Summer diet of seabirds from the Frans Josef Land archipelago, Russian Arctic

JAN M. WĘSŁAWSKI, LECH STEMPNIEWICZ and KIRYL GALAKTIONOV

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Food samples from 102 seabirds from eight species (fulmar *Fulmarus glacialis*, common eider *Somateria mollissima*, glaucous gull *Larus hyperboreus*, kittiwake *Rissa tridactyla*, arctic tern *Sterna paradisaea*, Brünnich's guillemot *Uria lomvia*, black guillemot *Cepphus grylle*, little auk *Alle alle*) were collected during the period August 1991–1993 in the southern part of the Frans Josef Land archipelago, 80°N, 53°E. The pelagic amphipod *Parathemisto libellula* and polar cod *Boreogadus saida* were the two most commonly taken food items (frequency of occurrence over 50% and weight contribution more than 70%). Ice-associated crustaceans contributed to some 10% of the weight in the samples. In general, the food composition was very similar to that reported from Svalbard. However, birds from Frans Josef Land fed on a lower diversity of prey compared to Svalbard populations.

Jan M. Węsławski, Institute of Oceanology, Polish Academy of Sciences, Powstańców Warszawy 55, 91-967 Sopot, Poland; Lech Stempniewicz, Department of Vertebrate Ecology and Zoology, University of Gdańsk, Legionów 9, 80-441 Gdańsk, Poland; Kiryl Galaktionov, Murmansk Marine Biological Institute, Russian Academy of Sciences, Vladimirskaja 17, 183023 Murmansk, Russia.

Introduction

The Frans Josef Land archipelago belongs to one of the least known areas in the European Arctic with regard to marine ecology. It was only recently that internationally organised expeditions (Russian/Norwegian/Polish) collected a sizeable amount of data on the marine mammal, bird and invertebrate fauna of Frans Josef Land (Gjertz & Mørkved 1992, 1993).

Seabirds as consumers constitute an important component of the Arctic ecosystem (Croxall 1987). The number of seabirds breeding and feeding in the area provides reliable data on marine food supplies which can be used for comparisons between different regions and different years in the same area (Cairns 1987; Furness & Nettleship 1991). In the neighbouring Svalbard archipelago, this topic has been studied by Hartley & Fisher (1936), Lydersen et al. (1989), Stempniewicz & Węsławski (1992), and Mehlum & Gabrielsen (1993). There is a lack of such data from Frans Josef Land, with the exception of old and rather anecdotal reports by Gorbunov (1932), Demme (1934) and Węsławski & Skakuj (1992).

The present paper describes the summer diet of seabirds from this area. The paper also presents possible differences between feeding of the same seabird species in two European Arctic regions, Svalbard and Frans Josef Land archipelagoes. The regions are geographically close, but different as to climatic, hydrographic and ecological conditions (Węsławski 1993). In general, Svalbard is exposed to the strong influence of the warm West Spitsbergen Current, while Frans Josef Land is situated in the High Arctic zone covered year round with drifting ice. For this reason differences in seabirds feeding are expected.

Material and methods

During three consecutive summer seasons (August 1991, 1992, 1993) joint Russian, Norwegian and Polish expeditions worked in the area of Hooker Island and the neighbouring islands of the southern-central part of Frans Josef Land archipelago (Fig. 1). Seabirds were collected in the vicinity of the colony at Rubini Rock, Hooker Island. The same samples were used for analysis of chemical pollutants and parasites (Matishov 1993) as well as for morphometry and the study of food content. A total of 102 specimens from eight seabird species (fulmar *Fulmarus glacialis*, common eider *Somateria mollissima*, glaucous gull *Larus hyperboreus*, kittiwake *Rissa tridactyla*, arctic tern *Sterna pardisaea*, Brünnich's guillemot *Uria lomvia*, black guillemot *Cepphus*

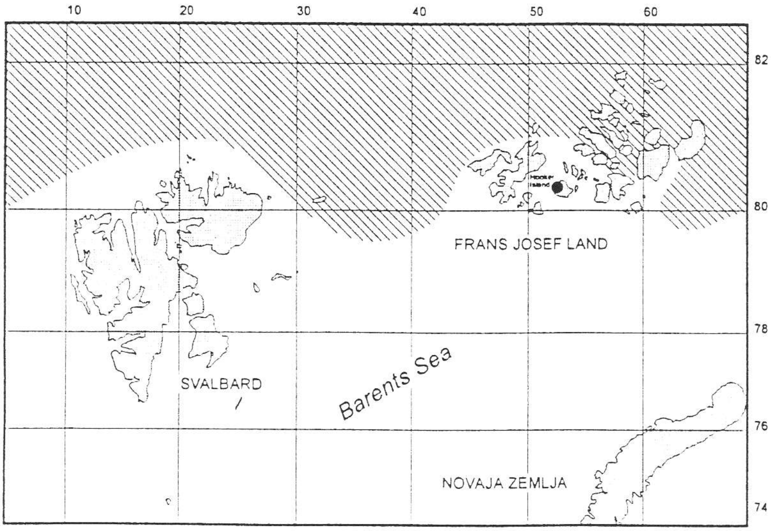

Fig. 1. Sketch map of the study area. The dashed area shows the mean summer ice pack range. The black dot indicates sampling locality.

grylle, little auk *Alle alle*) were examined. All food samples from a given seabird species collected in different seasons of the study were pooled because of low sample size.

Birds were dissected immediately after being shot. Oesophagus and stomach contents were preserved in a 4% formaldehyde solution and analysed two months later in the laboratory. In the case of the little auks, the contents of the gular pouches were also used as food samples. Each sample was washed on 0.5 mm mesh size screen and analysed under stereo microscope. The material was sorted and then identified to the lowest possible taxonomic level. The number, length and weight of all identifiable food items were noted. Standard deviation was calculated only for mean length values of the most numerous food items. In instances where only fragments of prey items were found (fish otoliths, polychaete jaws, crustacean rostra, etc.), the original lengths and weights were calculated from the formulas presented by Berestovskij et al. (1989), Bradstreet (1980), and Lydersen et al. (1989). The number of fish and polychaetes ingested was estimated as half the number of otoliths and jaws found in the samples. Calorific values of fresh, not fragmented specimens of all prey taxa were measured according to the method described in Szaniawska & Wołowicz (1986).

The following coefficients were used to present the results of the analyses of the food samples. Frequency of occurrence (F%) was determined for each bird species as percent number of samples (stomachs) containing given prey type. Also the mean number of a given food item per sample (numerical abundance) and percentage by number, weight and energy of particular prey taxa were calculated.

Cluster analyses were performed using the PRIMER programme (Carr 1993) (Plymouth Marine Laboratory, UK) and the Bray-Curtis index of similarity, based on the frequency of occurrence matrix. Empty stomachs and those containing single food item were excluded.

Results

Food content

Fulmar *F. glacialis*. – Remains of four prey taxa were identified in the food samples. Polar cod *Boreogadus saida* was the largest prey item (140 mm), and pelagic polychaetes were most numerous. Fish (*B. saida* and sculpin *Myoxocephalus* spp.) constituted about 85% of food weight. Remains of macrophytes and plastic debris were found in each stomach. No ice-associated crustaceans were identified in the fulmar diet. (Table 1).

Common eider *S. mollissima*. – Seven prey taxa were found. All stomachs contained gastropods (*Margarites helicinus*), constituting about 84% of the items and more than 55% of the food weight.

Table 1. Stomach contents of five seabird species and food items characterisitics.

Seabird species and prey items	Mean length (mm)	Mean wet weight (mg)	Total number of individuals	Frequency of occurrence F%	Percentage by number	Percentage by weight
Fulmaris glacialis (n = 5)						
Polychaeta spp.	60	200	3	60	27.3	4.0
Margarites spp.	10	491	1	20	9.1	3.3
Boreogadus saida	141	7.589	1	20	9.1	50.7
Myoxocephalus scorpius	60	5.220	1	20	9.1	34.9
Pisces n.det.	50	1.000	1	20	9.1	6.7
terrestrial plants	5	4	1	20	9.1	0.0
macrophytes	10	20	2	40	18.2	0.3
plastic debris	5	20	1	20	9.1	0.1
Somateria mollissima (n = 5)						
Polychaeta spp.	60	200	1	20	2.7	0.7
Margarites spp.	10	491	31	100	83.8	55.8
Onisimus spp.	10	14	1	20	2.7	0.1
Gammarellus homari	30	511	1	20	2.7	1.9
Gammarus setosus	25	207	1	20	2.7	0.8
Weyprechtia pinguis	15	43	1	20	2.7	0.2
Boreogadus saida	162	11.087	1	20	2.7	40.6
Larus hyperboreus (n = 5)						
Boreogadus saida	180	11.000	2	40	20.0	8.0
Pisces n.det.	50	1.000	2	40	20.0	0.7
birds remains	100	50.000	5	100	50.0	91.2
gravel	10	100	1	20	10.0	0.0
Sterna paradisaea (n = 5)						
Polychaeta (pelagic)	60	200	1	20	7.7	4.2
Apherusa glacialis	10	5	1	20	7.7	0.1
Gammarus setosus	25	207	3	60	23.1	12.9
Gammarellus homari	30	511	5	100	38.5	53.3
Gammarus wilkitzkii	25	206	2	40	15.4	8.6
Pisces n.det.	60	1.000	1	20	7.7	20.9
Cepphus grylle (n = 5)						
Atylus carinatus	30	250	1	20	4.3	0.4
Gammarellus homari	25	250	1	20	4.3	0.4
Onisimus spp.	15	50	1	20	4.3	0.1
Gammarus wilkitzkii	15	150	2	40	8.7	0.4
Parathemisto libellula	12	25	1	20	4.3	0.0
Lebbeus polaris	60	800	4	40	17.4	4.7
Boreogadus saida	140	7.500	8	80	34.8	88.1
Myoxocephalus scorpus	60	1.000	2	20	8.7	2.9
Pisces n.det.	60	1.000	2	20	8.7	2.9
gravel			1	20	4.3	0.0

Benthic amphipods (*Gammarellus homari*, *Gammarus setosus*, *Weyprechtia pinguis*, *Onisimus* spp.) were the second in importance. Ice-associated crustaceans were not present in the food samples (Table 1).

Glaucous gull *L. hyperboreus*. – Remains of juvenile birds were found in each stomach. They included Brunnich's guillemots, kittiwakes and little auks. Large polar cods (18 cm) were found in two stomachs. Birds contributed to more than 90% of the energy intake (Table 1).

Kittiwake *R. tridactyla*. – Eight prey taxa were found. The largest prey found was a 16 cm polar cod *B. saida*, and the smallest was a 4 mm long *Calanus glacialis*. The most common food items were Amphipoda (*apherusa glacialis – 46% and Parathemisto libellula* – 32% of all items). Polar cod of mean length 13 cm was the most important food component. It constituted about 90% of food weight and energy intake. Ice-associated crustaceans contributed to only 4% of energy intake (Table 2).

Table 2. Stomach contents in the Kittiwake *Rissa tridactyla* (n = 19) and food items characteristics.

Prey item	Mean (SD) length (mm)	Mean wet weight (mg)	Total number of individuals	Energetic value (kJ/g dw)	Frequency of occurrence F%	Mean number of individuals	Percentage by number	Percentage by weight	Percentage by energy
Polychaeta spp. *(pelagic)*	60.0 (—)	200	5	19.7	16	0.5	0.8	0.4	0.3
Calanus spp.	7.0 (1.09)	7	43	26.0	16	3.9	6.7	0.1	0.1
Apherusa glacialis	6.4 (1.35)	2	297	19.7	22	27.0	46.0	0.3	0.1
Gammarus wilkitzkii	25.0 (—)	207	55	16.0	16	5.0	8.5	5.0	3.9
Parathemisto libellula	10.8 (2.14)	13	208	16.7	84	18.9	32.2	1.6	0.9
Meganyctiphanes norvegica	30.0 (—)	270	4	22.0	16	0.4	0.6	0.5	0.4
Boreogadus saida	133.1 (19.90)	5,000	30	24.2	58	2.7	4.7	89.8	92.1
Myoxocephalus scorpius	60.0 (—)	5,220	1	22.0	5	0.1	0.2	2.3	2.1
terrestrial plants	5.0 (—)	4	1		5	0.1	0.2	0.0	
macrophytes	10.0 (—)	20	1	19.7	5	0.1	0.2	0.0	0.0

Table 3. Stomach contents in the Brunnich's Guillemot *Uria lomvia* (n = 11) and food items characteristics.

Prey item	Mean (SD) length (mm)	Mean wet weight (mg)	Total number of individuals	Energetic value (kJ/g dw)	Frequency of occurrence F%	Mean number of individuals	Percentage by number	Percentage by weight	Percentage by energy
Polychaeta spp. *(pelagic)*	60.0 (—)	200	2	18.0	18	0.2	0.9	0.2	0.1
Onisimus spp.	10.0 (—)	14	2	18.0	18	0.2	0.9	0.0	0.0
Rhachotropis aculeata	8.0 (—)	8	1	16.0	9	0.1	0.4	0.0	0.0
Gammarus wilkitzkii	25.0 (—)	207	9	16.0	54	0.8	4.0	0.8	0.6
Gammarus setosus	25.0 (—)	207	3	16.0	18	0.3	1.3	0.3	0.2
Parathemisto libellula	14.5 (2.43)	48	156	16.7	92	14.2	68.7	3.0	1.7
Thysanoessa inermis	25.0 (—)	156	28	22.0	9	2.5	12.3	1.9	1.4
Boreogadus saida	150.7 (21.86)	10,000	22	24.2	54	2.0	9.7	92.8	94.9
Pisces n.det.	50.0 (—)	1,000	2	24.2	18	0.2	0.9	0.9	0.9
gravel	10.0 (—)	100	2		18	0.2	0.9	0.1	0.0

Table 4. Stomach and gular pouch contents in the Little Auk *Alle alle* (n = 47) and food items characteristics.

Prey item	Mean (SD) length (mm)	Mean wet weight (mg)	Total number of individuals	Energetic value (kJ/g dw)	Frequency of occurrence F%	Mean number of individuals	Percentage by number	Percentage by weight	Percentage by energy
Ostracoda spp.	3.0 (—)	3.0	5	16.0	2	0.5	0.1	0.1	0.0
Calanus spp.	6.4 (1.21)	7.0	3,404	26.0	49	309.5	84.4	71.9	73.5
Mysis oculata	20.0 (—)	38.0	5	22.0	11	0.5	0.1	0.7	0.6
Onisimus spp.	10.0 (—)	14.0	4	16.0	6	0.4	0.1	0.2	0.2
Acanthostepheia spp.	8.0 (—)	8.0	1	16.0	2	0.1	0.0	0.0	0.0
Apherusa glacialis	7.3 (1.91)	4.0	530	19.7	49	48.2	13.1	5.7	4.4
Gammarus wilkitzkii	25.0 (—)	207.0	9	16.0	15	0.8	0.2	7.2	7.7
Parathemisto libellula	9.5 (3.18)	13.0	43	16.7	64	3.9	1.1	2.4	1.9
Thysanoessa longicaudata	25.0 (—)	156.0	3	22.0	6	0.3	0.1	1.8	1.8
Thysanoessa inermis	25.0 (—)	156.0	18	22.0	6	1.6	0.4	10.8	11.0
Sabinea septemcarinata (larvae)	10.0 (—)	10.0	4	22.0	9	0.4	0.1	0.2	0.1
Liparis spp.	—	—	1	—	2	0.1	0.0	—	—
Pisces (larvae)	10.0 (—)	20.0	4	24.2	9	0.4	0.1	0.3	0.4

Arctic tern *Sterna paradisaea*. – Six food taxa were identified. An unidentified fish of ca. 10 cm length was the largest prey item. Gammarid crustaceans (*G. homari*, *G. setosus*, *Gammarus wilkitzkii*) were the most numerous and contributed to more than 70% of the food weight. Nearly 10% of the food mass was formed by ice-associated crustaceans (Table 1).

Brünnich's guillemot *Uria lomvia*. – Nine prey taxa were found. The smallest was an 8 mm long amphipod (*Rhachtropis aculeata*) and the largest was 16 cm long polar cod. *P. libellula* was the most numerous prey constituting about 69% of the items. Polar cod was the main food item both as to weight (93%) and energy value (95%). Ice-associated crustaceans were of negigible importance and constituted less than 1% of prey weight and energy (Table 3).

Black guillemot *Cepphus grylle*. – Eight food taxa were identified. Polar cod (16 cm long) was the largest prey item. Fish were most important, both in number (nearly 45% of items), and in food weight (90%). Decapods and gammarids contributed to less than 10% of the food intake (Table 1).

Little auk *Alle alle*. – Thirteen prey taxa were identified (Table 4). The largest food item was the snail fish *Liparis* spp. of ca. 60 mm length found in one stomach only. The smallest items were 3 mm long Ostracoda. The most numerous taxon was *C. glacialis* represented both by subadult (copepodit IV and V) and adult specimens of 6 to 8 mm long. They constituted 84% of the total number of prey items, and 72% of the food weight. The second most important prey was *Thysanoessa inermis* (about 11% of weight and energy value). Ice-associated Amphipoda (*A. glacialis* and *G. wilkitzkii*) contributed to more than 12% of energy intake, while 73% was provided by copepods (Table 4).

Food selection and competition

Some distinct differences in the size class distribution of most common zooplankters occurring in Frans Josef Land surface waters (Koszteyn & Kwaœniewski 1992) and in the collected food samples were found. The largest specimens of *C. glacialis* (6–10 mm), the middle sized specimens of *P. libellula* and the lower mean fraction of *A. glacialis* were chosen by feeding seabirds. In general, only food items 6 mm long or bigger were selected. Smaller preys constituted less than 7% of total number of items ingested by birds studied.

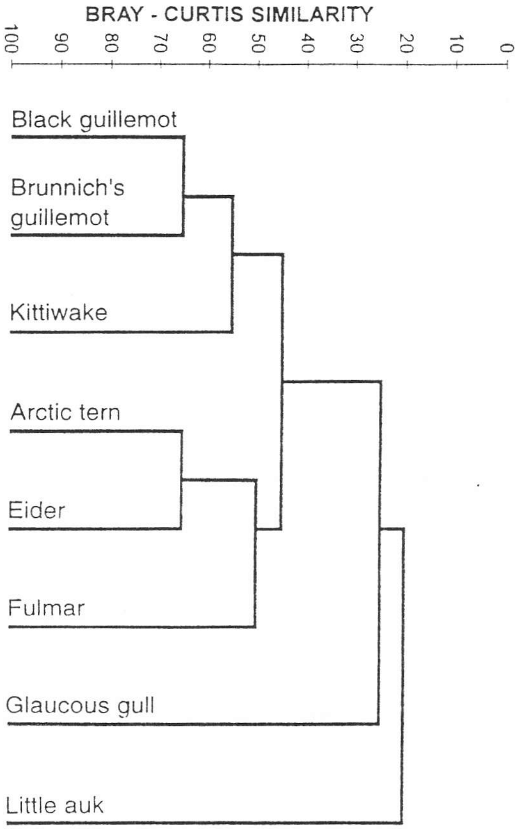

Fig. 2. The dietary overlap-cluster of prey similarity.

Cluster analysis of seabird diet similarity shows closely related diets of the kittiwake, Brünnich's and black guillemots, all relied mainly on polar cod and *P. libellula*. It appears also that on Frans Josef Land eiders and arctic terns exploit similar food resources (gammarid Amphipods). The little auks took mainly *Calanus* (70% of food weight and energy) and were separated from other seabirds as well as the glaucous gulls occupying the distant niche of carnivore and scavenger (Fig. 2).

Among the three most numerous seabirds compared, the little auks took the smallest, kittiwakes the medium sized, and Brünnich's guillemots the largest prey items (Fig. 3; Tables 3, 4). In our study seabirds utilising similar food resources (large dietary overlap) preferred different length classes of the same prey. Because of small samples only size of the most common prey items of the kittiwakes and Brünnich's guillemots (a pair of species with considerable dietary overlap) were compared. Brünnich's guillemots took significantly larger polar cods ($t = 3.02$, $df = 50$, $P < 0.005$) and *P. libellula* ($t = 15.60$, $df = 362$, $P < 0.001$) than the kittiwakes.

Polar cod was the only prey item used by nearly all investigated birds. It contributed to more than 90% of energy intake in the diets of four most numerous seabirds. *P. libellula* was second of importance with regard to the frequency of occur-

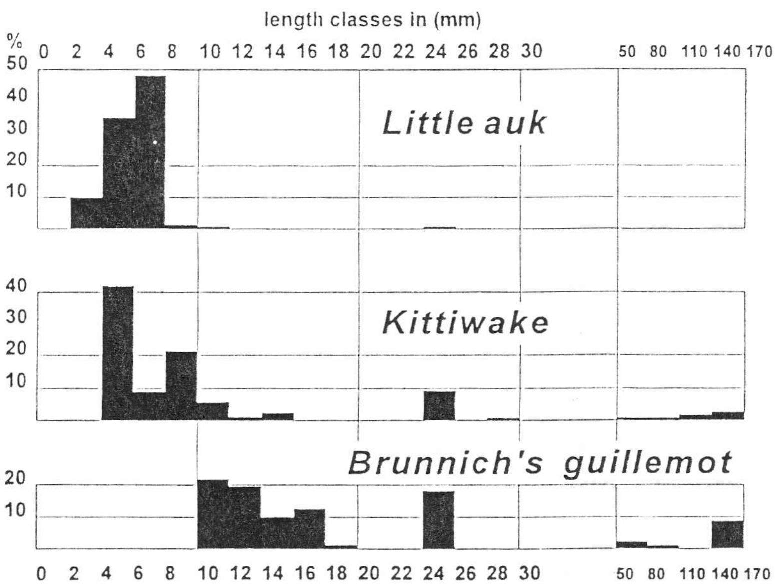

Fig. 3. Length frequency of all prey items taken by the most common seabirds in Frans Josef Land.

rence in birds stomachs, but did not contribute significantly to the total energy consumption.

Discussion

Optimal foraging theory (Stephens & Krebs 1986) predicts minimising foraging costs (in case of seabirds the costs of flights to feeding grounds, prey location, choice, pursuit, etc.), and maximising energy gains (energy income as a result of feeding). During the breeding period the seabirds should therefore exploit the feeding grounds situated close to colony, offering abundant prey, easy to locate and catch. To obtain more energy during one feeding trip the birds would have to choose sites with high available prey density and food items of maximal size in relation to their carrying capacity. The longer the distance between the colony and the feeding grounds the bigger food load is more profitable (Croxall 1987).

Larger prey taxa (*B. saida*, *G. wilkitzkii*, *P. inermis*) usually constituted the higher proportion of summer diets of the same seabirds in Frans Josef Land (Tables 2, 3, 4) than in Svalbard (Mehlum & Gabrielsen 1993). In addition, selecting bigger prey species within the same genera (*C. glacialis* versus *C. finmarchicus*, and *P. libellula* versus *T. abyssorum*; Węsławski & Skakuj 1992) could result in larger average size of food items in Frans Josef Land seabirds. However, considerable local and seasonal variability in diets demonstrated by Mehlum & Gabrielsen (1993) for Svalbard seabirds as well as small sample size in this study make the above statement uncertain.

On the other hand however, mean individual size of *P. libellula* taken by Frans Josef Land seabirds was smaller compared to Svalbard (Mehlum & Gabrielsen 1993). That may reflect the peripheral character of *P. libellula* population in West Spitsbergen, where adult, large size classes are more frequent. In Frans Josef Land, at the centre of population occurrence (Koszteyn et al. in press) more even size frequency may be observed, so more accessible and common are middle sized individuals. No differences were found in mean size of polar cod taken by seabirds from Svalbard and Frans Josef Land. That may indicate similar distribution of class sizes in polar cod populations in both areas compared.

Seabirds are opportunistic within the food spectrum they are morphologically, physiologically and behaviourally adapted to exploit. Some of them use a wide food range, like the glaucous gull feeding on marine invertebrates, fish, eggs, birds, carrion and offal, in varying proportions depending on local and seasonal availability (Stempniewicz & Węsławski 1992). Eiders are less opportunistic and feed on benthic amphipods and thin-shelled gastropods throughout their distribution area in the European Arctic, but usually take locally abundant species of preys (Hartley & Fisher 1936; Uspenskij 1979; Lydersen et al. 1989; Mehlum 1989). Food specialists such as the little auk, use a very narrow feeding niche limited basically to zooplankton. However, even the little auk diet may vary considerably in different areas and seasons. In spring their diet consists mainly of calanoid copepods while in August they take first of all amphipods (*Parathemisto* sp., *A. glacialis*) and the polar cod (Bradstreet & Cross 1982; Lydersen et al. 1989; Mehlum & Gabrielsen 1993).

The relatively low diversity of High Arctic pelagic ecosystems results in somewhat artificial similarity of seabird diet in different arctic regions. The polar cod and *P. libellula*, the most important food components of Frans Josef Land seabirds, are also reported as main food preys in Svalbard (Lydersen et al. 1989; Mehlum & Gabrielsen 1993) and in the Canadian Arctic (Bradstreet 1980).

Some differences in seabird diets in the two, geographically very close areas (Frans Josef Land and Svalbard) may be a result of some distinct differences between these areas concerning climate and hydrology, which influence the composition of the marine fauna. Pack ice arrives scarcely in the Svalbard waters during the summer and stays far from the western coast where the majority of seabird colonies are situated. In Frans Josef Land waters pack ice is present throughout the year. The coastal ice-covered waters of Frans Josef Land are apparently rich in pelagic crustacean resources, contributed to by sympagic fauna (estimated by Gulliksen & Lonne 1991 to 1–10 g/m^3), neritic plankton (decapoda larvae, amphipods – 0.5 g/m^3; own data) and marine plankton (copepods – 1 g/m^3; own data). Ice-associated fauna contributed to some 20% of seabirds' food in Frans Josef Land. Mehlum & Gabrielsen (1993) report a similar number for ice covered waters in the northern Barents Sea. In the Canadian Arctic, close to the fast ice edge, sympagic species contribute to ca. 10% of seabirds' diet (Bradstreet & Cross 1982).

The number of food taxa (zooplankton and fish) recorded in the summer diets of seabirds is considerably lower in Frans Josef Land than at Svalbard. In total, the same three most numerous seabird species (little auk, Brünnich's guillemot and kittiwake) take 19 prey taxa in Frans Josef Land and at least 36 in Svalbard waters. Ten species of fish were found in the food samples from Svalbard and only three from Frans Josef Land. The latter did not contain representatives of such important groups of marine invertebrates as Gastropods, Cephalopods, Decapods and Chaetognaths (Hartley & Fisher 1936; Mehlum & Gabrielsen 1993; this study). Lower sample size in this study may partly be responsible for that. Compared to the study by Demme (1934) on Frans Josef Land seabirds of the same species, our data are stikingly different. Demme (1934) recorded very few polar cod and no *Parathemisto*, but she found the hyperbenthic gammarid *Atylus carinatus* as predominating in the food sample collection of over 150 seabirds from Hooker Island. Difference in methods (not described in Demme's paper) might be partly responsible for this discrepancy, otherwise the interpretation is difficult.

We may consider all common, subsurface living animals of 5 to 200 mm length as potential prey taxa for seabirds. There are at least 50 such species in Svalbard waters and no more than 30 in Frans Josef Land (Węsławski et al. 1994), so one might expect a larger overlap in diet and increased interspecific competition among seabirds in Frans Josef Land. In the situation common on Frans Josef Land, however, when the potential prey is brought up to the surface, pushed into shallow shore water, closely associated with ice, etc., i.e. it aggregates in a natural or extorted way in the sites easily accessible for birds, different seabird species can then feed on the same food resources. This does not involve an increase of the interspecific competition because food resources are usually superabundant in such places. In other words different seabirds exploit the same feeding niche despite that normally they separate their feeding grounds by zones (e.g. inshore feeding black guillemot and offshore feeding Brünnich's guillemot) or by layers (e.g. surface feeding kittiwake, subsurface feeding little auk and bottom feeding black guillemot).

Patchy distribution of zooplankton in the sea makes location of prey aggregations by feeding birds difficult. A key question is a presence of any indication which the birds can perceive, making location easier. The presence of pack ice may be one such indicator (the sympagic fauna constitutes about 20% of the diet). Birds may use pack ice as an aid in finding at least one fifth of their food. The remaining prey can also be found in such places, which are not, however, closely associated with ice floes.

Franz Josef Land is situated further north and east than Svalbard and pack ice occurs there permanently in the sounds between the islands throughout the year. During the breeding season seabirds can find abundant and easily available food close to the colony. Our observations show that the majority of seabirds nesting on Rubini Rock forage in the Mellenius Sound, i.e. a few km from the colony. The specific hydrological situation in the sounds (strong tidal currents, upwellings, whirl-pools, etc.) concentrate the food and favour the seabirds feeding there. For instance, mass presence of half-dead pelagic invertebrates pushed by tidal currents into the shallow water along the shore-line was very often observed during our field work. They were exploited extensively by the kittiwakes. In western Spitsbergen however, the large colonies are often situated in the fjords (Norderhaug et al. 1977) and seabirds usually fly some tens of km to their feeding grounds in the open sea.

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