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Diet of Harp Seals (*Phoca groenlandica*) in Divisions 2J and 3KL During 1991–93

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Abstract

An understanding of geographical and seasonal variations in diet and distribution is necessary before an estimate of the impact of seals on commercial fish species can be made. The diet of harp seals (*Phoca groenlandica*) in Div. 2J and 3KL was determined by reconstructing the contents of 588 prey-containing stomachs recovered from 1991 to 1993. Although preliminary, this study showed that there was considerable seasonal, geographical and interannual variation in the diet of harp seals in Div. 2J and 3KL. Geographical differences were observed among inshore harp seals; based on wet weight, sculpins (Cottidae) were the major component of the diet of seals in Div. 2J (although prevalence was small), whereas Arctic cod (*Boreogadus saida*), Atlantic herring (*Clupea harengus*), shrimp (*Pandalus* sp.) and squid were the major prey in harp seals from Div. 3KL. While Arctic cod was the major prey consumed in both summer and winter, herring and squid gained importance for harp seals during the summer as these prey species moved inshore. There was also evidence of interannual variation in the diet, with harp seals depending more heavily on crustacean prey in 1992 than in 1991. Atlantic cod was not a major component of the diet in these areas.

Except in two stomachs from samples collected during April 1992, Atlantic cod was not found in the stomachs of offshore seals collected in areas without commercial cod trawlers during 1992 and 1993. While cod were the predominant prey of harp seals caught in the nets of cod-directed trawls, the size classes of cod found in the stomachs were similar to, or smaller than, cod discarded by the trawlers.

Key words: *Boreogadus saida*, capelin, *Gadus morhua*, hooded seals, Newfoundland

Introduction

Pinnipeds are among the largest carnivores in marine ecosystems and therefore may be significant predatory components of marine ecosystems (e.g. Laws, 1977). In spite of this potential importance in marine ecosystems relatively little quantitative data are available on the diets of many marine mammals.

In northeastern Canada, harp seals (*Phoca groenlandica*) inhabit coastal and offshore waters from the Gulf of St. Lawrence to the southern Arctic (Finley *et al.*, 1990; Sergeant, 1965). Based on estimates of pup production, Shelton *et al.* (MS 1992) estimated that the total population in the Northwest Atlantic in 1990 was approximately 3.1 million. Thus, the harp seal has been assessed as a predominant mammalian piscivorous predator in the area.

Assessing the potential impact of harp seals as predators is difficult since they possess a broad spectrum in diet which varies seasonally and geographically. To date, our knowledge of the diets of harp seals in eastern Canada has been based on stomach content analyses (for a review of the literature on harp seal diet see Wallace and Lavigne, 1992). Most studies have used a variety of non-comparable methods, most commonly, frequency of occurrence. This has been calculated as either the proportion of stomachs which contain a particular prey or the overall numbers of each prey species present. Although frequency of occurrence has the advantage of computational simplicity, it does not provide information about the amount of each species in a stomach or the size of the prey consumed (Bowen *et al.*, 1993). Records of length and weight of prey provide the best means to determine which prey are satisfying the energy requirements of the seals, while simple occurrence frequencies may overestimate the importance of numerous small prey in the diet while underestimating the contribution of larger, less common items (Bigg and Fawcett, 1985). Further, since studies have often reported diet composition in different seasons or locales using dissimilar measures, it has been difficult to estimate the relative significance of different prey items in the seasonal intake of harp seals (e.g. Finley *et al.*, 1990).

In this paper we have begun to assess the relative contributions of prey species by estimating their sizes as reconstructed from otoliths and other hard parts recovered from harp seal stomachs. Preliminary analyses are presented of harp seal diets in Div. 2J and 3KL from 1991 to 1993, in summer and winter for inshore and offshore areas. It is noted that previous studies have primarily relied on samples collected in inshore areas. Little is known about the diet of harp seals in offshore areas, although seals are known to feed some distance from shore, particularly during the winter and spring (Sergeant, 1973; Stenson and Kavanagh, unpublished data). It is noted that stomach samples from offshore areas are difficult to obtain, and have not produced data used in most previous diet reconstructions (e.g. Finley *et al.*, 1990; Murie and Lavigne, 1991; Sergeant, 1973). In this study we were able to obtain samples from both inshore and offshore areas.

Methods

The stomachs of 645 harp seals were examined from animals collected in inshore and offshore waters around Newfoundland and Labrador (Div. 2J, 3K and 3L) from 1991 through to the spring of 1993 (Table 1). Seals were obtained using five methods: inshore net, inshore shot, offshore net by-catch, offshore trawl and offshore shot. Seals were collected during most months of the year, although fewer were recovered during the summer to reflect these seals' annual migratory pattern. The samples collected between April and September were designated as "summer" samples and those taken between October and March as "winter" samples. No effort was made to focus on the sex or age of seals killed, nor on the time of day they were collected. All sampled seals were sexed, and two age groups were used in the analyses: pups as 0-group up to age 1 year, and older seals aged 1+ years.

In the field, each stomach was ligated and removed from the seal soon after death, and frozen at –20°C. At analysis, the whole stomachs were thawed and weighed on an electronic balance to the nearest 0.1 g. Each stomach was then placed in a large tray to prevent loss of contents. If present, whole prey items were removed, weighed to the nearest 0.1 g and measured to the nearest 1.0 mm (fork length in teleosts, or total length in cephalopods). Saggital otoliths were removed from intact fish skull cases. Cephalopod beaks were removed from the buccal capsules of whole squids. All hard parts were stored dry. Free otoliths, squid beaks, and small invertebrate prey were recovered by visual inspection, after washing the stomach contents with fresh water through a stack of three to four sieves of decreasing mesh sizes. Previous work has demonstrated that over 90% of otoliths are recoverable using this method (Murie and Lavigne, 1985). After the contents were removed, the empty stomach was again weighed to determine the wet weight of the contents. To facilitate comparison of the diets of the harp and hooded seals in offshore areas, we reconstructed prey frequencies and weights from intestine contents rather than stomachs since few of the hooded seal stomachs contained prey.

Whole fish were identified to species level. Where only otoliths were recovered, the fish species were identified by comparing recovered otoliths to reference material collected in waters around Newfoundland, or to a published otolith identification key (Härkönen, 1986). The total number of recovered otoliths of each species was used to calculate the number of individual prey in each stomach. If left and right otoliths could be distinguished, the side with the greater number was used to

TABLE 1. Season, collection method and number of harp seal stomachs (n = 645) recovered from Div. 2J and 3KL in 1991 and 1992.

Division	Season	Sampling method	No. of seals collected
2J (inshore)	Summer	Shot	8
	Winter	Net	60
3KL (inshore)	Summer	Shot	113
		Net	18
		Unknown	3
	Winter	Shot	132
		Net	22
3KL (offshore)	Summer	Shot	5
		Net	65
		Offshore trawl	2
	Winter	Shot	99
		Offshore trawl	118

determine the number of prey eaten. Where it was not possible to distinguish between left and right otoliths, the number of individuals consumed was estimated by dividing the total number of otoliths by two.

Only otoliths with minimal or no erosion were used to estimate the size of prey consumed. Degree of erosion was determined by comparing the surface and edge features of the recovered otolith with those in the reference collections. Otoliths which had complete surface detail, and whose margins displayed a similar degree of topography to reference material were measured to the nearest 0.1 mm using vernier calipers (otoliths longer than 5 mm) or an Apple Macintosh™-based image analysis system (fragile otoliths and those shorter than 5 mm). In most species, measurements were taken from the rostrum to the posterior edge of the otolith, parallel to the sulcus. Greenland halibut (*Reinhardtius hippoglossoides*) otoliths were measured across the widest chord.

Squid were identified by comparing either intact individuals, when present, or the upper beaks to published descriptions (Dawe, 1988; Lilly and Osborne, MS 1984). The number of squid consumed was assumed to be equal to the number of the more numerous beak halves. Whole squid beaks were measured if they were intact and showed no erosion. Squid beaks were measured from the tip of the beak to the base of the hood (*Illex* sp.) or from the tip to the margin angle (*Gonatus* sp.).

Length and wet weight of fish and squid were estimated from regressions relating these two measures to otolith or beak dimensions, respectively. The total biomass of prey in a stomach was estimated by summing the estimated wet weights of all prey items found therein. To estimate the biomass represented by eroded otoliths, it was assumed that eroded otoliths of each species were originally the same size as the average of the uneroded measured otoliths in that stomach. The number of prey items with eroded otoliths in each stomach was then multiplied by the average length and weight determined from uneroded otoliths of the same species. Estimated energy density (Joules per wet weight (g)) values for each prey were taken from literature (Anon., 1969; Croxall and Prince, 1982; Griffiths, 1977; Hislop *et al.*, 1991; Hodder *et al.*, 1973; Liem, 1943; Montevecchi and Piatt, 1984; Steimle and Terranova, 1985), or obtained from proximal content analyses performed at the Canadian Department of Fisheries and Oceans, Inspection Section laboratories in St. John's, Newfoundland.

Results

Inshore diet

Proportion of stomachs containing food. Most (86.5%) of the 356 inshore harp seal stomachs contained prey remains (Table 2). The proportion was not significantly different between 1991 and 1992 (Chi square = 0.26, df = 1, $\rho = 0.6$), or between summer and winter (Chi square = 0.78, df = 1, $\rho = 0.38$).

Seals recovered from Div. 2J had a statistically similar (Chi square = 3.5, df = 1, $\rho = 0.06$) proportion of prey-containing stomachs to Div. 3KL. A similar proportion (Chi square = 0.12, df = 1, $\rho = 0.73$) of female harp seals had stomachs containing prey as males. All four 0-group seals (pups) had prey in their stomachs in comparison to 86.3% of 1+ aged seals.

Composition of the diet. There was little difference in the mean number of prey types which were found in prey-containing stomachs from inshore areas between years (1991 = 2.53 species/stomach; 1992 = 2.58 species/stomach), seasons (summer = 2.61 species/stomach; winter = 2.52 species/stomach) or age classes (0-group = 2.25 species/stomach; 1+ = 2.57 species/stomach). The suites of prey consumed by males and females were similar.

TABLE 2. The number and percentage of harp seal stomachs containing prey recovered from inshore areas of Div. 2J and 3KL described under different criteria.

Group	No. of stomachs	Percentage of stomachs containing prey
1991	224	83.9
1992	132	90.9
Summer	141	93.6
Winter	215	81.8
Div. 2J	68	67.2
Div. 3KL	288	90.7
Males	156	84.0
Females	200	88.5
1+Seals	351[a]	86.3
Pups	4	100.0
Overall	356	86.5

[a] One seal was of unknown age.

More than 30 prey were identified to the genus or species level (prey species) from the 308 food-containing harp seal stomachs collected in Div. 2J and 3KL (Table 3). Most numerous were Arctic cod, capelin, Teuthoid squid, other cod species, Atlantic herring and the *Pandalus* shrimp. Prey species found in more than 10% of prey-containing stomachs included Arctic cod (57.1% of stomachs), capelin (28.9%), *Pandalus* shrimp (24.0%), Atlantic herring (17.9%), Hyperiid crustaceans (16.2%), *Thysanoessa* sp. (euphausiids, 14.9%), Atlantic cod (11.4%) and *Liparis* sp. (10.1%).

TABLE 3. Estimated numbers and percent frequency of occurrence of prey in harp seal stomachs recovered from inshore areas of Div. 2J and 3KL in 1991 and 1992.

Prey species	Number	Percent frequency of occurrence[a]
Atlantic Herring (*Clupea harengus*)	273	17.9
Capelin (*Mallotus villosus*)	1 628	28.9
Lanternfish (Myctophidae)	1	
Gadoid	24	3.6
Gadus sp.	106	6.5
Atlantic Cod (*Gadus morhua*)	123	11.4
Rock Cod (*Gadus ogac*)	12	
Arctic Cod (*Boreogadus saida*)	3 268	57.1
Sand Lance (*Ammodytes dubius*)	88	3.9
Fourline Snakeblenny (*Lumpenus medius*)	3	
Blenny	1	
Shanny (*Lumperus maculatus*)	8	
Eelpout	88	8.8
Arctic Eelpout (*Lycodes reticulatus*)	10	
Redfish (*Sebastes marinus*)	1	
Sculpin (Cottidae)	37	1.6
Shorthorn Sculpin (*Myoxocephalus scorpius*)	1	
Long-horned Sculpin (*M. octodecemspinosus*)	3	
Liparis sp.	75	10.1
Righteye Flounder (*Pleuronectidae*)	17	3.2
American Plaice (*Hippoglossoides platessoides*)	13	
Greenland Halibut (*Reinhardtius hippoglossoides*)	12	1.3
Unknown Fish	41	6.2
Illex illecebrosus (squid)	14	1.3
Teuthoidea (squid)	331	9.7
Gonatus fabricii (squid)	1	
Hyperiidae (crustacean)	37	16.2
Mysidae (mysid)	2	
Mysis sp. (mysid)	1	
Euphausiacea (euphausiid)	5	
Meganyctiphanes norvegica (euphausiid)		
Thysanoessa sp. (euphausiid)	24	14.9
Natantia (shrimp)	19	4.5
Hippolytidae (shrimp)	1	
Eualus sp. (shrimp)	1	
Eualus fabricii (shrimp)	14	
Eualus macilentus (shrimp)	51	6.5
Spirontocaris spinus (shrimp)	5	
Lebbeus polaris (shrimp)	1	
Pandalus sp. (shrimp)	87	8.4
Pandalus borealis (shrimp)	34	1.3
Pandalus montagui (shrimp)	61	14.3
Crangonidae (shrimp)	1	
Argis dentata (shrimp)	11	3.2
Hyas sp. (crab)	7	
Birds	1	
	6 542	800

[a] As a percentage of the 308 prey-containing stomachs.

Six prey species (Arctic cod, herring, *Pandalus* shrimp, sculpin, Teuthoid squid and capelin) accounted for almost 90% of the estimated wet weight of food eaten in both 1991 and 1992 (Table 4). Atlantic cod contributed only 2.8% of the total wet weight and 2.4% of the total energy intake of these seals.

Contributions by energy were similar to those for wet weight (Table 4), although herring, with its high energy density, was relatively more important in terms of energy provided than weight.

Annual variation in the diet. There was little difference between 1991 and 1992 in the weight of most major prey items consumed by these harp seals (Table 4). Arctic cod was the most important prey species in both years, but contributed almost 20% less in 1992 than in 1991. In its place *Pandalus* shrimp, *Thysanoessa* sp. and capelin contributed relatively more to the total weight of prey consumed in 1992, whereas sculpin and squid contributed substantially less.

Seasonal variation in the diet. Relative contributions, by wet weight, of prey consumed by harp seals in Div. 2J and 3KL during summer and winter were different. Arctic cod was the major component in both seasons, but was more important during the winter (Table 5), as were *Pandalus* shrimp and sculpins. In contrast, herring, capelin and squid were more important to the diet during the summer.

TABLE 4. Estimated minimum, total wet weight (g) and energy (kJ) of prey accounting for 95% of the total weight in prey-containing harp seal stomachs recovered in inshore Div. 2J and 3KL areas during 1991 (n = 188) and 1992 (n = 120).

	1991		1992		Overall			
	Weight	(%)	Weight	(%)	Weight	(%)	Energy	(%)[a]
Arctic Cod	99 169	(57.8)	23 556	(38.0)	122 724	(52.6)	687 254	(52.7)
Atlantic Herring	19 137	(11.2)	8 627	(13.9)	27 764	(11.9)	249 875	(19.2)
Capelin	5 116	(3.0)	5 235	(8.4)	10 352	(4.4)	77 639	(6.0)
Gadus sp.	4 079	(2.4)	68		4 147	(1.8)	19 908	(1.5)
Greenland Halibut	526	(0.3)	2 466	(4.0)	2 992	(1.3)	17 951	(1.4)
Pandalus sp. (shrimp)	4 096	(2.4)	11 143	(18.0)	15 239	(6.5)	60 957	(4.7)
Righteye Flounder	1 354	(0.8)	1 245	(2.0)	2 599	(1.1)	10 914	(0.8)
Sculpin	12 919	(7.5)	14		12 933	(5.5)	69 840	(5.4)
Teuthoidea (squid)	13 490	(7.9)	518	(0.8)	14 007	(6.0)	58 831	(4.5)
Thysanoessa sp. (euphausiid)	775	(0.4)	4 438	(7.2)	5 213	(2.2)	17 724	(1.4)
	171 513.3		61 894.2		233 407.5		1 301 801.2	

[a] Energy percentage values are calculated using only those species listed.

TABLE 5. Estimated minimum, total wet weight (g) of prey accounting for 95% of the total weight in prey-containing 1+ harp seal stomachs recovered in inshore Div. 2J and 3KL areas in summer (n = 132) and winter (n = 176).

	Summer weight	(%)	Winter weight	(%)
Arctic Cod	39 054	(41.1)	83 670	(60.4)
Atlantic Cod	944	(1.0)	5 495	(4.0)
Atlantic Herring	20 717	(21.8)	7 047	(5.0)
Capelin	5 686	(6.0)	4 643	(3.3)
Gadus sp.	1 764	(1.9)	2 383	(1.7)
Greenland Halibut	2 466	(2.3)	526	(0.4)
Pandalus sp. (shrimp)	2 006	(2.1)	13 231	(9.6)
Sculpin	12		12 921	(9.3)
Teuthoidea (squid)	12 137	(12.8)	1 870	(1.3)
Thysanoessa sp. (euphausiid)	3 717	(3.9)	1 495	(1.1)
	94 957.9		138 403.7	

Age and geographic variation in the diet. There were differences in the relative amounts of major prey species consumed in different geographic regions (Table 6). The age 1+ seals consumed different relative masses of prey species in Div. 2J and 3KL. Sculpins were the major prey item in seals in Div. 2J, with the cod species (other than Atlantic and Arctic) providing a smaller proportion of total prey weight. The cod accounted for 11.4% of prey weight, but were small in size (mean length = 15.6 cm). Despite their contribution to the total weight of prey consumed, sculpins were found in only 1.6% of prey-containing stomachs (Table 3).

Arctic cod provided most of the prey mass eaten by the age 1+ seals in Div. 3KL (57%). These older seals consumed herring, shrimp and squid to a lesser extent. Atlantic cod represented less than 0.1% of the total weight of prey consumed.

Small sample size (n = 4) necessitates caution when examining the age 0-group diet (Table 6). However, it was noted that these pups had consumed small prey consisting of capelin and invertebrates.

Offshore diet

A total of 232 prey-containing stomachs recovered from harp seals in offshore areas of Div. 2J and 3KL were examined (Table 7). The samples were divided into four groups: seals shot during directed research cruises (MV *Brandal*), offshore shot recoveries, offshore gillnets and from seals caught during commercial trawling operations.

Although the locations of these samples were similar, the timing of the samples varied; the MV *Brandal* samples were collected from Department of Fisheries and Oceans, St. John's, Newfoundland, sampling zones (Numbers 326, 330 and 346) in February, the offshore trawl samples from zones 325, 330, 332, 343 and 346 in January and February, the offshore shot samples from zones 330, 343, 345, 346, 347 in April and the gillnet samples from zones 328, 330, 333, and 346 in April to July.

Proportion of stomachs containing food. As in the case of the inshore samples, most (80.3%) of the 288 offshore harp seal stomachs contained prey remains. This proportion was not significantly different among the recovery sources: MV *Brandal* cruise (64.1%), offshore gillnet (87.7%), offshore trawl (92.4%) and offshore shot recoveries (61.5%) (Chi square = 4.98, df = 3, ρ = 0.17).

Composition of the diet. On average, there were fewer prey species found in prey-containing stomachs from offshore areas than inshore (MV *Brandal* = 1.8 species/stomach; offshore gillnet = 2.1 species/stomach; offshore trawl = 1.24 species/stomach; offshore shot = 1.4 species/stomach).

Capelin was by far the most important prey component of harp seals taken on the MV *Brandal* cruise (85.8% of weight; Tables 7 and 8). Sand lance, righteye flounder and capelin accounted for most of the prey weight consumed by harp seals recovered from offshore gillnets. No Atlantic cod were found in either of these recovery methods.

TABLE 6. Number (N) and estimated wet weight (g) of prey species accounting for 95% of total, reconstructed wet weight of prey-containing harp seals (n = 307)[a] recovered in inshore Div. 2J and 3KL areas.

	Age 1+ Seals				0-Group Seals	
	2J		3KL		3KL	
	N	Weight (%)	N	Weight (%)	N	Weight (%)
Arctic Cod	77	794 (4.1)	3 167	121 930 (57.0)		
Atlantic Cod	6	895 (4.7)	117	5 544		
Atlantic Herring			273	27 764 (13.0)		
Capelin	192	1 087 (5.7)	1 417	9 243 (4.3)	1	22.0 (48.4)
Other Cod	14	2 187 (11.4)	92	1 960 (0.9)		
Eelpout					1	2.4 (5.3)
Euphausiacea (euphausiid)						14.9 (32.7)
Hyperiidae (crustacean)					1	4.3 (9.4)
Pandalus montagui (shrimp)	8	7.4	53	14 841 (6.9)	5	1.9 (4.2)
Righteye Flounder	1	113	16	2 486 (1.2)		
Sculpin	34	12 919 (67.2)	3	14.0		
Teuthoidea (squid)			331	14 007 (6.5)		
Other Fish[b]		610 (3.2)		12 878 (6.0)		
Other Invertebrates[b]		263 (1.4)		8 589 (4.0)		
	42 stomachs	19 215.3	261 stomachs	213 899.4	4 stomachs	45.5

[a] The age of one seal was undetermined.

[b] These include all prey items not listed above.

TABLE 7. Number, estimated wet weight (g) and mean length (cm) of prey types accounting for 95% of total, reconstructed wet weight of prey-containing harp seals (n = 232) recovered from offshore areas, 1991 and 1993 (n = the number of stomachs containing prey).

	MV *Brandal* Cruise shot recoveries (n = 25)		Offshore gillnet recoveries (n = 57)		Offshore trawl recoveries (n = 110)		Offshore shot recoveries (n = 40)	
Prey type	Weight (%)	Length (SE)	Weight (%)	Length (SE)	Weight (%)	Length (SE)	Weight (%)	Length (SE)
Atlantic Cod					377 511 (97.0)	35.2 (0.3)	4 730 (45.2)	40.8 (1.1)
Capelin	24 003 (85.8)	13.0 (0.1)	8 540 (21.0)	9.5 (0.1)	335 (0.1)	9.7 (0.1)	83	12.9 (1.0)
Redfish					1 191 (0.3)	26.6 (1.1)		
Righteye Flounder	1 483 (5.3)	23.1 (3.6)	11 003.1 (27.1)	19.2 (1.2)	556 (0.1)	19.6 (1.6)	107 (1.0)	27.3 (–)
Sand Lance			19 668 (48.4)	13.2 (0.4)		13.2 (0.2)		
Teuthoidea (squid)	299 (1.1)	21.3 (2.9)			4 163 (1.1)	20.4 (4.7)	4 963 (47.4)	30.3 (4.6)
Hyperiidae (Crustacean)	16		1		210 (0.05)		489 (4.7)	
Other Fish[a]	1 935 (6.9)		384 (0.9)		4 072 (1.0)		8.9	
Other Invertebrates[a]	230 (0.8)		27 (0.07)		176 (0.04)		80 (0.8)	
	27 965.0		40 638.0		388 213.6		10 469.6	

[a] These include all prey items not listed above.

TABLE 8. Estimated number (N), frequency of occurrence (%) and wet weight (g) of prey in the diets of harp and hooded seals reconstructed using intestine contents recovered during MV *Brandal* offshore cruise, February 1993.

	Number of prey				Frequency of occurrence		Wet weight of prey			
	Harp		Hooded		Harp	Hooded	Harp		Hooded	
Prey Species	N	%	N	%	(29 Intestines)	(9 intestines)	Weight	%	Weight	%
Arctic Cod	3	0.4			6.9		15.0	0.2		
Atlantic Cod			12	18.2		33.3			2 420.7	37.4
Blue Hake			2	3.0		11.1			490.0	7.6
Capelin	639	89.0	4	6.1	93.1	55.6	5 473.9	89.6	52.0	0.8
Common Grenadier			8	12.1		11.1				
Greenland Halibut	12	1.7	3	4.5	17.2	22.2	450.9	7.4	85.2	1.3
Hookear Sculpin	13	1.8			3.4		35.3	0.6		
Liparis sp.	1	0.1			3.4		1.2	0.02		
Redfish	1	0.1	4	6.1	3.4	22.2	11.5	0.2	454.5	7.0
Righteye Flounder	2	0.3	1	1.5	6.9	11.1	3.3	0.1	209.0	3.2
Scaled Lancetfish	2	0.3			6.9					
Vahl's Eelpout	1	0.1			3.4		51.0	0.8		
Witch Flounder			12	18.2		22.2			1 771.6	27.4
Unknown			1	1.5		11.1				
Hyperiidae (crustacean)	10	1.4			24.8					
Illex sp. (squid)	14	1.9	19	28.8	17.2	44.4	66.3	01.1	988.8	15.3
Natantia	2	0.3								
Pandalus sp. (shrimp)	18	2.5			34.5					
		718		66				6 108.5		6 472.0

In contrast, harp seals caught in the nets of offshore trawls directed towards cod in Div. 2J and 3KL consumed Atlantic cod almost exclusively, by wet weight (97%). Squid (47.4%) and Atlantic cod (45.2%) were the most important prey, by weight, in seals shot as part of other offshore recoveries (Table 7).

Figures 1 and 2 illustrate the length-frequency distributions of Atlantic cod caught by commercial trawlers originating from Newfoundland ports during January and February 1991 and 1992 (Fig. 1A and 2A), and the length of cod in the stomachs of harp seals caught by these vessels (Fig. 1C and 2C). The commercial trawl catches contained cod between 25 and 82 cm in length and the discards consisted of cod between 25 and 55 cm in length.

In both 1991 and 1992 the Atlantic cod found in harp seal stomachs (Fig. 1C and 2C) were similar in size to those discarded by the trawlers, or smaller (Fig. 1B and 2B). While there were few cod found in inshore harp seals, their sizes were smaller than those taken in the commercial fishery (Fig. 2D).

To determine if the lack of Atlantic cod in the stomachs of seals from the MV *Brandal* cruise was due to the unavailability of cod to the seals, the intestinal contents of harp and hooded seals recovered in the same area were compared, and it was found that the latter species were finding Atlantic cod to eat (Table 8). In fact, Atlantic cod accounted for a major percentage of the total weight of prey consumed (37.4%) by hooded seals (and to a lesser extent witch flounder, squid and blue hake). Harp seals taken in the same area were relying almost exclusively on capelin (89%) as food.

Discussion

It is necessary to assess the degree of variation in diet and distribution of harp seals before an estimate of their effect on commercial fish species can be made. This preliminary study shows that there are seasonal, geographical and interannual variation in the diet of harp seals in Div. 2J and 3KL.

While most harp seals in this study had prey remains in their stomachs, this should not be extrapolated to include the entire year. Samples for this study were not taken during breeding or moulting periods when harp seals normally fast (Ronald and Healey, 1981), as stomach samples taken during these times are more likely to be empty. The samples taken from moulting animals in the offshore shot analyses, which had empty stomachs, were also not included in the analyses.

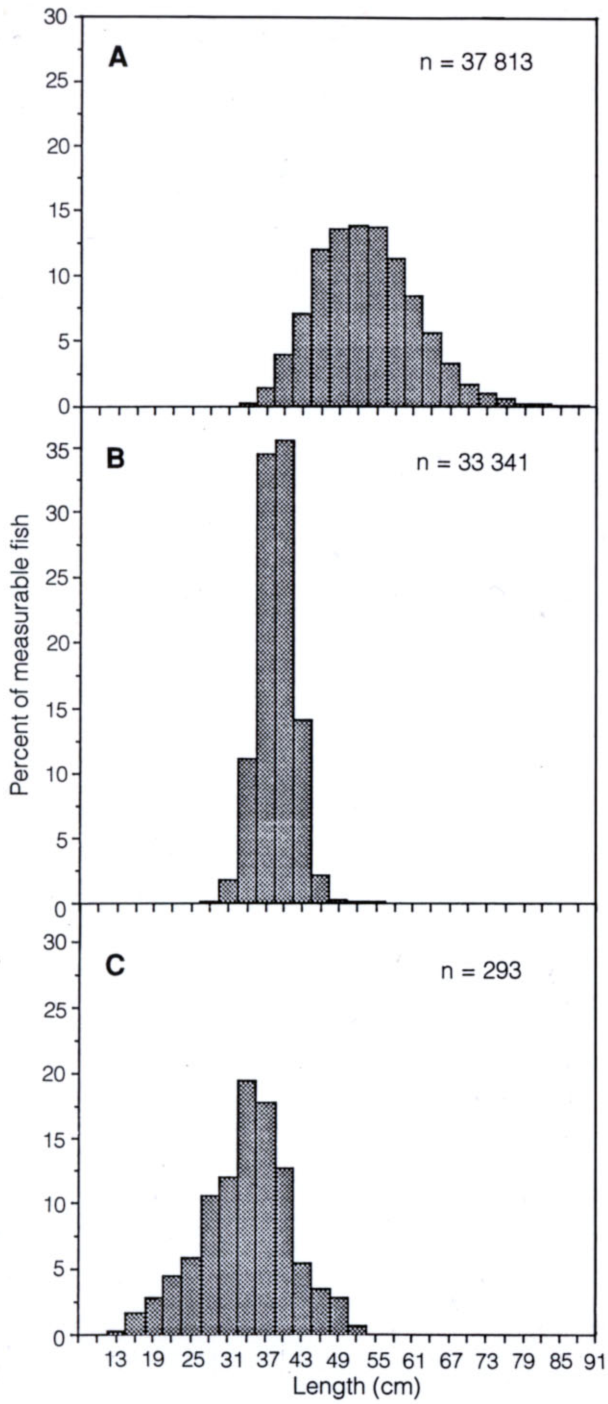

Fig. 1. Length-frequency distributions of Atlantic cod, Div. 2J and 3KL, 1991. (**A**) caught by commercial trawlers (Div. 3KL), (**B**) discarded by commercial trawlers (Div. 3KL), and (**C**) contained in stomachs of harp seals caught in nets offshore. (n = the number of cod measured.)

As has been found in previous studies of seals (e.g., Wallace and Lavigne, 1992), harp seals taken inshore in Div. 2J and 3KL had consumed a variety of prey. By far the most important prey species by prevalence, weight or energy, was Arctic cod (*Boreogadus saida*). These results are similar to studies of harp seals in the Northeast Canadian Arctic (Finley *et al.*, 1990), Northwest Greenland (Kapel and Geisler, MS 1979) and the Southeast Canadian Arctic (Sergeant, 1973; Sergeant, 1991). Atlantic herring was also a significant component of the diet, but primarily during the summer.

There was some difference between 1991 and 1992 in the importance of major prey species consumed by harp seals in inshore areas. Arctic cod was the most important in both years, but contributed almost 20% less in 1992 than in 1991. The *Pandalus* shrimp, *Thysanoessa* sp. (euphausiid) and capelin contributed relatively more to the total weight of prey consumed in 1992, while sculpin and squid contributed less. Atlantic cod and herring were of similar importance in both years. Larger sample sizes, data from more years and better information of fish populations will be necessary before we can determine if these dietary changes are based on alterations of prey stock abundance or distribution.

While Arctic cod was the major prey consumed in both summer and winter, herring and squid gained importance for harp seals during the summer as these prey species moved inshore. This may represent a shift by harp seals to locally abundant, schooling prey, or prey which are more energy rich, as is the case for herring which move inshore to spawn.

Geographical differences were observed among harp seals recovered from inshore areas, however, particularly the preponderance of sculpin by weight in Div. 2J should be viewed with caution. The 34 large sculpin which accounted for 67% of the prey weight consumed, were recovered from only four age 1+ seals (which represented only 9.5% of the prey-containing stomachs). This discrepancy between the relative frequency and weight measures in Div. 2J illustrates a weakness in diet reconstruction from stomach contents: small sample sizes can produce deceptive results. Thus, while Arctic cod, herring, *Pandalus* shrimp and squid were the major prey of harp seals in Div. 3KL, more samples should be analyzed before credible comparisons can be made between Div. 2J and 3KL.

Similarly, with only four 0-group harp seals present in our samples, it was not feasible to make firm conclusions about age differences in harp seal diet. However, it appeared (Table 4) that pups were eating smaller prey than older seals, with a greater reliance on invertebrates, as documented previously by Sergeant (1973).

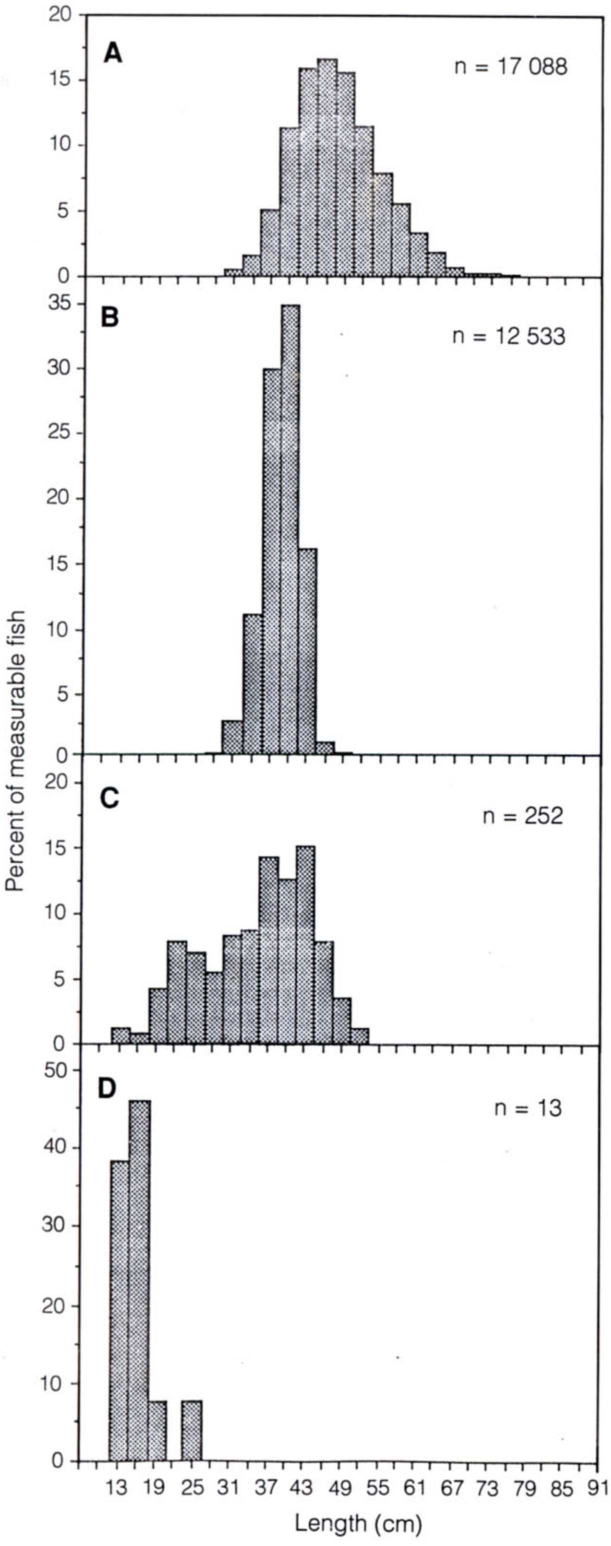

Fig. 2. Length-frequency distributions of Atlantic cod, Div. 2J and 3KL, 1992. (**A**) caught in commercial trawlers (Div. 3KL), (**B**) discarded by commercial trawlers (Div. 3KL), (**C**) contained in stomachs of harp seals caught in nets offshore, (**D**) contained in stomachs of harp seals caught inshore. (n = number of cod measured.)

Our results suggest that Atlantic cod was a relatively minor component of the diet of harp seals in inshore areas of Div. 2J and 3KL. This is similar to the findings of other studies which also examined seals caught primarily in inshore areas (e.g., Foy *et al*., 1981; Murie and Lavigne, 1991; Sergeant, 1973; Sergeant, 1991; Wallace and Lavigne, 1992). The cod in the stomachs in this study were generally small.

This study represents the first time seals from offshore areas were examined. The importance of cod to seals in offshore areas was difficult to estimate due to the small sample sizes and variation in diet among seasons, and/or method of recovery. For example, seals taken in offshore trawls contained almost exclusively Atlantic cod, while seals collected in the same area during the winters of 1992/93 contained none. The distribution of size classes of cod found in seals caught by trawlers, and anecdotal reports of harp seals feeding on discarded cod, suggests that the high prevalence of cod in these stomachs may, in part, be due to harp seals feeding on discarded fish. This would overemphasise the importance of cod if applied to the population as a whole.

The absence of Atlantic cod in the MV *Brandal* cruise samples does not appear to be due to the unavailability of cod in the area. Hooded seals were feeding on Atlantic cod in this area while harp seals were apparently eating other species. Surveys of offshore waters conducted in conjunction with groundfish hydroacoustic surveys indicated that harp seals were abundant in this area (Div. 3KL border) during February of 1992 and 1993, whereas high densities of cod were present in 1992 only (Stenson and Kavanagh, unpublished data). Therefore harp seals may not be present in this area simply to feed on pre-spawning concentrations of Atlantic cod.

No Atlantic cod were found in the stomachs of harp seals taken in gillnets, while they comprised a major portion of the diet of seals shot in offshore areas (Table 7). However, these cod were present in only two adult females which represented a small proportion (5%) of the stomachs recovered using this method. This again points out the potential effects that sample variation can have within a small sample. Further offshore sampling will permit us to determine if these two females, like the four stomachs containing scuplin from seals in Div. 2J (Table 6), accurately represent the diet of the population.

Although reconstruction of stomach contents allowed us to estimate the size of prey consumed, there are limitations. Stomach content reconstruction assumes that seals eat the heads (and therefore otoliths) of their prey. If this is not the case, the prey consumption will be underestimated and the size range misrepresented. While this may be happening, it is known harp seals can and do eat whole, large cod to at least 53 cm in length. Also, the rate of digestion of otoliths may be related to their size; smaller otoliths may be eroded more than those from larger fish. This effect would tend to yield a skewed size distribution with the lengths of smaller fish being underestimated to a greater degree than those of larger fish. Sampling of seals in areas where there are fish of known size, may indicate if there is a prey size preference.

Although preliminary, these studies show that there is seasonal, geographical and interannual variation in the diet of harp seals. However, in light of this variation and the relatively small sample sizes available from some areas, our limited knowledge concerning spatial overlap between seals and their prey, and the ongoing nature of these studies, we cannot make a clear assessment of the harp seal's impact on Atlantic cod stocks at this time.

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References

ANON. 1969. United States – Canadian tables of feed composition. Subcommittee on Feed Composition, National Academy of Sciences, 1684.

BIGG, M. A., and I. FAWCETT. 1985. Two biases in diet determination of northern fur seals (*Callorhinus ursinus*). *In*: Marine Mammals and Fisheries, J. R. Beddington, R. J. H. Beverton and D. M. Lavigne, (eds.), p. 284–291. Massachusetts: George Allen and Unwin Ltd.

BOWEN, W. D., J. W. LAWSON, and B. BECK. 1993. Seasonal and geographic variation in the species composition and size of prey consumed by grey seals (*Halichoerus grypus*) on the Scotian Shelf. *Can. J Fish. Aquat. Sci.*, **50**: 1768–1778.

CROXALL, J. P., and P. A. PRINCE. 1982. Calorific content of squid (Mollusa: cephalopods). *British Antarctic Survey Bulletin*, **55**: 27–31.

DAWE, E. G. 1988. Length-weight relationships for short-finned squid in Newfoundland and the effect of diet on condition and growth. *Trans. Amer. Fish. Soc.*, **117**: 591–599.

FINLEY, K. J., M. S. W. BRADSTREET, and G. W. MILLER. 1990. Summer feeding ecology of harp seals in relation to Arctic cod in the Canadian high Arctic. *Polar Biology*, **10**: 609–618.

FOY, M. G., D. A. DeGRAAF, and R. A. BUCHANAN. 1981. Harp seal feeding along the Labrador coast, 1979–1981. *Petro-Canada Explorations Ltd*.

GRIFFITHS, D. 1977. Caloric variation in Crustacea and other animals. *J. Anim. Ecol.*, **46**: 593–605.

HÄRKÖNEN, T. J. 1986. Guide to the otoliths of the bony fishes of the northeast Atlantic. Hellerup, Denmark: Danbiu.

HISLOP, J. R. G., M. P. HARRIS, and J. G. M. SMITH. 1991. Variation in the calorific value and total energy content of the lesser sandeel (*Ammodytes marinus*) and other fish preyed on by seabirds. *J. Zool.*, **224**: 501–517.

HODDER, V. M., L. S. PARSONS, G. H. WINTERS, and K. SPENCER. 1973. Fat and water content of herring in Newfoundland and adjacent waters, 1966–71. *Tech. Rep. Fish. Res. Bd. of Can.*, **365**: 49 p.

KAPEL, F. O., and A. GEISLER. MS 1979. Progress report on research on harp and hooded seals in Greenland, 1978–79. *NAFO SCR Doc.*, No. 10, Serial No. N021, 12 p.

LAWS, R. M. 1977. The significance of vertebrates in the Antarctic marine ecosystem. In: Adaptation within Antarctic ecosystems, G.A. Llano (ed.), p. 411–438. Washington: Smithsonian Institution.

LIEM, A. H. 1943. Seasonal variation in the fatness of "sardine" herring. *Fish. Res. Board. Can.*, **34**: 17–19.

LILLY, G. R., and D. R. OSBORNE. MS 1984. Predation by Atlantic cod (*Gadus morhua*) on short-finned squid (*Illex illecebrosus*) off eastern Newfoundland and in the northeastern Gulf of St. Lawrence. *NAFO SCR Doc.*, No. 108, Serial No. N905, 16 p.

MONTEVECCHI, W. A., and J. PIATT. 1984. Composition and energy contents of mature inshore spawning capelin (*Mallotus villosus*): implications for seabird predators. *Comp. Biochem. Physiol.*, **78A**: 15–20.

MURIE, D. J., and D. M. LAVIGNE. 1985. Digestion and retention of Atlantic herring otoliths in the stomachs of grey seals. *In*: Marine Mammals and Fisheries, J. R. Beddington, R. J. H. Beverton and D. M. Lavigne (eds.), p. 292–299. London: Allen and Unwin.

1991. Food consumption of wintering harp seals, *Phoca groenlandica*, in the St. Lawrence estuary, Canada. *Can. J. Zool.*, **69**: 1289–1296.

NETTLESHIP, D. N. 1993. Proximate composition and energy content of prey species of Atlantic Puffin. In prep.

RONALD, K., and P. J. HEALEY. 1981. The harp seal *Phoca groenlandica* (Erxleben, 1777). *In*: Handbook of marine mammals, S. H. Ridgway and R. J. Harrison (eds.), p. 55–88. London, England: Academic Press.

SERGEANT, D. E. 1965. Migrations of harp seals *Pagophilus groenlandicus* (Erxleben) in the Northwest Atlantic. *J. Fish. Res. Board Can.*, **22**: 433–463.

1973. Feeding, growth, and productivity of Northwest Atlantic harp seals (*Pagophilus groenlandicus*). *J. Fish. Res. Board. Can.*, **30**: 17–29.

1991. Harp seals, man and ice. *Can. Spec. Publ. Fish. Aquat. Sci.*, **114**: 153.

SHELTON, P. A., N. G. CADIGAN, and G. B. STENSON. MS 1992. Model estimates of harp seal population trajectories in the Northwest Atlantic. Fisheries and Oceans. *CAFSAC Res. Doc.*, No. 89, 23 p.

STEIMLE, F. W. J., and R. J. TERRANOVA. 1985. Energy equivalents of marine organisms from the continental shelf of the temperate Northwest Atlantic. J. *Northw. Atl. Fish. Sci.*, **6**: 117–124.

WALLACE, S. D., and D. M. LAVIGNE. 1992. A review of stomach contents of harp seals (*Phoca groenlandica*) from the Northwest Atlantic. *International Marine Mammal Association*. 92-03.