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Stomach contents of autumn-feeding marine vertebrates from Hornsund, Svalbard

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ABSTRACT. Stomachs of 171 vertebrates (two species of fish, eight of birds and two of seals) from Hornsund, Svalbard, were collected between 7 September and 5 October 1984. Arctic cod *Boreogadus saida* and the amphipod *Parathemisto libellula* were the main prey species of black guillemots *Cepphus grylle*, little auks *Alle alle*, puffins *Fratercula arctica*, Brunnich's guillemots *Uria lomvia*, kittiwakes *Rissa tridactyla* and ringed seals *Phoca hispida*. Fulmars *Fulmarus glacialis* preyed mainly on the squid *Gonatus fabricii* and the polychaete *Nereis irrorata*. Eiders *Somateria mollissima* preyed mainly on bivalves and on the amphipod *Gammarellus homari*. *G. homari* and *Gammarus oceanicus* were the most important prey species of striped snailfish *Liparis liparis*, while shorthorn sculpin *Myoxocephalus scorpius* mainly preyed upon *G. homari* and *Anonyx sarsi*. Glaucous gulls *Larus hyperboreus* took many different prey including birds and tundra plants. Only one bearded seal *Erignathus barbatus* stomach with content was available for this study.

Contents

Introduction

In this study we investigated stomach contents of marine vertebrates in a Svalbard fjord. Hornsund was chosen because it is the site of the Polish polar station (Figure 1) where studies of the marine invertebrate fauna had previously been made (Skoworon 1977, Weslawski 1983, Weslawski and Kwasniewski 1983, Moskal and Zajaczkowski 1984). In addition to the stomach contents analyses, connections between predators and prey were described. Hornsund is of special interest also because of its particularly complicated and variable hydrological conditions, with occurrence of Atlantic waters, arctic waters and transformed coastal waters of different origin (Weslawski and Kwasniewski 1983).

Material and methods

Stomach samples from 20 fish, 144 birds and seven mammals were collected between 7 September and 5 October 1984. Fish were caught using nets with 50–200 mm mesh set at 1–100 m depths. Eel-traps with and without bait were also used. Birds were usually shot while they were foraging. Collections were spread over the entire study period to get a representative picture of autumn diet. Seals were collected by shooting. The stomach contents (in birds, including oesophagus content) were washed onto a sieve of mesh size 0.5 mm, weighed to the nearest 0.5 g and preserved in 40% ethanol. Samples were sorted to the lowest possible taxonomic level using available keys and reference material. Otoliths were measured to the nearest 0.1 mm. Two otoliths from the same species found in one sample and differing by less than 0.2 mm in length were considered to be from the same fish. In samples where arctic cod *Boreogadus saida* was a dominant prey species, standard length of the cod was calculated from otolith length using the regression: fish length = 2.198x + 1.588, where x = otolith length (Frost and Lowry 1981). Predators were divided into a dissimilarity matrix according to the frequency of different prey species identified, using the Bray-Curtis dissimilarity index (Bray and Curtis 1957):

$$d_{1,2} = \frac{\sum_{j=1}^{n} |x_1 j - x_2 j|}{\sum_{j=1}^{n} (x_1 j + x_2 j)}$$

where $x_1 j$ and $x_2 j$ are the frequencies of the jth prey species of predator 1 and 2, and $d_{1,2}$ is the difference between the predators. The program for this cluster analysis was CLUSTAN (Wishart 1978) and results are presented as a dendrogram using 'group average sorting' (Lance and Williams 1967).

Results

Fish

Only 20 specimens of two species of fish were caught:

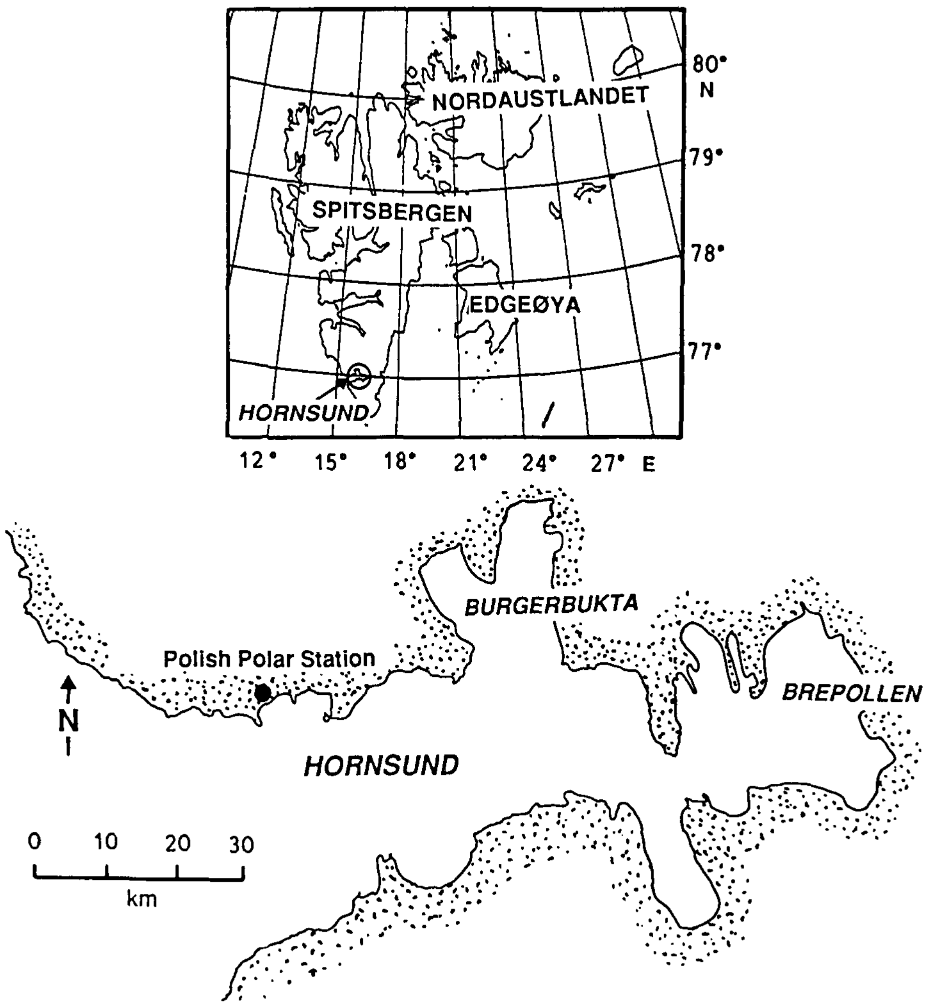

Fig. 1. Location map.

shorthorn sculpin *Myoxocephalus scorpius* and striped snailfish *Liparis liparis*. Of 17 shorthorn sculpins, 14 contained identifiable food (mean wet weight 3.1 g, sd ± 4.2.). Amphipods *Gammarellus homari* and *Anonyx sarsi* were their most important prey (Table I). Fifteen of the sculpins were females with roe. Three striped snailfish contained identifiable food (mean weight 0.67 g, sd ± 0.3). Amphipods *G. homari* and *G. oceanicus*, together with polychaetes, seemed to be their dominant prey.

Birds

Eight species of seabird were sampled; efforts were made to obtain 20 specimens of each. Results are summarized in Table 2. Stones were found in 41 of the stomachs from representatives of all species.

Fulmars *Fulmarus glacialis*. Seventeen of the 20 fulmars contained identifiable food (mean weight 1.3 g, sd ± 1.7). Most fulmar stomachs contained only indigestible remains of prey, mainly beaks from squid *Gonatus fabricii* and jaws from polychaets *Nereis irrorata*. In three stomachs (15%) pieces of plastic were found.

Eiders *Somatera mollissima*. Seventeen of 20 eiders contained identifiable food (mean wet weight 19.2 g, sd ± 9.3). Amphipods *G. homari* and fragments of bivalves were the most common prey. Bryozoans were found in some samples which also contained algae.

Glaucous gulls *Larus hyperboreus*. Fourteen of 18 glaucous gulls contained identifiable food (mean wet weight 12.9 g, sd ± 17.2). These have a varied menu including algae and tundra plants. Remains of other birds were found in half of the stomachs investigated. One glaucous gull regurgitated a complete fulmar head when it was shot. Glaucous gulls were also frequently observed scavenging on seal carcasses.

Kittiwakes *Rissa tridactyla*. Seventeen of 20 kittiwakes contained identifiable food (mean wet weight 2.4 g, sd ± 2.6). Arctic cod and *Parathemisto libellula* were the two dominant prey species, closely followed by *N. irrorata* and pteropods. Pieces of plastic were found in one kittiwake stomach (5%). Kittiwakes ate arctic cod of length 6.60 cm ± 4.8.

Black guillemots *Cepphus grylle*. All 20 black guillemots collected contained identifiable food (mean wet weight 5.9 g, sd ± 4.0). Their diet was varied, consisting of both benthic and planktonic prey species. Arctic cod and *P. libellula* were the most common food items. *Mysis oculata* was also a significant prey. Black guillemots took arctic cod of mean standard (fork) length

Table 1. Stomach content analyses of fish. nd = not determined to genus or species.

	Hydroida	Polychaeta nd	Harmatoe nd	Gastropoda nd	Ostracoda nd	Harpactoida nd	*Mysis oculata*	*Caprella septentrionalis*	Lysianassidae nd	*Onisimus littoralis*	*Onisimus edwardsi*	*Anonyx sarsi*	*Orchomene minuta*	*Ischyroceros* sp	*Gammarellus homari*	*Gammarus* sp	*Gammarus setosus*	*Gammarus oceanicus*	Pisces nd
Myxocephalus scorpius (N = 17)																			
Total no. of items	-	7	2	2	1	-	2	1	1	4	5	48	-	14	23	-	37	12	1
% frequency	-	4.4	1.3	1.3	0.6	-	1.3	0.6	0.6	2.5	3.1	30.0	-	8.8	14.4	-	23.1	7.5	0.6
No. with taxon presen	1	7	2	2	1	-	2	1	1	3	1	10	-	5	11	-	4	2	1t
% occurrence	7.1	50.0	14.3	14.3	7.1	-	14.3	7.1	7.1	21.4	7.1	71.4	-	35.7	78.6	-	28.6	14.3	7.1
Liparis liparis (N = 3)																			
Total no. of items	-	2	-	-	-	1	-	-	-	-	2	-	3	1	5	3	-	4	-
% frequency	-	9.5	-	-	-	4.8	-	-	-	-	9.5	-	14.3	4.8	23.8	14.3	-	19.0	-
No. with taxon present	-	2	-	-	-	1	-	-	-	-	1	-	1	1	3	1	-	2	-
% occurrence	-	66.7	-	-	-	33.3	-	-	-	-	33.3	-	33.3	33.3	100	33.3	-	66.7	-

4.70 cm ± 4.9.

Brunnich's guillemots *Uria lomvia.* Nineteen of the 21 Brunnich's guillemot specimens caught had identifiable food (mean wet weight 3.3 g, sd ± 3.7). Arctic cod was the most common prey, followed by *P. libellula* and coalfish *Polachius virens.* Plastic items were found in five stomachs (24%). Brunnich's guillemots took arctic cod of mean standard (fork) length 4.77 cm ± 4.1.

Puffins *Fratercula arctica.* Thirteen of 14 puffins contained identifiable food (mean wet weight 1.2 g, sd ± 0.9). Arctic cod was found in all 13 stomachs. *P. libellula* and *Calanus* sp. were the only invertebrates occurring in more than one stomach. One bird had five herrings *Clupea harengus* in its bill and one in its stomach. Puffins fed on arctic cod of mean standard (fork) length 4.60 cm ± 4.0.

Little auks *Alle alle.* Eleven little auks contained identifiable food (mean wet weight 1.2 g, sd ± 0.9). Arctic cod and *P. libellula* were the most important prey species, but such benthic fish as striped snailfish are also common prey. Plastic debris was found in five stomachs (45%). Little auks were not present in Hornsund when field work began. They appeared suddenly in the fjord on 29 and 30 September, when all 11 were collected. Little auks took arctic cod of mean standard (fork) length 3.37cm ± 2.0.

Mammals

Ringed seals *Phoca hispida* . Five collected had identifiable food (mean wet weight 117.8 g, sd ± 60.0). Arctic cod was the most common prey, followed by *P. libellula* and *M. loculata* (Table 3). Ringed seals took arctic cod of mean standard (fork) length 5.57 cm ± 4.7.

Bearded seals *Erignathus barbatus.* Of two specimens taken, one contained only nematodes and cestodes. The other had a stomach content of wet weight 585 g containing the following species: *G. homari, Sclerocragnon boreas, S. ferox, Hyas* sp. and *Agurus* sp. Decapods composed 208 g of the wet weight; this stomach contained also 251 operculi from *Buccinum* sp. and eight otoliths from coalfish.

Links between predators and prey

A simplified food web was drawn, based on the most significant prey species of each predator, excluding bearded seals for which data were insufficient (Figure 2). Two basic food chains, pelagic and benthic, were identified. In the former, arctic cod and *P. libellula* were key organisms; in the benthic chain, benthic fish and eider were the main predators, taking mainly amphipods and bivalve molluscs.

Cluster analysis showed the degree to which predators competed for prey. All eight bird species and ringed seals were matched against 38 of the most common prey species. Little auks, Brunnich's guillemots, ringed seals, black guillemots, puffins and kittiwakes fed from a relatively similar food base (Figure 3), the first three having very similar diets. Fulmars, eiders and glaucous gulls differed from these six predators and from each other in choice of food.

Discussion

Limitations of this study are apparent. Sampling spread throughout one month covers a wide range of feeding opportunities, but in these circumstances samples of even 20 of each species are inadequate for thorough statistical evaluation of the importance of the different prey species, or of possible age and sex differences in the diets. Though total wet weight of stomach contents from the different predators was registered, fractions of the contents were counted but not weighed; thus numbers of specimens in the tables indicate frequency but not biomass. Bradstreet's (1980) mitigation of this problem, using length-frequencies of each prey taxon and converting these to estimates of relative dry weight, might have improved the data. Hard, indigestible or slowly digestible parts of prey, like otoliths, squid beaks and polychaete jaws, pass only slowly through the digestive tract and accumulate in stomachs with time (Nazarenko 1967). Swanson and Bartonek (1970), working on bird diets, suggested minimizing such bias by collecting actively feeding birds, removing food items immediately after death and analyzing only items found in the oesophagus and proventriculus. However, this sampling adds substantially to our knowledge of predator-prey relations in the Svalbard marine area.

Table 2. Stomach content analyses of birds. nd = not determined to genus or species.

	Algal fragments	Tundra plant fragments	Polychaeta nd	*Nereis irrorata*	Gastropoda nd	Gastropoda nd eggs	*Buccinum* sp	*Buccinum* sp eggs	*Margarites groenlandicus*	Pteropoda nd	*Helicina* sp	*Bivalvia* sp	*Gonatus fabricii*	Crustacea nd	*Calanus* sp	*Harpactoida* sp	*Mysis oculata*
Fulmarus glacialis (N = 20)																	
Total no. of items	-	-	-	228	-	-	-	-	-	-	-	-	25	-	-	-	18
% frequency	-	-	-	72.6	-	-	-	-	-	-	-	-	8.0	-	-	-	5.7
No. in which present	-	-	-	14	-	-	-	-	-	2	-	-	7	-	-	-	1
% occurrence	-	-	-	82.4	-	-	-	-	-	11.8	-	-	41.1	-	-	-	5.9
Somateria molissima (N = 20)																	
Total no. of items	-	-	-	-	3	-	20	-	4	-	-	-	-	-	-	-	500
% frequency	-	-	-	-	0.5	-	3.0	-	0.6	-	-	-	-	-	-	-	75.3
No. in which present	-	-	4	-	2	-	2	-	2	-	-	6	-	2	-	-	1
% occurrence	-	-	23.5	-	11.8	-	11.8	-	11.8	-	-	35.3	-	11.8	-	-	5.9
Larus hyperboreus (N = 18)																	
Total no. of items	-	-	1	-	-	-	-	-	3	-	-	-	-	-	-	-	1
% frequency	-	-	0.9	-	-	-	-	-	2.8	-	-	-	-	-	-	-	0.9
No. in which present	5	4	1	-	-	1	-	1	1	1	-	1	-	-	-	-	1
% occurrence	35.7	28.6	7.1	-	-	7.1	-	7.1	7.1	7.1	-	7.1	-	-	-	-	7.1
Rissa tridactyla (N = 20)																	
Total no. of items	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-
% frequency	-	-	-	28.0	-	-	-	-	-	-	-	-	-	-	-	-	-
No. in which present	-	-	-	5	-	-	-	-	-	4	-	-	-	-	-	-	-
% occurrence	-	-	-	27.8	-	-	-	-	-	22.2	-	-	-	-	-	-	-
Cepphus grylle (N = 20)																	
Total no. of items	-	-	-	1	-	-	-	-	7	-	-	-	1	-	1	1	61
% frequency	-	-	-	0.4	-	-	-	-	3.0	-	-	-	0.4	-	0.4	0.4	26.2
No. in which present	-	-	1	1	2	-	-	-	5	-	-	3	1	-	1	1	7
% occurrence	-	-	5.0	5.0	10.0	-	-	-	25	-	-	15.0	5.0	-	5.0	5.0	35.0
Uria lomvia (N = 21)																	
Total no. of items	-	-	-	1	-	-	-	-	1	-	-	-	1	-	-	-	-
% frequency	-	-	-	0.6	-	-	-	-	0.6	-	-	-	0.6	-	-	-	-
No. in which present	-	-	-	1	-	-	-	-	2	-	-	-	1	-	-	-	-
% occurrence	-	-	-	5.3	-	-	-	-	10.5	-	-	-	5.3	-	-	-	-
Fratercula arctica (N = 14)																	
Total no. of items	-	-	-	-	-	-	-	-	-	-	-	-	1	-	9	-	-
% frequency	-	-	-	-	-	-	-	-	-	-	-	-	0.8	-	6.8	-	-
No. in which present	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-
% occurrence	-	-	-	-	-	-	-	-	-	-	-	-	7.7	-	15.4	-	-
Alle alle (N = 11)																	
Total no. of items	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
% frequency	-	-	-	-	-	-	-	-	-	-	3.4	-	-	-	-	-	-
No. in which present	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
% occurrence	-	-	-	-	-	-	-	-	-	-	27.3	-	-	-	-	-	-

	Amphipoda nd	Hyperiidae nd	*Parathemisto* sp	*Parathemisto abyssorum*	*Parathemisto libellula*	*Hyperia galba*	*Onisimus littoralis*	*Anonyx* sp	*Anonyx sarsi*	Ampeliscidae nd	Oedicerotidae nd	*Paroediceros lynceus*	*Monoculodes borealis*	*Gamarellus homari*	*Gamarus* sp	*Gammarus wilkitzkii*	*Gammarus oceanicus*	*Gammarus setosus*
Fulmarus glacialis (N = 20)																		
Total no. of items	-	1	-	29	5	1	1	-	-	-	-	-	-	-	-	-	2	-
% frequency	-	0.3	-	9.2	1.6	0.3	0.3	-	-	-	-	-	-	-	-	-	0.6	-
No. in which present	-	1	-	1	1	1	1	-	-	-	-	-	-	-	-	-	1	-
% occurrence	-	5.9	-	5.9	5.9	5.9	5.9	-	-	-	-	-	-	-	-	-	5.9	-
Somateria molissima (N = 20)																		
Total no. of items	-	-	1	-	-	-	4	-	49	-	-	1	-	74	1	-	1	2
% frequency	-	-	0.2	-	-	-	0.6	-	7.4	-	-	0.2	-	11.2	0.2	-	0.2	0.3
No. in which present	-	-	1	-	-	-	1	-	4	-	-	-	-	8	1	-	1	2
% occurrence	-	-	5.9	-	-	-	5.9	-	23.5	-	-	5.9	-	47.1	5.9	-	5.9	11.8
Larus hyperboreus (N = 18)																		
Total no. of items	-	-	-	-	-	-	90	-	-	-	1	-	1	-	-	-	-	-
% frequency	-	-	-	-	-	-	34.9	-	-	-	0.9	-	0.9	-	-	-	-	-
No. in which present	1	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-	-	-
% occurrence	7.1	-	-	-	-	-	7.1	-	-	-	7.1	-	7.1	-	-	-	-	-
Rissa tridactyla (N = 20)																		
Total no. of items	-	-	-	-	31	-	-	-	-	-	-	-	-	1	1	-	-	-
% frequency	-	-	-	-	33.3	-	-	-	-	-	-	-	-	1.1	1.1	-	-	-
No. in which present	2	-	-	-	5	-	-	-	-	-	-	-	-	1	1	-	-	-
% occurrence	11.1	-	-	-	27.8	-	-	-	-	-	-	-	-	5.6	5.6	-	-	-
Cepphus grylle (N = 20)																		
Total no. of items	-	-	-	-	96	1	-	-	-	1	-	-	-	6	-	3	1	-
% frequency	-	-	-	-	41.2	0.4	-	-	-	0.4	-	-	-	2.6	-	1.3	0.4	-
No. in which present	1	-	-	-	11	1	-	-	-	1	-	1	-	7	-	3	1	-
% occurrence	5.0	-	-	-	55	55	-	-	-	5.0	-	5.0	-	35.0	-	15.0	5.0	-
Uria lomvia (N = 21)																		
Total no. of items	-	-	5	-	33	-	-	1	-	-	-	-	-	2	2	-	-	-
% frequency	-	-	2.9	-	19.1	-	-	0.6	-	-	-	-	-	1.2	1.2	-	-	-
No. in which present	1	-	5	-	5	-	-	1	-	-	-	-	-	2	2	-	-	-
% occurrence	5.3	-	26.3	-	26.3	-	-	5.3	-	-	-	-	-	10.5	10.5	-	-	-
Fratercula arctica (N = 14)																		
Total no. of items	-	-	-	-	6	-	1	-	-	-	-	-	-	-	1	1	-	-
% frequency	-	-	-	-	4.4	-	0.8	-	-	-	-	-	-	-	0.8	0.8	-	-
No. in which present	-	-	-	-	2	-	1	-	-	-	-	-	-	-	1	1	-	-
% occurrence	-	-	-	-	15.4	-	7.7	-	-	-	-	-	-	-	7.7	7.7	-	-
Alle alle (N = 11)																		
Total no. of items	-	-	-	-	18	-	-	-	-	-	-	-	-	-	5	2	-	-
% frequency	-	-	-	-	20.4	-	-	-	-	-	-	-	-	-	5.7	2.3	-	-
No. in which present	-	1	-	-	7	-	-	-	-	-	-	-	-	-	4	2	-	-
% occurrence	-	9.1	-	-	63.6	-	-	-	-	-	-	-	-	-	36.4	18.2	-	-

Continued

Table 2. Continued.

	Melita formosa	*Thysanoessa inermis*	Brachiura nd	Decapoda nd	*Hyas* sp	*Hyas araneus*	Bryozoa nd	Echinodermata nd	Tunicata nd	Pisces nd	*Clupea harengus*	*Salvelinus alpinus*	*Pollachius virens*	*Boreogadus saida*	*Lumpenus* sp	*Lumpenus lampretiformis*	Zoarcidae nd	*Myxocephalus scorpius*	*Liparis liparis*	Aves nd
Fulmarus glacialis (N = 20)																				
Total no. of items	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-
% frequency	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3	0.6	-	-	-	-	-	-
No. in which present	-	-	-	-	-	-	-	-	-	9	-	1	1	2	-	-	-	-	-	-
% occurrence	-	-	-	-	-	-	-	-	-	52.9	-	5.9	5.9	11.8	-	-	-	-	-	-
Somateria molissima (N = 20)																				
Total no. of items	-	-	-	-	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-
% frequency	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-	0.2	-	-	-	-	-	-
No. in which present	-	-	3	-	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-
% occurrence	-	-	17.5	-	5.9	5.9	5.9	-	-	-	-	-	-	5.9	-	-	-	-	-	-
Larus hyperboreus (N = 18)																				
Total no. of items	-	-	2	-	-	-	-	-	3	-	-	-	-	3	-	-	-	-	1	-
% frequency	-	-	1.9	-	-	-	-	-	2.8	-	-	-	-	2.8	-	-	-	-	0.9	-
No. in which present	-	-	2	-	-	-	2	2	2	-	-	-	-	2	-	-	-	-	1	7
% occurrence	-	-	14.3	-	-	-	14.3	14.3	14.3	-	-	-	-	14.3	-	-	-	-	7.1	50.0
Rissa tridactyla (N = 20)																				
Total no. of items	-	-	-	-	-	-	-	-	-	-	-	-	1	32	-	-	-	-	1	-
% frequency	-	-	-	-	-	-	-	-	-	-	-	-	1.1	34.4	-	-	-	-	1.1	-
No. in which present	-	-	-	-	-	-	-	-	-	4	-	-	1	9	-	-	-	-	1	-
% occurrence	-	-	-	-	-	-	-	-	-	22.2	-	-	5.6	50.0	-	-	-	-	5.6	-
Cepphus grylle (N = 20)																				
Total no. of items	1	1	1	1	-	-	-	-	-	-	-	-	2	36	-	9	-	1	1	-
% frequency	0.4	0.4	0.4	0.4	-	-	-	-	-	-	-	-	0.9	15.5	-	3.9	-	0.4	0.4	-
No. in which present	1	1	1	1	-	-	-	-	-	8	-	-	2	12	-	2	-	1	1	-
% occurrence	5.0	5.0	5.0	5.0	-	-	-	-	-	40.0	-	-	10.0	60.0	-	10.0	-	5.0	5.0	-
Uria lomvia (N = 21)																				
Total no. of items	-	14	-	-	-	-	-	-	-	--	-	-	9	87	1	-	5	-	11	-
% frequency	-	8.1	-	-	-	-	-	-	-	-	-	-	5.2	50.3	0.6	-	2.9	-	6.4	-
No. in which present	-	1	-	1	-	-	-	-	-	3	-	-	5	14	1	-	2	-	2	-
% occurrence	-	5.3	-	5.3	-	-	-	-	-	15.8	-	-	26.3	73.7	5.3	-	10.5	-	10.5	-
Fratercula arctica (N = 14)																				
Total no. of items	-	-	-	-	-	-	-	-	-	-	6	-	1	103	-	-	-	-	4	-
% frequency	-	-	-	-	-	-	-	-	-	-	4.5	-	0.8	77.4	-	-	-	-	3.0	-
No. in which present	-	-	-	-	-	-	-	-	-	7	1	-	1	13	-	-	-	-	1	-
% occurrence	-	-	-	-	-	-	-	-	-	53.8	7.7	-	7.7	100	-	-	-	-	7.7	-
Alle alle (N = 11)																				
Total no. of items	-	-	-	-	-	-	-	-	-	3	-	-	-	5.1	-	-	-	-	6	-
% frequency	-	-	-	-	-	-	-	-	-	3.4	-	-	-	58.0	-	-	-	-	6.8	-
No. in which present	-	-	-	-	-	-	-	-	-	3	-	-	-	9	-	-	-	-	5	-
% occurrence	-	-	-	-	-	-	-	-	-	27.3	-	-	-	81.8	-	-	-	-	45.5	-

Little information has previously been available on the feeding habits of shorthorn sculpins and striped snailfish from Svalbard. This study shows that the most important prey of these benthic fish were common benthic amphipods. Neither fish seems to be important prey for higher vertebrates, though remains of striped snailfish were found in the stomachs of six of the eight bird species studied, and also in ringed seals. Remains of shorthorn sculpin were found only in black guillemots.

Fish species preyed upon by seals and birds, but not examined by us as predators during this study, include arctic cod, coalfish, arctic char *Salvelinus alpinus*, *Lumpenus lampraetiformis* and herrings. Arctic cod (for the capture of which pelagic trawls or similar equipment are needed) were especially important prey species, taken by all higher vertebrates except bearded seals. Calculated fork lengths, based on Falk-Petersen and others (1986), indicate that most prey of this species were from age groups 0 to 2. This probably reflects the age distribution available for predators in the study area, since Falk-Petersen and others (*ibid.*) found a size-depth segregation in Svalbard waters, with smaller arctic cod dominant in the upper layers (15–80 m depth). Bradstreet and others (1986) by contrast suggested that arctic cod in Canadian arctic waters were not depth-segregated by size, at least within the diving ranges of the marine mammals studied.

Table 3. Stomach content analyses of seals. nd = not determined to genus or species.

	Polychaeta nd	Bivalvia juvenile nd	*Gonatus fabrici*	*Mysis oculata*	*Parathemisto libellula*	*Gammarellus homari*	*Gammarus wilkitzki*	Euphausiacea nd	Decapoda nd	Decapoda larvae nd	*Sabinea septemcarinata*	*Sclerocrangon* sp	*Eualus gaimardi*	*Pollachius virens*	*Boreogadus saida*	*Lumpenus lampraetiformes*	*Liparis liparis*
Phoca hispida (N = 5)																	
Total no. of items	-	4	7	59	63	8	4	1	5	2	3	3	23	11	288	4	10
% frequency	-	0.8	1.4	11.9	12.7	1.6	0.8	0.2	1.0	0.4	0.6	0.6	4.6	2.2	58.2	0.8	2.0
No. with taxon present	1	1	1	4	4	2	1	1	1	2	2	2	2	2	5	2	1
% occurrence	20.0	20.0	20.0	80.0	80.0	40.0	20.0	20.0	20.0	40.0	40.0	40.0	40.0	40.0	100.0	40.0	20.0

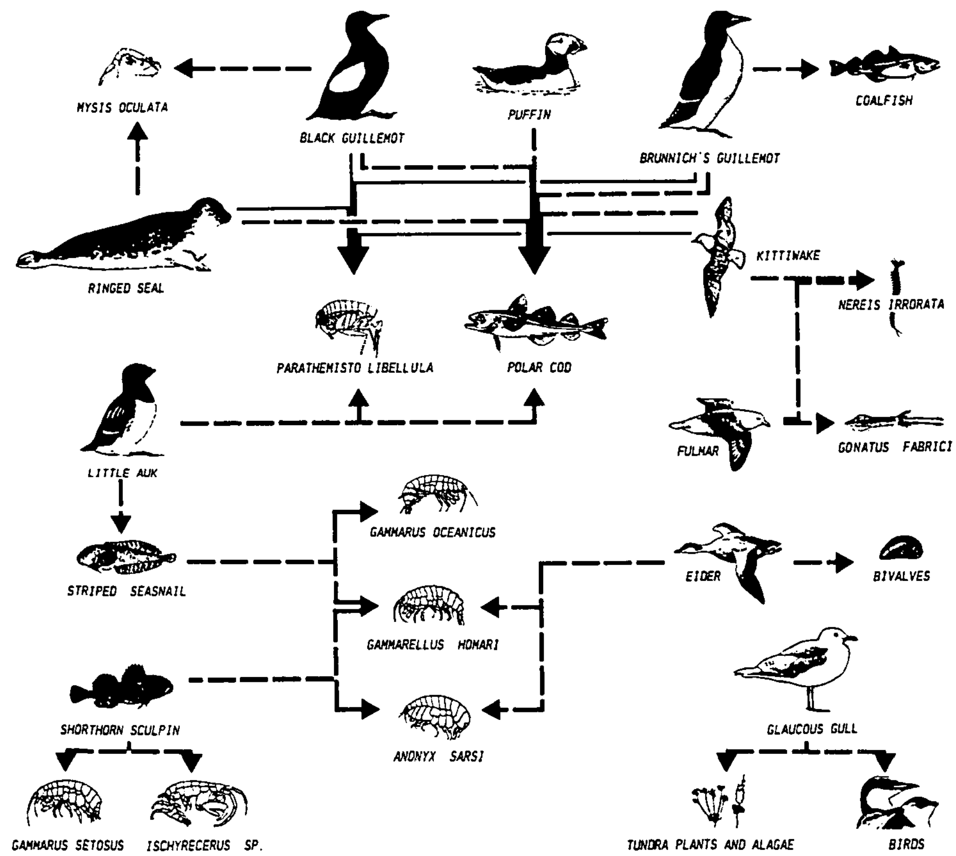

Fig. 2. Food web in Hornsund, autumn 1984, based on stomach content analysis of predators; only the most important prey species are included.

Fulmar stomachs from Hornsund yielded results similar to those from previous Svalbard studies (DeKorte 1972a, Mehlum and Gjertz 1984). Hartley and Fisher (1936), who sampled only until 12 September, found many of the species recorded in this study, but *Thyssanoessa inermis* totally dominated the content of the fulmar stomachs they investigated. *G. fabricii* and *N. irrorata* occurred often in stomachs of fulmars and other Hornsund birds during our study, but did not appear in plankton nets or other sampling devices at the time or before (Skowron 1977, Weslawski and Kwasniewski 1983, Kwasniewski 1985).

As recorded by Hartley and Fisher (1936), eiders were found to eat mainly benthic crustaceans and molluscs. In contrast, Løvenskiold (1964) found that moulting drakes in the area south of Hornsund were feeding largely on holothurians.

The roles of glaucous gulls as scavengers and avian predators are well established. Fragments of land plants were found in this species also by DeKorte (1972b). Our findings on kittiwakes agreed with those of Mehlum and Gjertz (1984) who recorded that kittiwakes mainly ate arctic cod and *P. libellula.* Earlier, Hartley and Fisher (1936) found *T. inermis* and *P. libellula* to be their commonest prey. The biology of the polychaet *N. irrorata,* found in fulmar and kittiwake stomachs in this present study, is not well known, but since this species is often found in stomachs of surface feeding birds, part at least of its life cycle must be pelagic.

Black guillemots in this study preyed on the greatest number of different species, with *P. libellula* and arctic cod dominant. Hartley and Fisher (1936) found them preying most commonly on *T. inermis* and *P. libellula,* while Mehlum and Gjertz (1984) found arctic cod and *Gammarus wilkitzkii* predominant in their diet. DeKorte (1972c) found that two black guillemot stomachs out of 19 contained only Gammaridae. In Brunnich's guillemots our study showed arctic cod and *P. libellula* as the dominant prey species; Hartley and Fisher (1936) recorded *T. inermis* as their main prey. All puffin stomach content included arctic cod; *P. libellula* and *Calanus* sp. were the second most significant prey. Hartley and Fisher (1936) found that puffins preyed on *T. inermis* and fish, including arctic cod.

Little auks too fed predominantly on *P. libellula* and arctic cod. *L. liparis,* a typical benthic fish, occurred in 45.5% of their stomachs. Fish have not previously been recorded as prey of little auks in the Svalbard area (Løvenskiold 1964, DeKorte 1972b, Norderhaug 1980, Mehlum and Gjertz 1984), though Norderhaug (1980) found a single fish larva. This species is known to eat arctic cod elsewhere in the Arctic (Bradstreet 1982). Though both Løvenskiold (*ibid.*) and Norderhaug (*ibid.*) claim that Hartley and Fisher (1936) had reported arctic

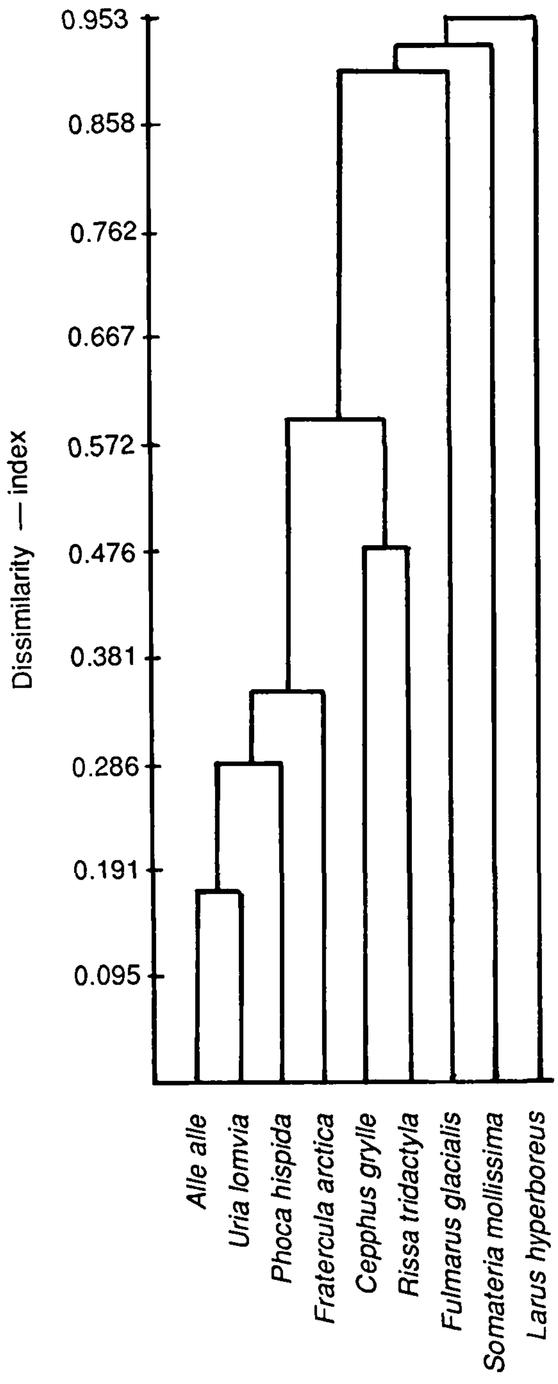

Fig. 3. Cluster analysis based on frequencies of prey species from nine predator species, Hornsund, autumn 1984.

cod and *Leptoclinus machulatus* in little auks' stomachs, that study clearly states that 'no fish were found'; important prey noted by Hartley and Fisher included crustaceans, notably *C. finmarchicus*, and also *P. libellula*, *M. oculata* and *T. inermis*.

We were studying the feeding of little auks at a time when *C. finmarchicus* did not dominate in the plankton. Norderhaug (1980), studying the same species during the breeding period in the Hornsund area of Svalbard, found that *C. finmarchicus* was the dominant prey. It may be that this was a common planktonic species at that time, and is preferred as food for the chicks. Previous studies in Hornsund (Skowron 1977, Kwasnieski 1985) indicate that the pelagic food base in the area must be inadequate for all the predator species living there. Most pelagic feeding birds may therefore have to search for food in the open sea, or find small-scale planktonic aggregations caused by hydrological phenomena within the fjord.

The effects of local upwelling close to glacier fronts, creating aggregations of macroplankton used by kittiwakes and fulmars, are described by Hartley and Fisher (1936), Stott (1936) and Dunbar (1951). We saw this phenomenon in Hornsund, where birds often fed along narrow lines of turbulent water during periods of gentle breezes. These lines probably originated as Langmuir cells, a hydrological phenomenon described by Ledbetter (1979) as one factor causing planktonic concentrations. Other mechanisms which may lead to plankton aggregations are the 'ice edge effect' (Cross 1982), and zones of contact between different water masses, for example the Polar Front described by Løvenskiold (1964) as the most important area of bird feeding. In 1975, 1979, and 1982 large amounts of pack-ice with associated planktonic communities drifted into Hornsund (Weslawski and Kwasniewski 1983). Macroplankton concentrations were not seen among pack-ice in Hornsund in 1984.

Some of the pebbles found in bird stomachs may have been swallowed accidentally; however, it is known that birds of many species swallow stones to help them with their digestion. Remains of nylon and other man-made plastic debris occurred in 14 of 144 stomachs (10%) during our study; ingesting species included fulmars, kittiwakes, Brunnich's guillemots and little auks. Fulmars frequently ingest plastic (Franeker 1985): Mehlum and Gjertz (1984) found such remains in five of 15 fulmar stomachs.

Few ringed seals were observed during the field work. Most of those observed seemed small and were probably subadults. Of five shot, four were in the age group 1–3 years. Hundreds of ringed seals are observed in Hornsund each spring, suggesting that this is a good breeding area Most leave in late summer; reasons for this movement are unknown, but local scarcity of food may be a contributary factor. Arctic cod, *P. libellula* and *M. oculata* were found in all five ringed seal stomachs. This agrees with analyses of stomach contents from other parts of Svalbard (Gjertz and Lydersen 1986).

Bearded seals were observed regularly throughout the study period, and are also observed regularly around the year from the Polish polar station. It seems therefore that Hornsund has a fairly stable year-round population, perhaps because this seal is reported to feed on benthic organisms which are present throughout the year. The single bearded seal stomach analysed gives little scope for generalization; except for coalfish, it had fed only on benthic organisms.

Conclusion

The results from Hornsund reveal separate pelagic and benthic marine food chains. In the former, arctic cod and *P. libellula* are central to the diets of ringed seals, black guillemots, puffins, Brunnich's guillemots, little auks and kittiwakes. In the benthic chain, benthic fish and eiders are the main predators, feeding mainly on benthic amphipods and bivalves. Fulmars differ from other pelagic birds in that their main prey consists of *N. irrorata* and *G. fabricii*: glaucous gulls are scavengers which feed also on algae and land plants.

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References

Bradstreet, M. S. W. 1980. Thick-billed murres and black guillemots in the Barrow Strait area, N.W.T., during spring: diets and food availability along ice edges. *Canadian Journal of Zoology* 58: 2120–40.

Bradstreet, M. S. W. 1982. Pelagic feeding ecology of dovekies, *Alle alle*, in Lancaster Sound and western Baffin Bay. *Arctic* 35(1): 126–40.

Bradstreet, M. S. W., Finley, K. J., Sekerak, A. D., Griffiths, W. B., Evans, C. R., Fabijan, M. J. and Stallard, H. E. 1986. Aspects of the biology of arctic cod (*Boreogadus saida*) and its importance in arctic marine food chains. *Canadian Technical Report of Fisheries and Aquatic Sciences* 1491.

Bray, J. R. and Curtis, J. T. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* 27: 325–49.

Cross, W. E. 1982. Under ice biota at Pond Inlet ice edge and in adjacent fast ice areas during spring. *Arctic* 35(1): 13–27.

DeKorte, J. 1972a. Birds, observed and collected by 'De Nederlandse Spitsbergen Expeditie' in west and east Spitsbergen, 1967 and 1968–69; first part. *Beaufortia* 19(253): 113–50.

DeKorte, J. 1972b. Birds, observed and collected by 'De Nederlandse Spitsbergen Expeditie' in west and east Spitsbergen, 1967 and 1968–69; second part. *Beaufortia* 19(257): 197–232.

DeKorte, J. 1972c. Birds, observed and collected by 'De Nederlandse Spitsbergen Expeditie' in west and east Spitsbergen, 1967 and 1968–69; third and last part. *Beaufortia* 20(261): 23–58.

Dunbar, M. J. 1951. Eastern Arctic waters. *Fisheries Research Board of Canada. Bulletin* 88.

Falk-Petersen, I. B., Frivoll, V., Gulliksen, B. and Haug, T. 1986. Occurrence and size/age relations of polar cod, *Boreogadus saida* (Lepechin), in Spitsbergen coastal waters. *Sarsia*, 71: 235–47.

Franeker, J. A. van. 1985. Plastic ingestion in the North Atlantic fulmar. *Marine Pollution Bulletin*, 16(9): 367–69.

Frost, K. J. and Lowry, L. F. 1981. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. *Fisheries Bulletin Washington*, 79(1): 187–92.

Gjertz, I. and Lydersen, C. 1986. The ringed seal (*Phoca hispida*) spring diet in northwestern Spitsbergen, Svalbard. *Polar Research*, 4: 53–6.

Hartley, C. H. and Fisher, J. 1936. The marine foods of birds in an inland fjord region in West Spitsbergen. Part 2 Birds. *Journal of Animal Ecology*, 5: 370–89.

Kwasniewski, S. 1985. *Zooplankton fjordu Hornsund (Southwest Spitsbergen) [Zooplankton from Hornsund (Southwest Spitsbergen)]* MSc thesis, University of Gdansk.

Lance, G. N. and Williams, W. T. 1967. A general theory of classificatory sorting strategies. 1. Hierarchical systems. *Computer Journal*, 9: 373–80.

Ledbetter, M. 1979. Langmuir circulation and plankton patchiness. *Ecological Modelling*, 7(4): 289–310.

Løvenskiold, H. 1964. Avifauna Svalbardensis. *Norsk Polarinstitutt Skrifter*, 129.

Mehlum, F. and Gjertz, I. 1984. Feeding ecology of sea birds in the Svalbard area - a preliminary report. *Norsk Polarinstitutt Rapportserie*, 16.

Moskal, W. Z. and Zajaczkowski, M. 1984. The biotope of Hornsund fiord bottom fauna. *Zeszyty Naukowe Wydziaiu BiNoZ, Seria Oceanografia.*

Nazarenko, Yu. I. 1967. On the feeding of the ringed seal in the northern European parts of the USSR. *Trudy Polyarnyy Nauchno-issledovatel'skiy Institut Morskogo Rybnogo Khozaystra i Okeanografi*, 21: 81–5.

Norderhaug, M. 1980. Breeding biology of the little auk (*Plautus alle*) in Svalbard. *Norsk Polarinstitutt Skrifter*, 173.

Soworon, L. 1977. *Zooplankton przybrzenych wod fiordu Hornsund. [Zooplankton of Hornsund fjord coastal waters].* MSc thesis, University of Gdansk, Poland.

Stott, F. C. 1936. The marine food of birds in an inland fiord region in West Spitsbergen. Part I. Plankton and inshore benthos. *Journal of Animal Ecology*, 5: 356–69.

Swanson, G. A. and Bartonek, J. C. 1970. Bias associated with food analysis in gizzards of blue-winged teal. *Journal of Wildlife Management*, 34: 739–46.

Weslawski, J. M. 1983. Observations on the coastal amphipoda of the Hornsund fiord (South West Spitsbergen). *Polskie Archiwum Hydrobiologii*, 30: 199–207.

Weslawski, J. M. and Kwasniewski, S. 1983. Application of biological indicators for determination of the reach and origin of sea currents within the region of Spitsbergen. *Polskie Archiwum Hydrobiologii*, 30: 189–97.

Wishart, D. 1978. *CLUSTAN. Users manual (3rd ed.).* Inter-University Research Council Series, Report 47.