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

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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 1996a, 1996b; 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 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 x 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 x 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 x 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 flyg, 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. |
|---|---|---|---|---|---|
| Prey type | All ages (n = 512) | Full grown (n = 393) | Chick/fledgling (n = 119) |
| | 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.

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

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

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Number of otoliths measured</th>
<th>Fish length (FL)</th>
<th>Fish weight (FW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glacier Lanternfish</td>
<td>795</td>
<td>53 (25–95)</td>
<td>1.7 (0.2–12.0)</td>
</tr>
<tr>
<td>Norway Pout</td>
<td>319</td>
<td>88 (38–179)</td>
<td>5.0 (0.5–35.8)</td>
</tr>
<tr>
<td>Blue Whiting</td>
<td>87</td>
<td>150 (30–242)</td>
<td>17.2 (0.3–71.8)</td>
</tr>
</tbody>
</table>
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 (Sabates 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.

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References


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