratne, S. 2008. Northern Fulmar predation of Common Murre. *The Wilson Journal of Ornithology* 120: 635–636.

Muus, B. 1990. Fisk. In: Muus, B., Salomonsen, F. & Vibe, C. (eds.) *Grønlands Fauna*. Gyldendal, Copenhagen.

Ojowski, U., Eidtmann, C., Furness, R. W. & Garthe, S. 2001. Diet and nest attendance of incubating and chick-rearing northern fulmars *Fulmarus glacialis* in Shetland. *Marine Biology* 139: 1193–1200

Olsen, B. 2003. Seabird data that can be used in modelling the ecosystem of Faroese waters. In: *Workshop on Ecosystem Modelling of Faroese Waters, Tórshavn 24–26 September 2002*: 38–39. Faroese Fisheries Laboratory, Tórshavn.

Olsen, B. & Nørrevang, A. 2005. Seabird fowling in the Faroe Islands. In: Randall, J. (ed). *Traditions of seabird fowling in the North Atlantic region*: 162–180. The Islands Book Trust, Port of Ness, Isle of Lewis.

Phillips, R. A., Petersen, M. K., Lilliendahl, K., Solmundsson, J., Hamer, K. C., Camphuysen, C. J. & Zonfrillo, B. 1999. The diet of the northern fulmar *Fulmarus glacialis*: reliance on commercial fisheries? *Marine Biology* 135: 159–170.

Sabate s, A., Rossi, S. & Reyes, E. 2003. Lipid content in the early life stages of three mesopelagic fishes. *Journal of Fish Biology* 63; 881–891.

Salomonsen, F. 1935. Aves. *Zoology of the Faroes*. Vol. III, Part II. Host and Son, Copenhagen.

Skov, H., Upton, A. J., Reid, J. B., Webb, A., Taylor, J. S., & Durinck, J. 2002. *Dispersion and vulnerability of marine birds and cetaceans in Faroese waters*. JNCC, Peterborough.

Tasker, M. L. 2004. Northern Fulmar *Fulmarus glacialis*. In: Mitchell, P. I., Newton, S. F., Ratcliffe, N. & Dunn, T. E. (eds). *Seabird populations of Britain and Ireland*: 49–62. Poyser, London.

Thompson, D. R., Furness, R. W. & Lewis, S. A. 1995. Diets and long-term changes in $\delta^{15}N$ and $\delta^{13}C$ values in northern fulmars *Fulmarus glacialis* from two northeast Atlantic colonies. *Marine Ecology Progress Series* 125: 3–11.

van de Putte, A., Flores, H., Volckaert, F. & van Franeker, J. A. 2006. Energy content of Antarctic mesopelagic fishes: implications for the marine food web. *Polar Biology* 29: 1045–1051.

van Franeker, J. A., Williams, R., Imber, M. J. & Wolff, W. J. 2001. Diet and foraging ecology of Southern Fulmar *Fulmarus glacialoides*, Antarctic Petrel *Thalassoica antarctica*, Cape Petrel *Daption capense* and Snow Petrels *Pagodroma nivea* spp. on Ardery Island, Wilkes Land, Antarctica. In: van Franeker, J. A. *Mirrors in Ice*. *Fulmarine petrels and Antarctic ecosystems*: Chapter 11, p 1–58. PhD Thesis, Rijksuniversiteit Groningen. Alterra, Texel.

van Franeker, J. A. 2004. *Save the North Sea Fulmar-Litter-EcoQO Manual Part 1: Collection and dissection procedures*. Alterra-rapport 672. Alterra, Wageningen.

van Franeker, J. A., Heubeck, M., Fairclough, K., Turner, D. M., Grantham, M., Stienen, E. W. M., Guse, N., Pedersen, J., Olsen, K. O., Andersson, P. J., & Olsen, B. 2005. *'Save the North Sea' Fulmar Study 2002–2004: a regional pilot project for the Fulmar-Litter-EcoQO in the OSPAR area*. Alterra-rapport 1162. Alterra, Wageningen.

Weslawski, J. M., Stempniewicz, L. & Galaktionov, K. 1994. Summer diet of seabirds from the Frans Josef Land archipelago, Russian Arctic. *Polar Research* 13: 173–181.

Wright, D. B. (ed.) 2005. *Discovering Statistics Using SPSS*. Sage Publications, London.