Diet of the ringed seal (*Phoca hispida*) in Greenland

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ABSTRACT

Analysis of 454 stomachs of ringed seals (*Phoca hispida*) collected from the Inuit hunt in six municipalities in West Greenland and 30 alimentary tracts collected by scientists in East Greenland, showed seasonal and regional differences in the diet. In Northwest and East Greenland polar cod (*Boreogadus saida*) and Arctic cod (*Arctogadus glacialis*) were the most dominant prey items. In contrast, seals in central West Greenland mainly preyed upon amphipods (*Parathemisto* spp.), capelin (*Mallotus villosus*), redfish (*Sebastes* sp.) and squid (*Gonatus* sp.), while capelin was the most important prey item in Southwest Greenland. The material from Uummannaq demonstrates seasonal variations, as euphausiids were common in spring, and snailfish (*Liparis* spp.) dominated from October through January, where after snailfish disappeared with the formation of fast ice. No age related differences in the diet were found in stomach samples from Avanersuaq, but in Upernavik crustaceans were more abundant in stomach samples from younger immature seals. Greenland halibut (*Reinhardtius hippoglossoides*) was only present in samples from seals older than 4 years. In Upernavik Arctic cod was the dominant prey item for seals caught in May at the ice edge, whereas polar cod dominated the samples from seals caught in open water.

INTRODUCTION

The ringed seal (*Phoca hispida*) is a diverse feeder with a diet ranging from pelagic amphipods to Arctic gadoids (i.e. polar cod (*Boreogadus saida*) and Arctic cod (*Arctogadus glacialis*)) and more temperate species like capelin (*Mallotus villosus*) and redfish (*Sebastes* spp.). The ringed seal takes planktonic, nektonic or benthic food and generally turns from inshore feeding on the epibenthic mysids, shrimps, other crustaceans or polar cod, to strictly macroplanktonic feeding in deeper, offshore waters (Frost and Lowry 1981a). Ringed seals sampled in drifting ice had stomach contents consisting of pelagic amphipods, while polar cod constituted an important prey species for seals in coastal areas (Johansen 1910). Pedersen (1931) found that mature ringed seals mostly appeared in coastal areas on the East Coast of Greenland, whereas younger seals mostly were found in open water. The most important prey item of mature seals was crustaceans, while the major prey item of younger seals was polar cod. An analysis of ringed seal stomach contents showed that the ringed seal in Avanersuaq municipality basically predated on polar cod (Vibe 1950). Ringed seals collected at Baffin Island in the summer periods in 1938 and 1940 were mainly feeding on *Parathemisto libellula* and Dunbar (1941) concluded that the ringed seals were planktonic feeders. McLaren (1958) studied ringed seal diet in southwestern Baffin Island, and *P. libellula*, *Mysis oculata* and polar cod were found to be the most important prey items. He concluded that ringed seals were opportunistic feeders and he found no food preferences related to age. Several studies have documented seasonal cycles of feeding habits (e.g. McLaren 1958, Johnson *et al.*1966, Smith, 1987, Weslawski *et al.* 1994).

In the northern part of Greenland the sea is covered by continuous fast ice in late winter. Ringed seals maintain breathing holes or seek cracks or openings in the fast ice. Hunting methods for ringed seals vary according to season (Kapel 1975, Teilmann and Kapel this volume). During late winter to early spring seals are caught in nets under the ice. In spring they are shot in open leads at the ice edge, or when they haul out on the ice (a hauled-out seal is called an uuttoq in Greenlandic, uuttut in plural). The break-up of the sea ice in late spring is the beginning of the open water hunting season, which lasts until late autumn. During this period, seals are shot from small dinghies equipped with outboard engines.

Earlier studies of ringed seal diet in Greenlandic waters are based on fragmentary or limited material (Johansen 1910, Pedersen 1931, Vibe 1950). The intentions with the present study are to elucidate the variation in ringed seal diet in seven widely separated areas in Greenland and to examine the seasonal variation in one area. The stomach mass and contents are examined in relation to hunting method, age and season.

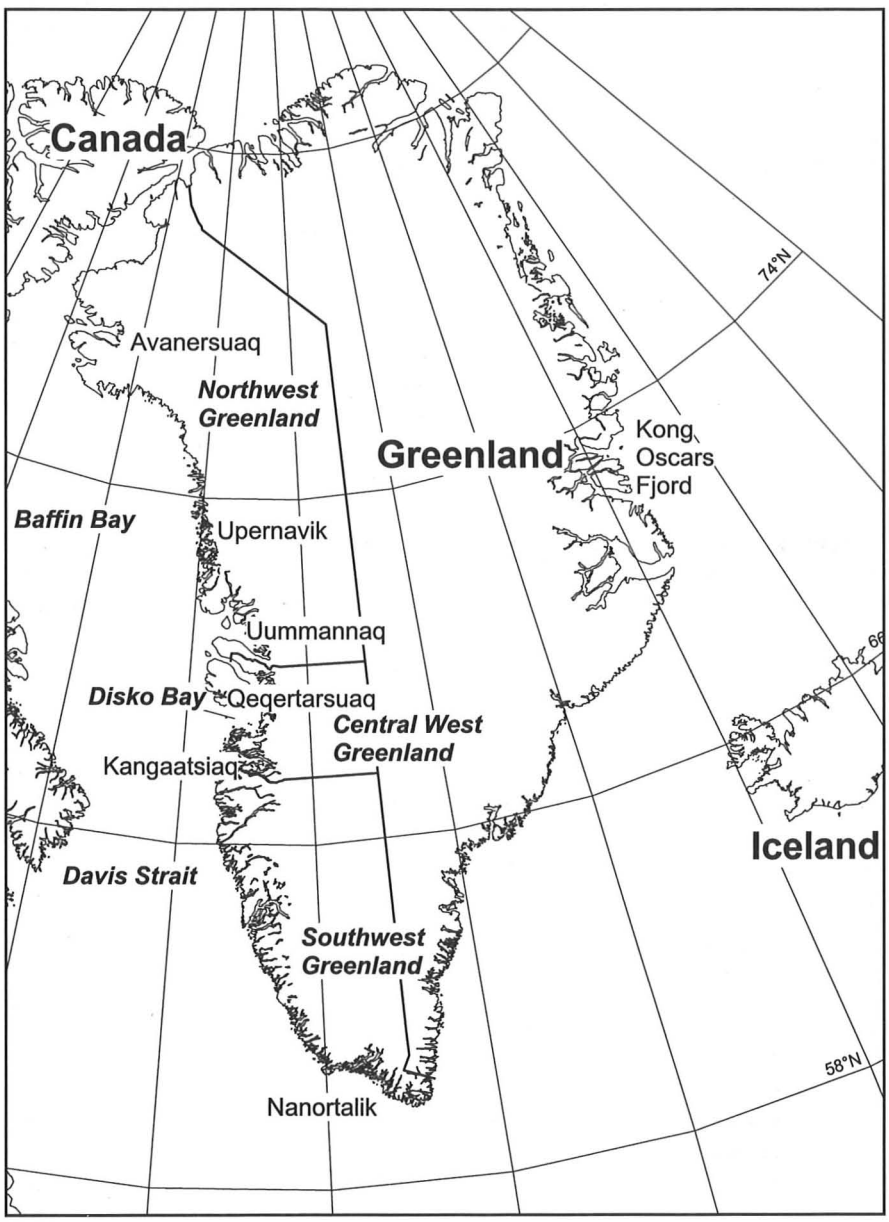

Fig. 1
Map of Greenland with municipalities and areas mentioned in the text.

MATERIALS AND METHODS

Materials presented in this study were collected from the Inuit ringed seal hunt in six municipalities in West Greenland during 1982 to 1987 (Fig. 1, Table 1). A total of 454 ringed seal stomachs were sampled. Additional 30 seals were sampled for scientific purposes in June and August-September 1985 in Kong Oscars Fjord, East Greenland. After removal from the seals, the stomachs were preserved by freezing. Standard body length (American Society of Mammalogists, 1967) was measured to the nearest cm. From each animal the lower jaw was removed and the of 254 seals was estimated by counting annular growth layers of the dentine of one canine tooth (Dietz *et al.* 1991). The remaining 200 animals were given an approximate age calculated from the correlation between the observed standard length and age (age = exp(- 19.978) * stdlength$^{4.49}$, r = 0.4653, N = 254). Additional information on sex, date of capture, locality and hunting method was recorded.

The ringed seal stomachs and intestines were kept frozen until analysed in the laboratory. After thawing, the content of the stomachs and intestines was removed, weighed and placed in a water bath. Undigested fish and invertebrate remains were removed from the sample and the remaining mixture of water and prey items were vibrated until otoliths and stones were deposited at the bottom of the water bath. After extracting the deposit, the rest of the contents were removed through a fine-mesh sieve.

Fish were identified to species using reference collection and standard identification keys (Fitch and Brownell 1968, Finley and Gibb 1982, Breiby 1985, Härkönen 1986). Crustaceans were identified using reference keys (Einarsson 1945, Couture and Trudel 1968, Enckell 1980). Cephalopod beaks were identified using Clarke's (1962) identification key.

The length of all otoliths, telsons and cephalopod beaks were measured to the nearest mm under a microscope. The ringed seal diet was determined by reconstructing the pre-ingestion size of the prey items using published otolith length to fish length and fish mass equations (Frost and Lowry 1981b, Finley and Gibb 1982, Bradstreet and Finley 1983, Härkönen 1986), telson plus uropod length to invertebrate mass relationship (Finley and Gibb 1982, Bradstreet and Finley 1983) and squid beak length to squid mass relationship (Clarke 1962). There is no published otolith length (OL) to fish length and fish mass equations for snailfish, Liparidae. Based on information on otolith length and fish mass (FW) from 22 fresh *Liparis fabricii* collected in West Greenland, the otoliths from *Liparis* spp. were grouped in three size categories (0.4mm<OL>0.8mm, 0.8mm<OL>1.2 mm, 1.2mm<OL>2.0mm) and given an approximate mass (1g, 5g, 10g).

All data were grouped by municipality, year and hunting method. The calculated mass of all invertebrate and fish remains in a stomach sample was summed to a total mass. Diet composition was expressed as frequency of occurrence and relative contribution by fresh mass.

RESULTS

The samples were collected discontinuously at different municipalities, where samples from Uummannaq were taken during nine months, while the sampling extended over two to three months at the remaining municipalities (Table 1). Of the 484 examined stomachs 149 were empty and 60 additional stomachs only contained small amounts of pebbles/stones. A total of 71% of the stomachs from the uuttoq (fast ice) hunting in West Greenland were empty, compared with 24% in net-caught and 14 % in open-water hunted seals. A similar pattern is shown in spring (April to June) catches from 1984-1987 in Uummannaq, where a total of 71 uuttoq seals and 70 netted seals were taken. In the uuttoq seals 78 % of stomachs were empty, compared with 17% among seals caught in nets (Table 1).

Further analyses on the influence of hunting methods, species composition by region and season are based on 275 seals with recognisable prey in their stomachs.

Influence of hunting methods

Seals taken in open water generally have larger and less fluctuating masses of stomach contents compared with seals taken in other habitats (Table 1). The weight of stomach contents of

Table 1. Mean mass (g) of ringed seal stomach contents distributed by municipality or area, month and hunting methods. Note that in Uummannaq and Kangaatsiaq the fjord ice forms in January and March, respectively. N indicates the number of examined stomachs.

Municipality or area	August	September	October	November	December	January	February	March	April	May	June
Avanersuaq	229.7	149.7									
N=88 Empty=14	(N=3)	(N=85)									
Upernavik			36.0							145.1	150.0
N=70 Empty=18			(N=2)							(N=60)	(N=8)
Uummannaq			116.0	164.3	213.0	43.9	72.9	97.0	46.1	16.9	8.0
N=165 Empty=69			(N=5)	(N=14)	(N=5)	(N=19)	(N=28)	(N=12)	(N=12)	(N=65)	(N=5)
Qeqertarsuaq								0.0	137.1	116.8	
N=41 Empty=19								(N=6)	(N=25)	(N=10)	
Kangaatsiaq							240.7	76.0	107.5		
N=58 Empty=15							(N=6)	(N=46)	(N=6)		
Nanortalik									120.3	162.9	
N=32 Empty=6									(N=15)	(N=17)	
Kong Oscars Fjord	30.7	69.9								7.7	44.3
N=30 Empty=8	(N=4)	(N=10)								(N=8)	(N=8)

Hunting methods	August	September	October	November	December	January	February	March	April	May	June
Netting						43.9	72.9	65.2	32.6	55.3	
N=124 Empty=30						(N=19)	(N=28)	(N=53)	(N=12)	(N=12)	
Ice edge										167.5	40.0
N=24 Empty=4										(N=23)	(N=1)
Open water	229.7	149.7	93.1	164.3	213.0		288.8	232.0	193.0	180.9	201.0
N=200 Empty=27	(N=3)	(N=85)	(N=7)	(N=14)	(N=5)		(N=6)	(N=4)	(N=26)	(N=45)	(N=5)
Uuttoq (fast ice)								37.1	108.8	10.2	27.9
N=106 Empty=76								(N=7)	(N=20)	(N=72)	(N=7)

seals taken in open water is by average four times larger than in seals taken as uuttut. In Uummannaq some increase in mean stomach mass is noted in late autumn followed by a decrease in January, the time when the fast ice appears (Table 1). The same could be noted in Kangaatsiaq, where mean stomach mass dropped when the ice appeared in March.

Species diversity in diet

Pooling all data from included regions indicates that the food of ringed seals in Greenland mainly comprises gadoids (polar cod and Arctic cod), capelin, redfish, pelagic crustaceans (*Parathemisto* spp.), benthic crustaceans (mysids) and cephalopods (Table 2, Figs 2-3). At least 21 different species were taken by ringed seals but the number is probably considerably higher because a number of species could only be determined to family, although it was obvious that more than one species was present (e.g. Zoarcidae, Cottidae and Liparidae). Exact species determination based on otoliths alone is impossible for several of these families. Furthermore, sampling over the full annual cycle in the different regions would certainly increase the number of prey species.

Diet in regions

Samples in Avanersuaq were taken in August and September. The primary prey items of ringed seals were hyperiid amphipods and polar cod, which made up 92.3% of all prey both by numbers and by relative contribution of mass. Most ingested specimens of polar cod were young and immature with a mean length of 77.1mm (SD 40.8), which suggests that the seals foraged on shoaling polar cod from the same age class. Also in the Upernavik municipality (most samples taken in May) polar cod dominated numerically in the diet but due to larger size, Arctic cod dominated the composition of the diet by weight. Amphipods and mysids were present in large numbers, but they contributed insignificantly to the diet on a mass basis. In the samples from Upernavik both the polar and especially the Arctic cod, were larger than those found in stomachs from Avanersuaq. Also, five otoliths from Greenland halibut (*Reinhardtius hippoglossoides*) were found in stomachs from Upernavik. Although these halibuts were among the largest fish eaten by the ringed seals they were only present in low numbers and thus did not contribute more than 4.3% to the mass of the diet.

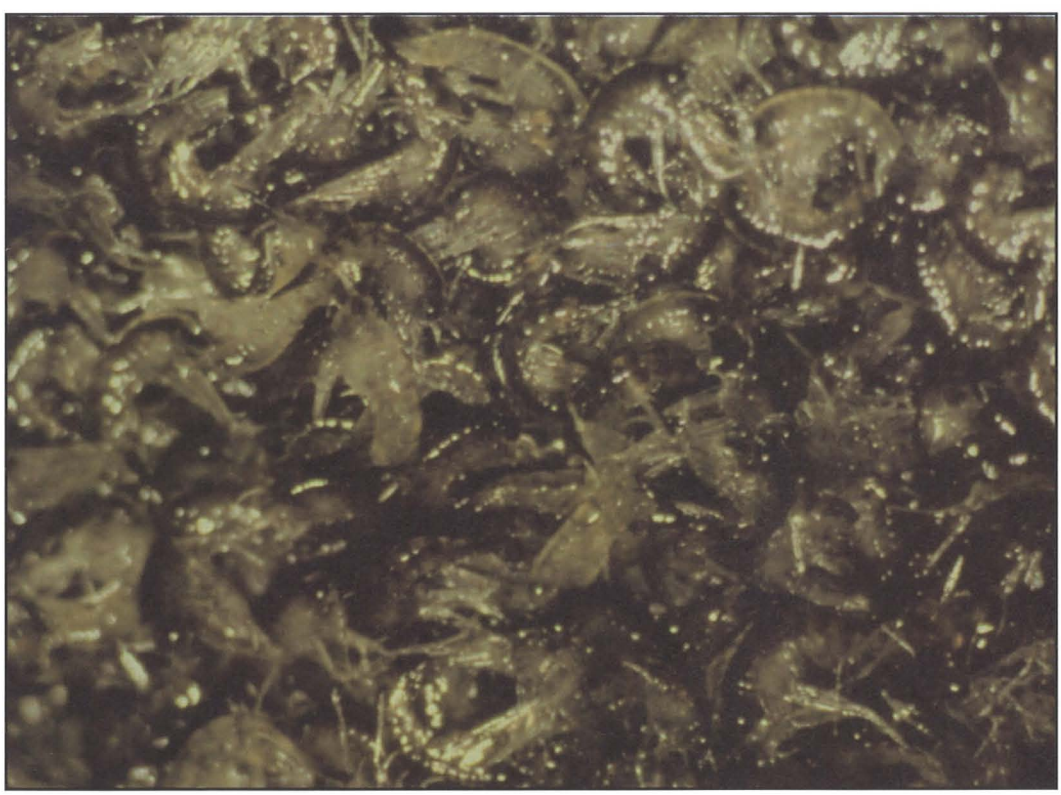

Fig. 2
The amphipod Parathemisto libellula taken by pelagic trawl at the east coast of Svalbard. Photo: T. Haug)

Table 2. Food items of ringed seals in different municipalities from West Greenland and from Kong Oscars Fjord in East Greenland. The frequency of occurrence is given as well as the relative contribution by mass and the estimated size (length) of each food item. N indicates the number of examined stomachs.

Municipality	Species	Number	%	Estimated weight(g)	%	Estimated length(mm)	S.D.
All municipalities	Mysidae	2193	4,0	1290	1,0		
	Parathemisto spp.	24170	44,5	10662	8,4		
	Eusirus cuspidatus	674	1,2	692	0,6		
	Gammarus wilkitzkii	34	0,6	0	0,0		
	Gammaracanthus loricatus	3	0	0	0,0		
	Thysanoessa spp.	7042	13,0	3871	3,1		
	Pandalus borealis	71	0,1	85	0,1		
	Hippolyte spp.	6	0,0	1	0,0		
	Crangon spp.	3	0	0	0,0		
	Gonatus fabricii	1033	1,9	8927	7,1		
	Roschia spp.	3	0,0	240	0,2		
	Mallotus villosus	3222	5,9	7954	6,3		
	Sebastes spp.	1230	2,3	2265	1,8		
	Reinhardtius hippoglossoides	34	0,1	5386	4,3		
	Gadus spp.	116	0,2	3376	2,7		
	Arctogadus glacialis	994	1,8	34884	27,6		
	Boreogadus saida	9418	17,4	36840	29,1		
	Clupea harengus	1	0,0	572	0,5		
	Liparis spp.	3232	6,0	8021	6,3		
	Lycodes spp.	120	0,2	303	0,2		
	Cottidae	532	1,0	1134	1,0		
	Unidentified	143	0,3	0	0,0		
	Total	54274	100,0	126503	100,0		
Avanersuaq 1985 N=88 (empty=14)	Mysidae	467	3,9	224	0,9	19,7	2,4
	Parathemisto spp.	5115	42,2	1933	7,8	30,0	5,8
	Thysanoessa spp.	1	0,0	1	0,0	20,5	
	Arctogadus glacialis	6	0,1	6	0,0	51,0	0,0
	Boreogadus saida	6072	50,1	21653	86,8	77,1	40,8
	Liparis spp.	216	1,8	1076	4,3		
	Cottidae	125	1,0	51	0,2	59,0	38,4
	Unidentified	117		1,0			
Upernavik 1985 N=70 (empty=18)	Mysidae	1561	31,5	1032	2,5	23,1	1,3
	Parathemisto spp.	282	5,7	201	0,5	35,1	5,2
	Thysanoessa spp.	201	4,1	133	0,3	22,9	1,1
	Pandalus borealis	8	0,1	8	0,0	12,4	4,3
	Hippolyte spp.	1	0,0	0	0,0	30,1	
	Gonatus fabricii	16	0,3	259	0,6		
	Reinhardtius hippoglossoides	5	0,1	1749	4,3	334,4	64,2
	Arctogadus glacialis	283	5,7	25225	62,2	206,4	45,8
	Boreogadus saida	2390	48,2	10942	27,0	102,1	33,8
	Liparis spp.	15	0,3	145	0,4		
	Cottidae	195	3,9	906	2,2	70,1	9,4
	Unidentified	5	0,1				
Uummannaq 1983-84	*Parathemisto spp.*	17244	68,3	7759	35,9	20,5	0,2
	Thysanoessa spp.	4809	19,0	2724	12,6	47,9	20,1

Table 2 (cont.)

Municipality	Species	Number	%	Estimated weight(g)	%	Estimated length(mm)	S.D.
N=120 (empty=37)	*Pandalus borealis*	57	0,2	47	0,2		
	Gonatus fabricii	5	0,1	65	0,3		
	Mallotus villosus	2	0,0	14	0,1	278,9	95,7
	Sebastes spp.	2	0,0	2	0,0	31,3	0,7
	Reinhardtius hippoglossoides	15	0,1	3532	16,3	118,0	4,5
	Arctogadus glacialis	2	0,0	421	1,9	104,9	32,5
	Boreogadus saida	123	0,5	245	1,1	101,5	19,1
	Liparis spp.	2983	11,8	6782	31,3	257,5	45,9
	Cottidae	7	0,1	49	0,2	36,5	2,2
	Unidentified	9	0,1				
Uummannaq	*Gonatus fabricii*	1	0,3	30	2,3		
1985	*Arctogadus glacialis*	4	1,2	160	12,2	157,0	9,9
N=22 (empty=17)	*Boreogadus saida*	332	96,5	1120	85,2	84,7	23,8
	Liparis spp.	4	1,2	5	0,3		
	Unidentified	3	0,9				
Uummannaq	*Parathemisto spp.*	81	59,6	52	9,5	30,2	5,3
1987	*Thysanoessa spp.*	5	3,7	3	0,5	20,5	
N=23 (empty=15)	*Gonatus fabricii*	5	3,7	288	52,5		
	Sebastes spp.	1	0,7	2	0,4	55,0	
	Reinhardtius hippoglossoides	1	0,7	10	1,8	117,0	
	Boreogadus saida	9	6,6	79	14,4	104,8	32,3
	Liparis spp.	14	10,3	14	2,5		
	Cottidae	20	14,7	101	18,4	75,8	7,4
Qeqertarssuaq	Mysidae	2	0,1	2	0,0	25,3	
1982	*Parathemisto spp.*	156	5,1	84	1,4	28,1	6,7
N=41 (empty=19)	*Thysanoessa spp.*	1963	63,5	973	16,7	20,1	0,9
	Pandalus borealis	6	0,2	30	0,5	53,1	
	Gonatus fabricii	15	0,5	113	1,9		
	Mallotus villosus	259	8,4	3036	52,2	119,1	15,5
	Sebastes spp.	681	22,0	1463	25,2	107,1	61,6
	Reinhardtius hippoglossoides	2	0,1	56	1,0	142,5	78,5
	Boreogadus saida	6	0,2	58	1,0	11,2	24,6
Kangaatsiaq	*Parathemisto spp.*	3	0,2			22,1	
1986	*Gammarus wilkitzkii*	3	0,2			12,0	
N=58 (empty=15)	*Thysanoessa spp.*	40	2,0	24	0,2	21,2	0,5
	Hippolyte spp.	5	0,3	0	0,0	22,8	
	Gonatus fabricii	961	47,0	7159	45,8		
	Gadus spp.	90	4,4	3246	20,8	197,3	76,3
	Mallotus villosus	136	6,7	1792	11,5	124,1	21,0
	Sebastes spp.	545	26,7	797	5,1	44,6	8,3
	Reinhardtius hippoglossoides	11	0,5	39	0,3	80,5	20,8
	Boreogadus saida	221	10,8	1988	12,7	100,0	32,7
	Clupea harengus	1	0,1	572	3,7	374,0	
	Cottidae	20	1,0	27	0,2	63,0	
	Unidentified	9	0,4				
Nanortalik	*Parathemisto spp.*	11	0,4	5	0,1	28,1	7,0
1986	*Gammarus wilkitzkii*	31	1,1			20,6	8,0
N=32 (empty=6)	*Thysanoessa spp.*	23	0,8	14	0,4	21,6	

Table 2 (cont.)

Municipality	Species	Number	%	Estimated weight(g)	%	Estimated length(mm)	S.D.
Gonatus fabricii	22	0,8	642	16,4			
	Mallotus villosus	2825	96,1	3112	79,6	95,8	17,3
	Sebastes spp.	1	0,0	1	0,0	47,0	
	Gadus spp.	26	0,9	130	3,3	137,0	10,2
	Boreogadus saida	1	0,0	6	0,2	93,0	
Kong Oscars	Mysidae	163	4,8	32	0,2		
1985 Fjord	*Parathemisto spp.*	1278	37,8	629	4,2	30,7	2,9
N=30 (empty=8)	*Eusirus cuspidatus*	674	19,9	346	2,3	28,9	1,8
	Gammaracanthus loricatus	3	0				
	Crangon spp.	3	0				
	Gonatus fabricii	8	0,0	372	2,5	162,5	77,0
	Roschia spp.	3	0,0	240	1,6	90	
	Arctogadus glacialis	699	20,7	9072	60,0	200,2	63
	Boreogadus saida	264	7,8	749	5,0	90,7	30,9
	Lycodes spp.	120	3,6	303	2,0	107,8	25,5
	Cottidae	165	4,9	3386	22,4	140,5	24,4

In Uummannaq, data from 1983-1984, showed that >90% of the prey items by numbers or mass percentage were hyperiid amphipods, euphausiids and snailfish (*Liparis* spp.) in 83 stomachs with contents. Although present, apparently the cod species were less important in Uummannaq in 1983-84, whereas halibut on a mass basis is the second most important fish species after *Liparis* spp. The importance of the cod species is re-established in the 5 stomachs from Uummannaq in 1985, whereas the 8 stomachs from 1987 on a mass basis had a preponderance of cephalopods (*Gonatus fabricii*). Except for Avanersuaq this cephalopod is present in stomachs from all regions.

In Qeqertarsuaq more boreal species like capelin and redfish are new but important components in the diet that also has substantial contribution from euphausiids. In the Kangaatsiaq municipality Gonatus fabricii again makes up the bulk of the mass of the stomach contents, but also gadoids, redfish and capelin are important prey items. The only herring (*Clupea harengus*) was found in a stomach from Kangaatsiaq. Since otolith width of this herring (2.5mm) was outside the range of the regressions given in Härkönen (1986) the size estimation must be considered uncertain.

Capelin followed by *Gonatus fabricii* was the primary prey items in the Nanortalik municipality, corresponding to >95% by both numbers and mass of stomach content. The lowest contribution by polar cods was found in Nanortalik. The sample from Kong Oscars Fjord in East Greenland showed again a high Arctic diet dominated by the two cod species (Arctic and

Fig. 3
Polar cod (Boreogadus saida) below drift ice in the Arctic. (Photo: B. Gulliksen)

Table 3. Relative contribution by mass of the dominating prey items in the ringed seal diets in May and June in the Upernavik municipality distributed by three hunting methods. N indicates the number of stomachs examined.

Hunting method	Arctic cod	Polar cod	Greenland halibut	Mysidae	Cottidae	Others
Ice edge						
N=24	91%		6%		3%	
Open water						
N=25	10%	70%		8%	7%	5%
Uuttoq						
N=18	56%	44%				

polar cod) and pelagic amphipods. The main difference to the samples from Northwest Greenland is the contribution by Cottidae to the diet in East Greenland. The length of the two cod species (Arctic cod and polar cod) showed a remarkable similarity between the samples from East and West Greenland. Apparently this is the preferred size or the size that is most available to the ringed seals.

Differences due to habitat and season

The samples from Upernavik in May-June were taken from three different habitats, i.e. open water, ice edge and fast ice (uuttoq seals) (Table 3). The dominating prey items in terms of estimated mass in seals taken from the ice edge was Arctic cod, whereas seals taken in open water mainly had been feeding on polar cod. Samples collected in the fast ice from uuttoq seals contained almost equal proportions by mass of Arctic and polar cod.

Stomach samples from Uummannaq in 1983-1984 were collected in the autumn, winter and spring seasons. In autumn *Parathemisto* spp. and *Liparis* spp. were primary prey items. *Liparis* spp. makes up 25% of the prey items in terms of numerical contribution in November and December (Table 4). After the fast ice has formed in January *Liparis* spp. decreases to 0.5% and is no longer present after February.

Age related differences in food consumption

Prey preferences in seals with known age was analysed in seals from Avanersuaq and Upernavik (Table 5). In Avanersuaq seals were caught in the open water season in August and September. Arctic cod was only present in seals older than 5 years, whereas polar cod and crustaceans appeared in all age groups. In Upernavik the seals were caught at the ice edge and in open water. In samples taken from the open water the proportion of crustaceans decreased with age and larger fish species (e.g. Arctic cod and Greenland halibut) were only present in seals older than 5 years.

DISCUSSION

McLaren (1958), Fedoseev (1965), Lowry *et al.* (1980) and Bradstreet and Finley (1983) all observed that ringed seals have a reduced food intake during the moulting period from April-May whereas feeding activity remain high throughout the winter. We noted similar seasonal and spatial variations in mass of stomach contents. In Uummannaq and Kangaatsiaq a reduced food intake is evident after the appearance of ice in January and March, respectively. However, at this time of the year hunting methods change from open water hunting to netting, which may affect the quantity of food contained in the stomachs of the seals. It is evident that stomachs collected from the open water hunting provide the largest and most stable sample of prey items. This is mainly due to the fast digestion of prey items in seal stomachs. Feeding experiments with captive seals indicate that no otoliths can be recovered in the stomach 12.9 hours after feeding (Murie and Lavigne 1986). Seals that have been hauling out on the ice for more than 12 hours can be expected to have only few remains from previous meals in their stomachs.

A large number of invertebrate (>60) and fish species (>10) have been reported as prey items of ringed seals from the Arctic (cf. Weslawski *et*

Table 4. Monthly frequency of occurrence of the four most important prey items for the ringed seal stomach samples collected in the Uummannaq municipality in 1983 and 1984. Quantification of the relative contribution by mass for *Liparis* spp. is not possible; thus instead the frequency of occurrence is shown.

Prey items	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Aprl	May	Jun	Jul
Liparis spp.			46	1868	1027	21	21					
Parathemisto spp.			1015	5516	2974	3413	3972	272	52	29	1	
Euphausiids			39	390	24	626	2331	1150	50	149	50	
Others			5	23	18	4	25	96	17	24	10	

al. 1994). Considering the large sample size, the number of species detected in ringed seal stomachs in Greenland is considerably lower than reported from other areas, e.g. Ungava Bay (McLaren 1958) and Svalbard (Weslawski *et al.* 1994). In Greenland ringed seals apparently select 2-4 key prey items that constitute more than 90% of the diet in each area. The most common prey size is 5-10cm for fish with a maximum size of about 20cm although prey as large as 35cm may occasionally be taken depending on age/size of the seals (see also Dunbar 1941, McLaren 1958, Smith, 1987).

A gradient in prey preferences/availability is indicated from North and East Greenland on one hand to central and Southwest Greenland on the other. In the two northernmost municipalities and in East Greenland the diet is dominated by high Arctic species like polar cod, Arctic cod and *P. libellula*. Squids and halibuts are apparently absent in the northernmost area but present in almost all other areas. More boreal species like capelin, redfish and halibuts are gradually increasing in importance to the south and in the southernmost area polar cod have apparently lost its importance. Non-shoaling ben-

Table 5. Dominating prey items in terms of estimated mass in ringed seal diet in relation to age. The stomach samples were collected in the Avanersuaq municipality and from ice edge and open water catches in the Upernavik municipality. N indicates the number of examined stomachs.

Avanersuaq municipality Age	Arctic cod %	Polar cod %	Crustacea %		N
0-1 yrs	0	85,3	14,7		5
1-3 yrs	0	79,2	20,8		27
4-5 yrs	0	78,4	21,6		12
>5 yrs	3,8	72,3	23,9		7
Upernavik municipality at the ice-edge **Age**	**Arctic cod %**	**Polar cod %**	**Crustacea %**	**Greenland halibut %**	**N**
0-1 yrs	-	-	-	-	0
1-3 yrs	69,9	30,1	0	0	10
4-5 yrs	75,7	5,5	2,2	16,3	6
>5 yrs	69,8	18,8	8,0	3,4	4
Upernavik municipality in open water **Age**	**Arctic cod %**	**Polar cod %**	**Crustacea %**	**Greenland halibut %**	**N**
0-1 yrs	0	45,0	54,9	0	4
1-3 yrs	0	73,0	26,5	0	14
4-5 yrs	0	89,4	10,6	0	2
>5 yrs	38,4	39,6	0	21,9	3

thic prey like Cottidae, Liparidae, halibuts and perhaps some of the unidentified cod species, seem generally less important than pelagic prey that occur in schools.

Apparently ringed seals in the northern seas of the Russia, Alaska, Canada and Northwest Greenland feed heavily on polar and Arctic cod most of the year (Chapski 1940, Vibe 1950, McLaren 1958, Lowry *et al.* 1980, Bradstreet and Finley 1983). Polar cod occur in the water column from 0-50 metres depth, however, they are also known to occur at greater depths and annual migrations of juvenile polar cod in late summer are well documented (Craig *et al.* 1981, Bradstreet *et al.* 1986). Polar cods are reported to be the major prey item for ringed seals in northern Alaska in the autumn and winter seasons (Lowry *et al.* 1980). According to Lowry *et al.* (1980) the amount of food eaten by ringed seals decreases in late spring and summer. In the same period the volume of polar cod in the diet decreases and benthic crustaceans become the most important food item. Bradstreet and Finley (1983) found polar cod in ringed seal stomachs collected throughout the year in the Canadian high Arctic. In our study, polar cod and Arctic cod were key components in the ringed seal diet for most of the year in Northwest Greenland and in East Greenland, but their importance in the diet was replaced by more boreal species in central and Southwest Greenland.

The ringed seals from Kangaatsiaq foraged on juvenile cephalopods. Kristensen (1984) reported that juvenile cephalopods, *Gonatus fabricii*, hatch in the early spring in the Davis Strait. A large number of small redfish were found in stomach samples from both Kangaatsiaq and Qeqertarsuaq. Redfish normally prefer water depths of 150 to 500 metres. They can however appear in more shallow waters if the sea temperature is suitable (J.J. Engelstoft, Greenland Institute of Natural Resources, pers. comm.). The capelin, a pelagic shoalfish, which prefers water depths from the surface down to 200 metres (Anon. 1985), was present in considerable numbers in samples from Qeqertarsuaq and further south.

Gjertz and Lydersen (1986) found that Cottidae was the second most common fish prey for ringed seals in northwestern Spitsbergen. This was also observed by McLaren (1958) in Ungava Bay, eastern Canada, and in our study in Kong Oscars Fjord, East Greenland. In West Greenland, however, Cottidae is not an important prey (see also Vibe 1950), and the difference is probably explained by the availability of Cottidae in relatively shallow fjords and bays, whereas ringed seals from the open more oceanic West Greenland coast have better access to pelagic species.

Samples collected using different hunting methods in Upernavik represent different ecological niches for the ringed seals. Seals from the ice edge mainly feed on Arctic cod, whereas the main prey of open water seals was polar cod. At northeastern Baffin Island seals, whales and marine birds all forage on polar cod at the ice edge, although both polar cod and Arctic cod remains were found in the stomachs of four ringed seals shot at the ice edge (Bradstreet and Cross 1982).

The samples from Uummannaq covered all seasons except summer. *Parathemisto* spp., *Liparis* spp. and euphausiids were the most important prey items, but there was some evidence of seasonal changes in the diet. The importance of *Parathemisto* spp. seemed to decrease during early spring as the importance of euphausiids increased during the same period. Many species of zooplankton, including euphausiids and hyperiid amphipods, have patchy distribution. *Parathemisto* spp. is known to form dense swarms during breeding in early spring and they could be easy food for ringed seals (Dunbar 1941). In this study the increasing presence of euphausiids during spring suggests that they at that time are more available food for ringed seals than *Parathemisto* spp.

The biology of *Liparis* spp. is almost unknown but apparently they are present in the ringed seal diet in large numbers in late autumn and almost disappear when the ice is formed in January. Similarly not much is known about *Lycodes* spp. But they are obviously taken by ringed seals in East Greenland. Both *Liparis* spp. and *Lycodes* spp. are reported from ringed seals from Svalbard (Weslawski *et al.* 1994).

Lowry *et al.* (1978) found no clear time-, sex-, or age-related differences in the ringed seal diet. In this study samples from Avanersuaq and from the ice edge in Upernavik showed no age-related differences in diet. Samples from the open water catch in Upernavik, however, showed that younger seals took relatively more crustaceans than adult seals. The decline in importance of crustaceans with age is in accordance with Bradstreet and Finley's (1983) observations from Canada but the pattern was not as clear as in ringed seals collected in Alaskan waters (Lowry *et al.* 1980).

It appears from our study that ringed seals in West Greenland concentrate their predation on shoaling prey, which is probably also the most abundant and easily available prey species. This is also in accordance with several other studies (e.g. McLaren 1958, Fedoseev 1965). Based on the knowledge that ringed seals feed on a variety of organisms representing several trophic levels, McLaren (1958) concluded that "food is not likely a limiting factor in the local distribution and numbers of the seal." Lowry *et al.* (1980), however, emphasised the role of food availability in influencing the movement of ringed seals. Certainly if ringed seals preferentially seek blooms of shoaling prey and they utilise a low number of species this will determine their movements since they will have to search for concentrations of prey.

ACKNOWLEDGEMENTS

The study was financed by the Commission for Scientific Research in Greenland (Kommissionen for Videnskabelige Undersøgelser i Grønland), the Danish Natural Science Council, the Greenland Institute of Natural Resources and the Department of Arctic Environment (National Environmental Research Institute). We would like to thank R. Dietz, E.W. Born, L. Brünner and L. Reimers who organised or participated in the sampling in Avanersuaq, Kangaatsiaq, Nanortalik, Qeqertarsuaq, Upernavik and Uummannaq (1987). R. Dietz and C.O. Nielsen estimated the age of the seals. We also thank K.R. Nielsen and M. Hammill for comments and criticism of the report. We are indebted to the Inuit hunters for their support and assistance in this study.

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