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Diet of the harbour seals *Phoca vitulina* of Dundrum Bay, north-east Ireland

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This study has shown that the main constituents of the diet of the harbour seals (*Phoca vitulina*) of Dundrum Bay, County Down, north-east Ireland, during the past few years (1995–2000) have been small flatfish and gadid fish, with the emphasis shifting from the beginning to the end of the study period from flatfish to gadids, principally whiting and haddock/pollack/saithe. During both 1995 and 1996 the diet of post-weaning pups consisted almost entirely of small gadid fish. The implications of this relatively poor diet, apparently deficient in oily fish, are considered—together with information on fish stocks in the north-west Irish Sea in recent years—in the context of an apparent decline both in the breeding population of harbour seals along the County Down coast and in the play behaviour of juvenile seals.

INTRODUCTION

This study of the diet of harbour seals (*Phoca vitulina* L.) in Dundrum Bay was initiated as part of an investigation into the status of the Co. Down population of harbour seals. The size of this population has varied in recent years, but summer counts of 600–700 animals (excluding newborn pups) have been considered as indicating favourable conservation status for the Co. Down coast (Montgomery-Watson, 1999; Wilson & Montgomery-Watson, in press). Since 1989 the number of seals and newborn pups has been declining in the traditional harbour seal stronghold of Strangford Lough (Figure 1; Montgomery-Watson, 1999; Wilson & Montgomery-Watson, in press). The cause of this decline is not yet understood. Human disturbance was considered not to be a major contributing factor (Wilson & Corpe, 1996) and organochlorine contaminants in harbour seal blubber appear to be at the lower end of the range previously reported for harbour seals in Europe (Mitchell & Kennedy, 1992). However, the link demonstrated between local distribution of harbour seals and the proximity of suitable foraging grounds (Thompson, 1993; Thompson et al., 1996) suggested the possibility that a decline in availability of suitable prey species might be contributing to a seal population shift away from the Co. Down coast.

Harbour seal diets on the Co. Down coast have not been described prior to this study. However, the diet of harbour seals has been studied during the past decade in many other parts of the British Isles, including the east coast of England (Hall et al., 1998), the Moray Firth in eastern Scotland (Pierce et al., 1991; Tollit & Thompson, 1996; Thompson et al., 1996), the West of Scotland (Boyle, 1990), Orkney (Pierce et al., 1990) and Shetland (Brown & Pierce, 1997, 1998; Brown et al., 2001). These studies have shown that harbour seals feed on a wide range of both demersal and pelagic species, most often on juvenile inshore fish. Foraging strategies are generally seen to represent a combination of selectivity (e.g. preference for certain size-classes of fish) and opportunism (e.g. taking the most abundant species). In the present study, trawl survey abundance data were available for some fish species in 1995, allowing us to compare the relative importance of different fish species in seal diets and trawl catches. Some of the previous studies have demonstrated both seasonal and inter-annual variation in the dietary constituents. Such changes in diet may have consequences for individual health. Thus, Thompson et al. (1996) showed that the body condition index of harbour seals in the Moray Firth was lower in years when the availability of clupeid fish was low and also demonstrated that the seals may suffer from macrocytic anaemia in such years (Thompson et al., 1997).

There is very little literature specifically on the diet of harbour seal pups during their first few months after weaning, although a few studies have suggested that the pups' diet may differ from that of older seals, and may initially consist of small prey items (Sergeant, 1951; Golitsev, 1972; Bowen, 1991). The quality and quantity of food available to pups is expected to be a critical determinant of local population status, since post-weaning pups failing to find sufficient food in the vicinity of their natal site may either not survive their first few months of independence, or disperse out of the area. There is evidence from seal counts all along the Co. Down coast (S.C. Wilson, unpublished data) that first year pups and older juveniles are less frequently observed compared with the late 1960s. At that time groups of young harbour seals could be observed regularly at several sites, typically engaging in physically energetic locomotor play behaviour beside the haul-out site for one to two hours on each falling tide before hauling out to rest (Wilson, 1974). During the period of the present study groups of young animals were seen regularly only at Minerstown in Dundrum Bay

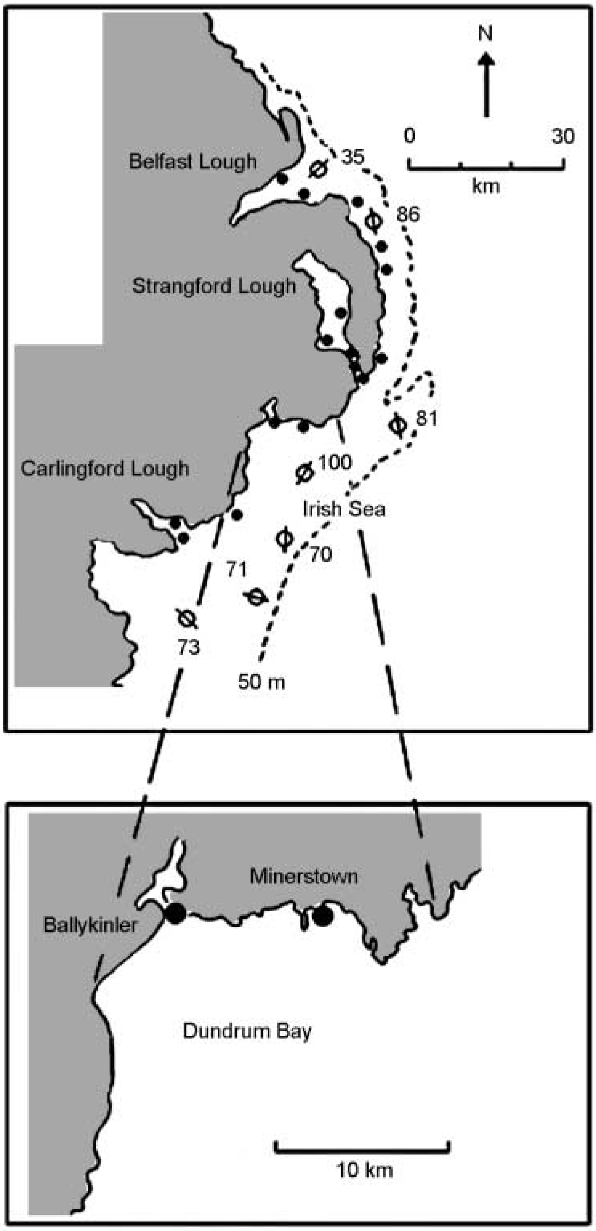

Figure 1. Map of the Co. Down coastline showing major traditional haul-out sites for harbour seals in summer and autumn (closed circle) and detail of the Dundrum Bay haul-out sites, where faecal samples were collected. DARD trawl survey stations with reference numbers are marked by open circles with line denoting trawl track in autumn 1995.

(Figure 1), and even there juvenile play has rarely been recorded in recent years during frequent comparable observation periods during the summer months (S.C. Wilson, unpublished data). These observations suggest the possibility that the decline over the past 25 years in juvenile play at Co. Down haul-out sites might be due to the young seals in recent years having less energy for locomotor play, which might in turn be related to their diet.

Thus, the aims of this study were to describe the diet of harbour seals in Dundrum Bay and to look for evidence of changes in diet between 1995–1996 and 1999–2000, and thereby determine (a) whether low dietary quality is a likely cause for the apparent decline in this population and change in the behaviour of juveniles; and (b) if diet selection could be related to prey availability. Additionally, we compare the diet of post-weaning pups with the general diet.

MATERIALS AND METHODS

The study was carried out by collecting faecal samples and analysing them for the remains of prey species. The two seal haul-out sites, Minerstown and Ballykinler in Dundrum Bay (Figure 1), from which samples were collected (Table 1), were chosen on account of the relative ease of collecting the samples without causing disturbance to the seals. At both sites the seals regularly vacated the site at low tide and the sites could then be easily accessed from the shore. Ballykinler (Figure 1) is a major seal assembly site with up to about 150 seals present in late summer, of which 10–15% have usually been grey seals (Wilson & Corpe, 1996). Minerstown (Figure 1) is a site to which post-weaning pups (probably including pups born at other Co. Down sites) continue to return. It is also an important assembly site for juvenile seals in addition to adults of both sexes. Up to about 50 seals use the site in the summer and autumn (Wilson & Corpe, 1996). Samples were collected both from the main haul-out site ('main colony') and also from a rock ('pup rock') near the high tide mark frequented almost exclusively in autumn and winter by post-weaning pups aged between 3–6 months (Table 1). These samples were analysed separately from the samples taken from the main colony in order to obtain some information on the diet of pups aged 3–6 months. Samples collected from two pups in August 1996 were also included in this data set as well as being described separately.

Each sample was cleaned in a glass vessel in water and detergent and washed through a 1-mm sieve (Prime & Hammond, 1987). All fish and invertebrate remains were collected from the sieve and stored in glass vials, initially in 70% alcohol and then dried. Fish prey items were identified from otoliths, according to a reference collection and guide (Härkönen, 1986). Otoliths were identified to species when possible, although no attempt was made to distinguish between the (very similar) otoliths from haddock (*Melanogrammus aeglefinus*), pollack (*Pollachius pollachius*) and saithe (*P. virens*), or between plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*), or between poor cod (*Trisopterus minutus*) and other *Trisopterus* species, or between different sandeel (Ammodytidae) species. Prey species from the 1995 samples were also identified from bones using a reference guide (Watt et al., 1996).

Fish lengths and weights were estimated from otoliths using the regressions given in Härkönen (op. cit.). No corrections were attempted to allow for diminution of otolith dimensions due to passage through the seal digestive tract; the results will therefore slightly underestimate fish size (Tollit et al., 1997). Estimated weights for invertebrate prey were not included in the analyses. The distributions of estimated fish lengths for whiting (*Merlangius merlangus*), haddock/pollack/saithe, *Trisopterus* spp. and flounder/plaice from the 1995 samples were compared with the distribution of fish lengths of whiting, haddock, poor cod and plaice respectively caught by trawls during the Department of Agriculture and Rural Development for Northern Ireland (DARD) groundfish survey of Autumn 1995. The survey was carried out using an otter trawl of 3 m vertical

Table 1. *Number of sampling visits to each site and samples collected.*

Site and year	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	TOTAL
MINERSTOWN 1995										
MAIN COLONY										
No. visits	1	2	7	12	1	0				23
No. samples	3	4	19	41	5	0				72
PUP ROCK										
No. visits							3	1	0	4
No samples							9	8	0	17
MINERSTOWN 1996										
MAIN COLONY										
No. visits	0	0	7	4	0	0				11
No. samples	0	0	19	10	0	0				29
PUP ROCK										
No. visits						1	0	2	1	4
No. samples						4	0	14	3	21
MINERSTOWN 1999										
Main colony										
No. visits	0	0	0	3	3	0				6
No. samples	0	0	0	6	4	0				10
MINERSTOWN 2000										
Main colony										
No. visits	0	0	6	4	0	0				10
No. samples	0	0	20	5	0	0				25
BALLYKINLER 1995										
No. visits	0	0	0	2	2	0				4
No. samples	0	0	0	17	21	0				38
BALLYKINLER 2000										
No. visits	0	0	1	2	0	0				3
No. samples	0	0	8	27	0	0				35

opening, fitted with a 20-mm mesh cod-end and towed over three nautical miles. Data from stations shown in Figure 1 were assumed to provide an indication of fish populations within seal foraging grounds beyond the immediate coastal zone near haul-out sites.

The average numbers of gadid, flatfish and sandeel otoliths (the most frequently occurring categories) were compared between years and between sites using Kruskal–Wallis tests (Siegel, 1956). The autumn diet of the post-weaning pups at Minerstown was also compared with results from the other samples. Within sets of samples, the relative numerical importance of gadids and flatfish was compared using Wilcoxon matched-pairs signed-ranks tests (Siegel, 1956). In addition, the numbers of otoliths representing each of four size categories of fish taken by post-weaning pups in the autumn were compared with the main colony using chi-squared tests.

RESULTS

Prey species identified from faecal samples

The occurrence of otoliths from each sub-set of samples is shown in Figure 2. The most commonly occurring prey species from Minerstown ('main colony') samples (Figure 2A) were gadid fish (mainly whiting and haddock, pollack or saithe) and flatfish (mainly plaice or flounder). Where similar species could be distinguished from bones, plaice outnumbered flounder and haddock outnumbered pollack and saithe. Other prey including cod, *Trisopterus* spp., ling (*Molva molva*), other flatfish, herring (*Clupea harengus*), sandeel, wrasse (Labridae), dragonet (*Callionymus* spp.), eel (*Anguilla anguilla*), and octopus (*Eledone cirrhosa*) were also sometimes found. Remains of small crustaceans, usually 1–2 claws thought to be from shrimp, were also found in several samples.

The samples from the 'pup rock' at Minerstown in late autumn (Figure 2B) showed less diversity of prey. Most contained whiting or haddock, pollack or saithe, with a few *Trisopterus* spp. Only two samples from each year (1995 and 1996) contained flatfish otoliths and one 1996 sample contained two argentine (*Argentina* spp.) otoliths.

The predominant prey in the samples from Ballykinler (Figure 2C) were flatfish, mainly plaice or flounder. However, whiting, haddock, pollack or saithe, *Trisopterus* spp., hake (*Merluccius merluccius*), sandeel, herring and octopus also occurred. Shrimp claws were also occasionally found.

Differences in number of fish of different types taken according to year and site

Comparison of the number of otoliths of gadid fish and flatfish in each sample) revealed significant differences between the years (Table 2A&B) There were on average more gadid otoliths in the 1996, 1999 and 2000 samples from Minerstown and in the 2000 samples from Ballykinler than in the 1995 samples from each site. (An exception to this was haddock/pollock/saithe otoliths, the occurrence

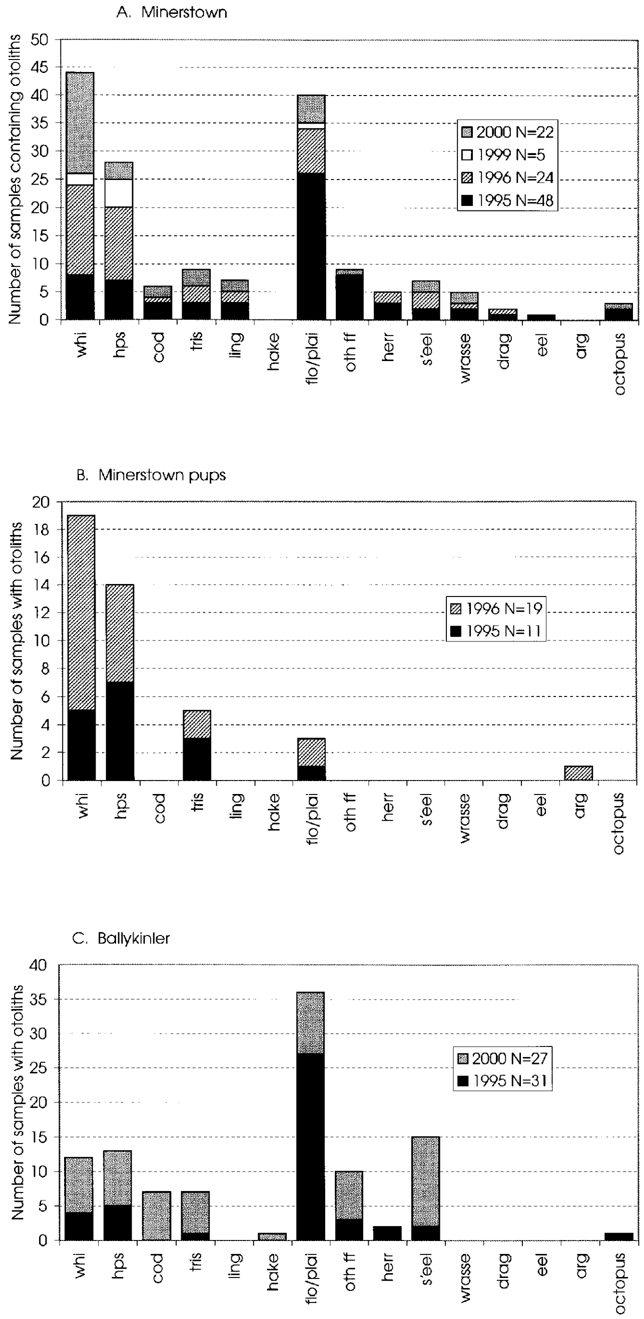

Figure 2. Occurrence of prey remains as identified by fish otoliths and cephalopod beaks. (A) Minerstown (May–September 1995, July–August 1996, August–September 1999, July–August 2000); (B) Minerstown pups (October–November 1995 and October–January 1996/97); (C) Ballykinler (August–September 1995 and July–August 2000). whi, whiting; hps, haddock, pollack or saithe; tris, *Trisopterus* sp.; flo/plai, flounder or plaice; oth ff, other flatfish; herr, herring; s'eel, sandeel; drag, dragonet; arg, argentine. Sample size (N) is for samples containing at least one otolith or beak.

of which decreased from 1996 to 2000). Conversely, there were fewer flatfish otoliths in particular, in 1996 and 2000 than in 1995. There were also more sandeels taken at Ballykinler in 2000 than in 1995.

There were also significant differences between the two sites (Table 2C), with more flounder/plaice taken at Ballykinler than Minerstown in 1995, and more sandeels and flatfish, but fewer gadids taken at Ballykinler in 2000.

In 1995 the pups at Minerstown were found to take more gadids but fewer flatfish than the main colony (Table 2D). The trends were similar in 1996 but non-significant, probably because of the increased number of gadids being taken by the main colony in 1996.

Proportion of fish prey species by estimated weight

The relative importance (proportion of estimated total fish weight) of each principal fish prey type found in the samples is shown in Figure 3. Gadid fish formed less than 20% of the diet of the Minerstown and Ballykinler groups in 1995 and 1996, but between 40% and 80% in 1999 and 2000. Gadids formed 88–97% of the diet of post-weaning pups during late autumn in both 1995 and 1996. Flatfish formed more than 75% of the diet in 1995, but less than 60% in 1999 and 2000. Herring amounted to around 6% of the diet of the Minerstown seals in 1995 and 1996, but otherwise did not form any detectable percentage of the diet. For comparison, the trawl catches of six of these fish species (cod, whiting, haddock, poor cod, herring and plaice) at the seven trawl stations (Figure 1) in autumn 1995 along the Co. Down coast are shown in Table 3A. The predominant species all along the coast in that particular season was whiting, although there was also a strong presence of haddock and plaice in Dundrum Bay. The highest overall biomass of these fish species along the Co. Down coast was in Dundrum Bay while the lowest was close to the mouth of Strangford Lough. The time-series of survey data for the Co. Down coastal stations show a marked growth and decline in haddock abundance during the 1990s, and high catch-rates of plaice in the mid 1990s (Table 3B). Catch-rates of herring were very variable, due to the patchy distribution of this shoaling fish.

Although the main species in the trawl catches were also eaten by seals, the high abundance of whiting in the trawls compared with other fish is reflected only in the diet of the pups, and not in the main colony either at Minerstown or Ballykinler.

Estimated size of fish prey

Estimates of the length of the fish prey calculated from otolith measurements from the 1995 samples indicated that the seals were preying mostly on juvenile gadids and flatfish. The frequency of occurrence of each size-class of fish prey corresponded well with the frequency of occurrence of the different size-classes of these species found at the near-by survey trawl stations. Most whiting and plaice/flounder were in the 100–200 mm range (Figure 4A&D), haddock/pollack/saithe were mainly in the 200–400 mm range (Figure 4B), and *Trisopterus* spp. were all in the 0–200 mm range (Figure 4C).

Content of samples from post-weaning pups

The samples taken from the 'pup rock' at Minerstown in the late autumn and early winter of 1995 and 1996–1997 contained the remains of only four types of fish: whiting, haddock/pollack/saithe, *Trisopterus* spp. and flounder/plaice. The size distribution of the fish taken

Table 2. *Analyses of the average number of otoliths per sample of otoliths for different types of fish prey. Kruskal–Wallis test results for differences between years at (A) Minerstown (main colony) and (B) Ballykinler, (C) differences between areas, and (D) differences between the 'main colony' and 'pup rock' at Minerstown. Wilcoxon test results (E) for comparative importance of gadids and flatfish within sample sets.*

A. *Between-year differences at Minerstown.*

Years	Whiting	HPS	All gadids	Flo/pla	All flatfish
1995 v 1996	96 > 95 $P<0.001$	96 > 95 $P=0.002$	96 > 95 $P<0.001$	95 > 96 $P=0.034$	95 > 96 $P=0.012$
1995 v 1999	n.s.	99 > 95 $P<0.001$	99 > 95 $P=0.003$	n.s.	n.s.
1995 v 2000	00 > 95 $P<0.001$	n.s.	00 > 95 $P<0.001$	95 > 00 $P=0.001$	95 > 00 $P<0.001$
1996 v 1999	n.s.	n.s.	n.s.	n.s.	n.s.
1996 v 2000	n.s.	96 > 00 $P=0.003$	n.s.	n.s.	n.s.
1999 v 2000	00 > 99 $P=0.029$	99 > 00 $P<0.001$	n.s.	n.s.	n.s.

B. *Between year differences at Ballykinler.*

Years	All gadids	Flo/pla	All flatfish	Sandeels
1995 v 2000	00 > 95 $P=0.001$	95 > 00 $P<0.001$	95 > 00 $P=0.013$	00 > 95 $P<0.001$

C. *Differences between Minerstown (M) and Ballykinler (B).*

Year	Whiting	HPS	All gadids	Flo/pla	All flatfish	Sandeels
1995	n.s.	n.s.	n.s.	B > M $P=0.037$	n.s.	n.s.
2000	M > B $P<0.001$	n.s.	M > B $P=0.020$	n.s.	B > M $P=0.049$	B > M $P=0.003$

D. *Differences between the main colony (M) and pup rock (R).*

Year	Whiting	HPS	All gadids	Flo/pla	All flatfish
1995	R > M $P=0.001$	R > M $P=0.007$	R > M $P<0.001$	M > R $P=0.023$	M > R $P=0.009$
2000	n.s.	n.s.	n.s.	n.s.	n.s.

E. *Relative importance of gadids (G) and flatfish (F).*

Year	Minerstown Main colony	Minerstown Pup rock	Ballykinler
1995	F > G ($P<0.001$)	G ≥ F ($P=0.05$)	F > G ($P<0.001$)
1996	G > F ($P<0.001$)	G > F ($P=0.002$)	–
1999	n.s.	–	–
2000	G > F ($P<0.001$)	–	n.s.

HPS, haddock, saithe and pollack; Flo/pla, flounder and plaice; n.s., non-significant.

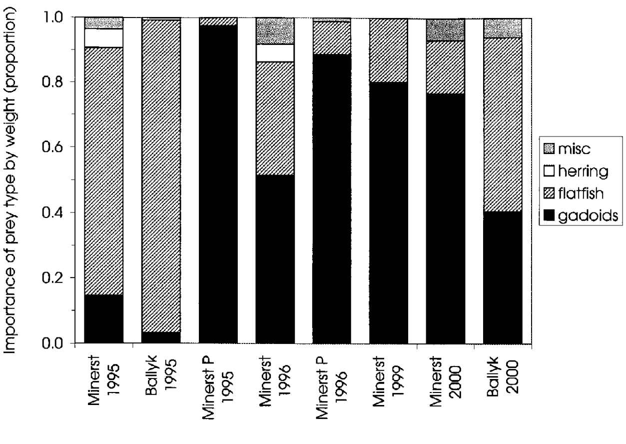

Figure 3. Proportion of fish constituents in the diet by estimated weight at the Minerstown and Ballykinler sites. P, post-weaning pups up to six months old.

was broadly similar to that in the samples from the main colony in the summer of 1995 (Figure 4). Nevertheless, when the samples from the 'pup rock' in 1995–1996 were compared with those taken from the main colony between May and the end of July 1995–1996 (i.e. before newly weaned pups would have begun to feed on fish prey), some differences were noted (Table 4), notably the samples from the 'pup rock' contained more haddock/pollack/saithe in the smallest size class (0–99 mm) than samples from the main colony, and also fewer flounder/plaice over 200 mm than in the main colony.

Of the samples collected from the 'pup rock' in late autumn and winter, only 1 out of 11 samples containing otoliths in 1995 and only 1 of 17 samples in 1996–1997 contained a large number of otoliths from fish estimated to be less than 100 mm in length. The 1995 sample included 76 otoliths from *Trisopterus* spp. (probably poor cod) of average fish length <10 cm and weight 7 g. This sample was taken (on 13 November) from underneath a pup known (from a radio-tracking study) to have been foraging during October in the southern region of Dundrum Bay (Wilson & Corpe, 1996). The 22 otoliths <100 mm from the 1996–1997 sample (taken on 7 January) were also all from *Trisopterus* spp. This sample also contained 21 larger whiting otoliths of average size 174 mm.

A few samples taken from the main colony in August (1 out of 11 samples with otoliths in 1995 and 4 out of 13 samples in 1996) also consisted mainly of otoliths less than 100 mm. Two of these samples were taken from underneath two pups on 13 August 1996 (i.e. 2–3 weeks post-weaning) and were found to contain otoliths from whiting and haddock/pollock/saithe of estimated average length 80 mm and weight 3 g. A sample from one of these pups contained 123 whiting otoliths and four *Trisopterus* spp. with a maximum fish length of 133 mm. This pup appeared to be relatively small (estimated at approximately 15–16 kg). The other pup's sample contained eight whiting otoliths, 13 of haddock/pollack/saithe, and maximum fish length of 109 mm. This pup was emaciated (approximately 11–12 kg) with ribs visible. The otoliths from fish <100 mm from the other three samples were from whiting and haddock/pollack/saithe, flounder/plaice and a few *Trisopterus* spp.

Table 3. *Catches (kg per three nautical mile trawls) at six DARD trawl survey stations along the Co. Down coast, for six species of fish eaten by seals resident in this region.*

A. *Station data for autumn 1995.*

Station	Cod	Whiting	Haddock	Poor cod	Herring	Plaice	Total
35	2	555	11	30	3	0	601
86	8	178	1	4	9	2	202
81	0	98	0	2	0	0	100
100	7	117	672	0	3	100	899
70	0	46	125	1	1	2	178
71	0	143	0	1	1	2	147
73	0	215	0	0	4	3	222

B. *Annual means for the six stations.*

Year	Cod	Whiting	Haddock	Poor cod	Herring	Plaice	Total
1991	7	234	27	26	8	7	308
1992	5	199	6	6	8	8	232
1993	3	281	15	17	16	8	342
1994	5	193	84	10	34	25	350
1995	2	193	116	6	3	15	335
1996	5	135	135	4	7	13	300
1997	5	252	131	11	77	8	484
1998	5	339	80	7	63	5	499
1999	4	253	101	9	7	4	378
2000	4	186	63	7	262	7	530

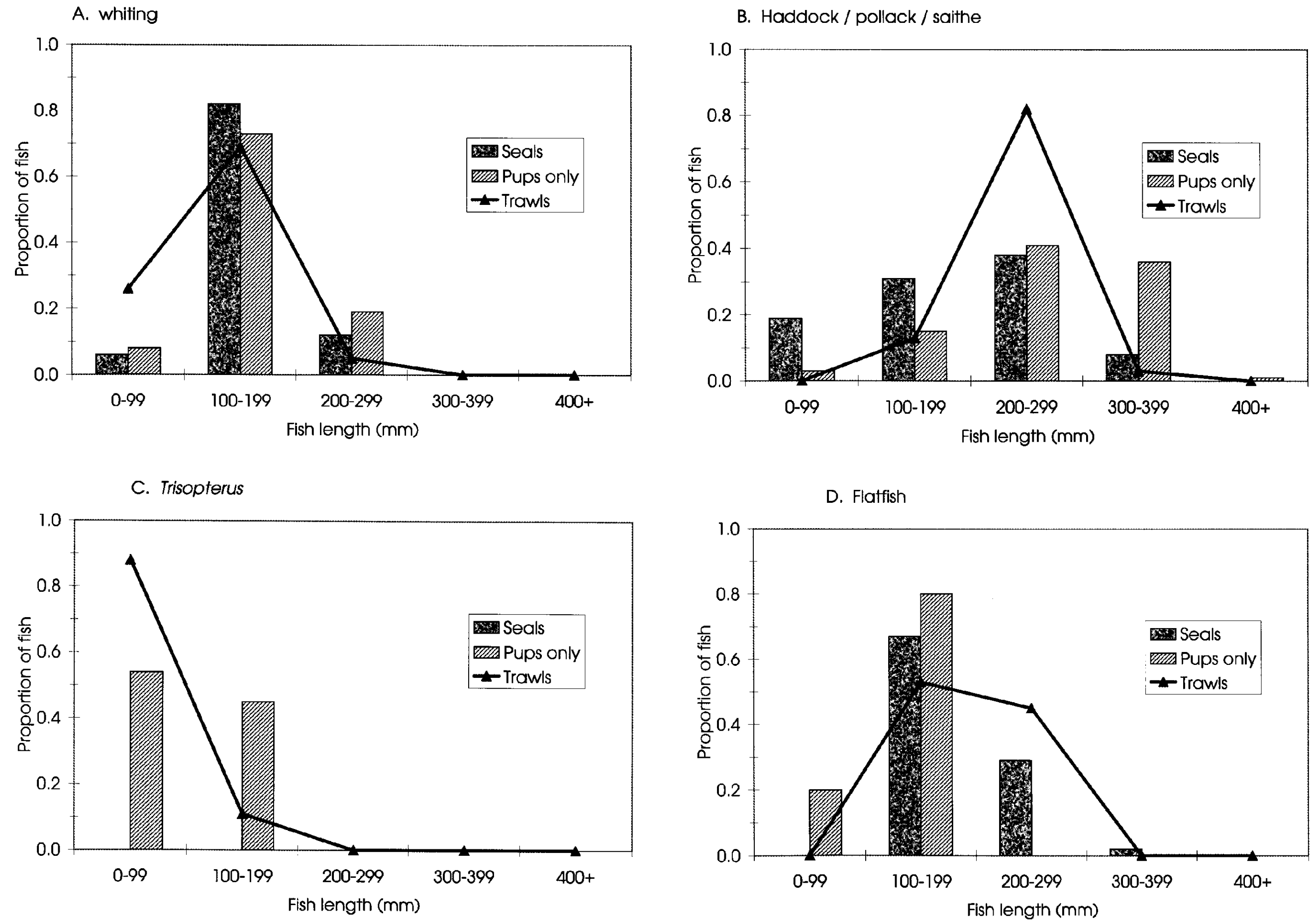

Figure 4. The number of fish prey of different sizes in the harbour seal diet, compared with the number of fish of different sizes inhabiting local coastal waters (DARD groundfish survey, autumn, 1995). (A) Whiting DARD trawls N=23,602 whiting; otoliths in samples from seals (main colony) N=17; in samples from pups only N=38. (B) Haddock/Pollack/Saithe DARD trawls N=4747 haddock; otoliths in samples from seals (main colony) N=56; in samples from pups only N=60. (C) *Trisopterus* spp. DARD trawls N=697 poor cod; otoliths in samples from seals (main colony) N=4 (not included in chart owing to small sample size); in samples from pups only N=84. (D) Flatfish DARD trawls N=1415 plaice; otoliths in samples from seals (main colony) N=825; in samples from pups only N=30.

Table 4. *Comparison of estimated fish size categories of samples at Minerstown taken from the 'main colony' (early summer to end of July 1995–1996) and the 'pup rock' (late autumn and early winter 1995–1996/1997).*

	Estimated fish size (mm)					
	0–99	100–199	200–299	300–399	400–499	chi-square test
WHITING						
Main Colony	11	55	21	0	0	P=0.019; df=2
Pup Rock	9	158	54	0	0	
HADDOCK/POLLACK/SAITHE						
Main Colony	3	1	13	3	0	P<0.001; df=3
Pup Rock	12	15	30	21	1	
FLOUNDER/PLAICE						
Main Colony	3	132	73	4	0	P<0.001; df=2
Pup Rock	5	33	3	0	0	
Main Colony N=17 (1995), 13 (1996), combined N=30						
Pup Rock N=11 (1995), 17 (1996/97), combined N=28						

DISCUSSION

The principal conclusion from this study thus far is that between 1995 and 2000 the harbour seals of Dundrum Bay appear to have been feeding primarily on small flatfish and gadid fish during the summer months, with the emphasis shifting from flatfish during 1995–1996 to gadids during 1999–2000, principally whiting and haddock/pollack/saithe. During both 1995 and 1996 the diet of post-weaning pups, aged between six weeks and five months, i.e. from late summer to early winter consisted principally of small gadids.

In all four years studied the diet composition data suggest that all age-classes of harbour seals were feeding almost totally on small demersal fish. The autumn 1995 trawl survey results suggest that the seals in Dundrum Bay in the late summer and autumn of 1995 may have been feeding opportunistically on whiting and haddock, but more selectively on plaice.

The distribution of fish shown in the 1995 trawl results corresponds approximately with the distribution of harbour seals along the coast in the summer and autumn of 1995. The high fish density, particularly of haddock and plaice, in Dundrum Bay was consistent with the strong presence of harbour seals of all ages, and including post-weaning pups at the Ballykinler and Minerstown haul-out sites during August and September 1995. Conversely, the relatively low fish densities in the vicinity of Strangford Lough were consistent with the conspicuous absence of pups from Strangford Lough and the immediately adjacent coastline during those months (Wilson & Corpe, 1996; Wilson & Montgomery-Watson, in press).

The time-series of DARD trawl surveys in the Irish Sea and along the Co. Down coast shows relatively high densities of plaice, flounder, young whiting and haddock in the vicinity of Dundrum Bay (Armstrong, 1999). Whilst the survey is restricted to water deeper than about 20 m, the rocky and weedy areas close inshore are likely to support populations of pollack, saithe, wrasse and young cod. These patterns reflect the diet of Dundrum Bay seals between 1995 and 2000. Furthermore, the size frequencies of prey in the seal diet corresponded approximately with those in the trawl survey. This again suggests the seals were probably feeding opportunistically rather than selectively. The finding of more whiting in the pup diet than in the main colony diet in 1995 suggests that post-weaning pups were adopting a more opportunistic foraging strategy than the more experienced seals that year, since whiting was found to be the most abundant inshore species caught in the trawls that season.

The trawl survey data presented here only give snapshots of fish distribution and abundance that will also be strongly influenced by small-scale patchiness of the fish. Nonetheless, the changes in haddock abundance through the 1990s at these stations (Table 3B) mirror the overall trends for the Irish Sea shown by Dickey-Collas et al. (2002). A substantial growth in the Irish Sea haddock population occurred following very strong year-classes produced in 1994 and 1996 so that by 1995/1996, high densities of haddock were present in coastal waters within the foraging range of seals (Table 3B). Weaker subsequent year-classes resulted in a decline in abundance of adult haddock by 2000, which is again shown in Table 3B. The abundance of adult whiting declined continuously in the western Irish Sea during the 1990s, a trend shown both by surveys (DARD, unpublished data) and commercial landings (ICES, 2001). However, recruitment has varied relatively little, and this is reflected in the lack of any trend in overall catch rate (Table 3B), as the inshore catches are predominantly small whiting. The increase in plaice catch-rates inshore in the mid-1990s, and the subsequent decline, is not mirrored in the overall Irish Sea stock (ICES, 2001) or the spawning stock in the western Irish Sea (Anon, 2002). The survey trends are driven by high catch-rates at Station 100 and could represent a localized decline off Dundrum Bay that could explain the decline in the contribution of the plaice/flounder component to the diet of the seals between 1995 and 2000.

There is some inconsistency between the findings in this study of a low proportion of clupeids in the diet and the relatively high abundance of sprat and juvenile herring found by acoustic surveys carried out during summer or autumn since 1991 (Armstrong, 1999). The latter author suggested that seals may have trouble catching these fish when they are shoaling off the seabed. However, the paucity of adult herring in the seals' diet is consistent with the acoustic surveys, which have shown a relatively low incidence of adult herring along the Co. Down coast. Adult herring are now mainly concentrated around the Isle of Man, i.e. more than 100 km from the Co. Down haul-out sites, and spawning off the Co. Down coast appears much reduced and probably of brief duration compared with other areas.

Consideration of the nutritional content of the predominant fish types found in the Dundrum seals' diet suggests the possibility that energy and possibly other nutritional deficiency may have been occurring during the years of this study. Gadid fish such as whiting and haddock, pollock and saithe have relatively low energy densities at less than 800 kcal kg^{-1}, while flatfish such as plaice and dab may be slightly higher, though less than 950 kcal kg^{-1} (Murray & Burt, 1977). *Trisopterus* spp. and sandeels have slightly higher energy densities, at around 1100 kcal kg^{-1}, but these were a very small component of the Dundrum seals' diet.

Herring and mackerel are both high-energy fish (1850 kcal kg^{-1}), although the energy density of clupeid fish increases at larger body size (Murray & Burt, 1977; Hislop et al., 1991). Mackerel were not detected at all in the Dundrum Bay seals' diet, while herring comprised less than 6% by weight in 1995 and virtually nothing in the other study years.

The diet of post-weaning pups up to six months of age, foraging locally along the Co. Down coast in 1995 and 1996 (Wilson & Corpe, 1996), was composed mostly of gadids. Samples from two pups aged about six weeks (and in three other samples from Minerstown during August) contained the remains of very small gadids of average length less than 100 mm. This finding is consistent with the findings in other seal species that post-weaning pups initially start to feed on very small inshore prey. Nevertheless, it seems likely that these post-weaning pups may experience an unfavourable cost/benefit ratio from feeding exclusively on small gadids, e.g. the 62 whiting of average weight 3 g each consumed by one of the two six-week old pups would yield a total gross energy intake of only about 150 calories, assuming 700–800 kcal kg^{-1}

(Murray & Burt, 1977). Certainly the second pup appeared to be severely undernourished.

When the Dundrum seals' diet is compared with harbour seals elsewhere in the UK during the summer and autumn, it appears to have contained a relatively low proportion of oily or high-energy fish and a high proportion of gadids compared to at least some other populations, such as Shetland (Brown et al., 2001) and the Moray Firth (Pierce et al., 1991). The Dundrum Bay seals' diet seems to resemble more closely the diet of the harbour seals in the Wash (East Anglia) between 1990 and 1992, in which gadids formed about 50% of the diet by weight in the late autumn months and 17–30% in the summer, while clupeids were virtually absent in all seasons (Hall et al., 1998).

The nutritional implications of the Dundrum Bay seals' gadid-rich and clupeid-poor diet may be two-fold. Firstly, seals may have a lower than optimum body weight. Thompson et al. (1996) found that the harbour seals in the Moray Firth were in poorer body condition in years when clupeids formed <11% of the diet, compared to 'good' clupeid years when the diet consisted of >60% clupeids. Also, the body lengths of 'yearling' seals were significantly greater after a 'good' clupeid year. Secondly, Thompson et al. (1997) compared erythrocyte parameters in harbour seals in the Moray Firth in 'good' and 'bad' clupeid years and found that in the 'bad' years the seals suffered from macrocytic anaemia *in addition to* lower body weight. However, the anaemia was attributed *not* to an absence of clupeids *per se*, but to the observed increase specifically in gadid fish (notably whiting) in those years. Gadid fish have been shown to contain an anti-metabolite which may reduce iron absorption in genetically susceptible predators, resulting in anaemia, decreased growth rates and increased mortality (Thompson et al., 1997). These findings may be highly relevant to the gadid-rich and clupeid-poor diet of the Dundrum Bay seals, at least during the months studied. Thompson et al. (1996) emphasize the probable negative impact of such a relatively poor diet on the survival of pups over their first winter.

Furthermore, the apparent lack of locomotor play by post-weaning pups and juveniles around the haul-out site during the period of this study, in contrast to the situation in the late 1960s (Wilson, 1974; unpublished observations), is consistent with a hypothesis of low intake of food energy (together with possible anaemia) and increased time foraging. Although there was no study of the seals' diet in the late 1960s, adult herring were known to be more abundant then along the Co. Down coast than at the present time (Armstrong, 1999). Baldwin & Baldwin (1974, 1976) reported a lack of play among young squirrel monkeys when sparse food supplies caused them to spend an unusually large amount of time foraging. Conversely, Renouf et al. (1988) noted a significant increase in locomotor play in a captive harbour seal group when food intake was high. We suggest that a quantitative indicator of locomotor play occurrence at seal haul-out sites be developed in order to document any relationship between play occurrence and diet in wild populations of seals. Since the constituents of harbour seal diet are known to vary from year to year, depending on fluctuating availability, at other UK sites (Thompson et al., 1996; Brown et al., 2001), it is possible that the present situation for the Dundrum Bay seals may be temporary. Further monitoring of seal diet and trends in local fish stocks will be necessary to determine whether this is the case.

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