The diet of harbour seals *(Phoca vitulina)* at the southern limit of its European distribution (Normandy, France)

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ABSTRACT

Changes in habitat availability or resources are likely to have the biggest impact on survival or abundance of individuals found at the extremity of the population's range. In the case of such marginal populations, the first step in designing appropriate conservation plans is the identification of potential risks to the viability of the population, or subpopulation. For example, the interaction between coastal seals and fisheries is often considered as a major conservation issue, due to the potential co-exploitation of the same resources by both fishermen and seals. The diet of harbour seals was investigated by scat analysis at the southern extremity of their European range, in *Baie des Veys* (Normandy, France). A total of 121 scats, analysed following standard methodologies, revealed a diet largely dominated by mullets, *Mugilidae* (49% by mass), plaice, *Pleuronectes platessa* (29% by mass) and garfish, *Belone belone* (19% by mass). The diet of harbour seals at the edge of their European distribution differs from all previous studies conducted elsewhere, in terms of species composition, but shows a similar balance between fat and lean fish. Overall diet composition suggests a low potential for interaction with fisheries as commercial fishery target species are almost absent.

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INTRODUCTION

In the marine environment, resource heterogeneity can affect all trophic levels from plankton to top predators (Croxall 1992). The distribution of predators and their foraging strategies may be shaped by the spatial and temporal availability of their prey (Cuthill and Houston 1997). In the case of central place foragers, such as pinnipeds or sea birds, which exploit marine resources for food and use terrestrial sites to rest, breed or moult, prey availability around the colonies or resting sites has a direct impact on foraging strategy and success, and consequently on the survival and abundance of the population (*e.g.* Lunn *et al.* 1993, Beauplet *et al.* 2004, Womble and Sigler 2006). If the observed distribution of a species would reflect the spatial range over which the parameters defining its niche are favourable to its growth, then core areas of the distribution should correspond to optimal areas for feeding and breeding, whereas at the margins of the species' range the environmental conditions may be less favourable. Hence, the survival of small colonies found at the edge of the species' distribution, should be more sensitive to any changes in resource or habitat availability. On the other hand, animals which exploit these sub-optimal areas express a higher ecological plasticity compared to those living in the core of their range (Komers 1997).

Two sympatric seal species are abundant in European temperate waters: the grey, *Halichoerus grypus*, and the harbour, *Phoca vitulina*, seals. The former has been shown to travel extensively during its yearly cycle between locations separated by up to hundreds of kilometres (Hammond *et al.* 1993, Vincent *et al.* 2005) whereas the latter generally forages year-round in limited areas close to its haulout sites (Tollit *et al.* 1998, Vincent *et al.* 2010). By using restricted foraging areas, the diet of harbour seals is likely to be subject to local prey availability. Consequently harbour seals may be more sensitive to changes in prey availability around haulout sites than the larger grey seal. This issue could be critical in the case of marginal populations, which are thought to live in sub-optimal conditions.

Identifying potential risks is the first step fordesigning an adequate conservation plan. In seals, interactions with fisheries, either operational (interaction with fishing gears: by-catch, depredation) or biological (food web interactions, including but not only competition), have long been considered as a major conservation issue (Harwood and Croxall 1988, Ridoux *et al.* 2007). In the case of biological interactions, commercial or recreational fisheries may be important sources of changes in local prey availability (Heino and Godø, 2002). Harbour seal diet, foraging behaviour and potential interactions with fisheries have been largely investigated in the core of its European distribution located around the North Sea and the British Isles (Appendix 1 and references therein, Appendix 2). The present study describes prey preferences of the harbour seal at the edge of its range in order to compare its feeding ecology with other studies carried out in the core European distribution, and to assess the potential for biological interactions with local fisheries.

MATERIALS AND METHODS

Baie des Veys is located in Normandy, on the east coast of the Cotentin peninsula in France (Fig. 1). This site has been used by an increasing number of harbour seals: maximum seal counts from less than 10 animals in the early 1990s to 52 in 2005 (Elder 2006). An aerial survey carried out in the summer 2006 estimated a maximum of 62 seals including 11 pups (Gautier and Elder, unpublished data, pers. comm.).

A sample of 121 scats was collected at haulout sites, between June and September from 2000 to 2004, and stored frozen at -20°C. Scat analysis followed procedures generally used for pinnipeds (*e.g.* Pierce and Boyle 1991, Croxall 1993, Ridoux *et al.* 2007). Scat samples were washed on a 0.2 mm mesh size sieve. Fish items were identified to species level from the examination of diagnostic hard remains (otoliths and bones) using available keys and guides (Härkönen 1986) as well as our reference material *(Centre de Recherche sur les Mammifères Marins / Université de La Rochelle, CRMM/ULR)*. Diet composition

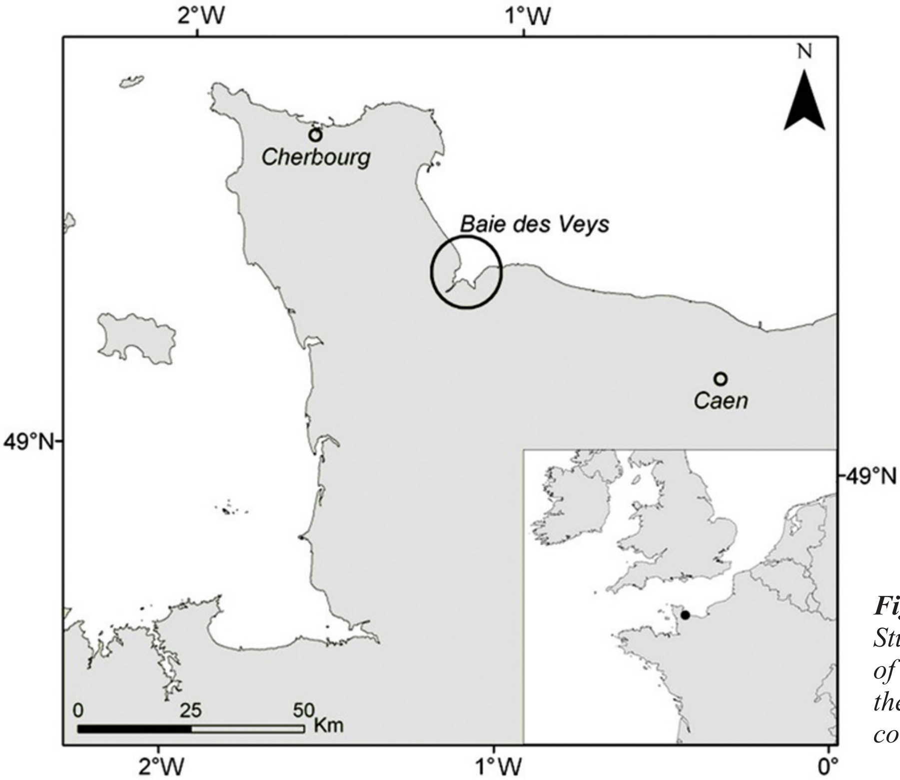

Fig. 1.
Study area: location of Baie des Veys on the French Channel coast.

was quantified by occurrence (number or proportion of scats containing a given prey taxon), relative abundance (number or proportion by number of individuals belonging to a given prey taxon over all samples) and reconstituted body mass (mass or proportion by mass of a given prey taxon over all samples). A prey was considered present in a sample when at least one diagnostic part was found. Otoliths were measured following standards, namely otolith length (OL) and otolith width (OW). These measurements were then converted to total body length and individual body mass by using available allometric relationships (Härkönen 1986, CRMM unpublished relationships). The reconstituted mass of a given prey taxon in a given sample was obtained by averaging individual body masses in that sample and multiplying this figure by the number of individuals of the same taxon in the same sample. Some remains of crustaceans, such as *Porcellanidae, Paguridae* or *Galatheidae*, corresponded to prey items of less than 10 mm long and were considered to be fish prey secondarily ingested by the seals; they were therefore discarded from the analyses.

Confidence intervals (95% CI) around the percentages by number and mass were generated for each prey species by bootstrap simulations of sampling errors (Reynolds and Aebischer 1991). The bootstrapping routine was written by using the R software (Ihaka and Gentleman 1996). Random samples were drawn with replacement and the procedure was repeated 1,000 times. The lower and upper bounds of the 95% CI were the 25th and 975th values previously ranked in increasing order. Possible biases related to applying regression and to the digestive erosion of otoliths – influencing the reconstituted body length and mass of fish prey - were not estimated.

Geographical diet variability at the European scale was examined by performing Correspondence Analyses (CAs) on published data. CA routines were performed by using the software XLSTAT© v5.1 (Addinsoft). CAs allowed the homogeneity of the studies and the existence of subgroups to be highlighted. The matrix was populated by most published data on the diet preferences of harbour seal described by scat analysis in European waters (Appendix 1 and reference therein). We used all peer-

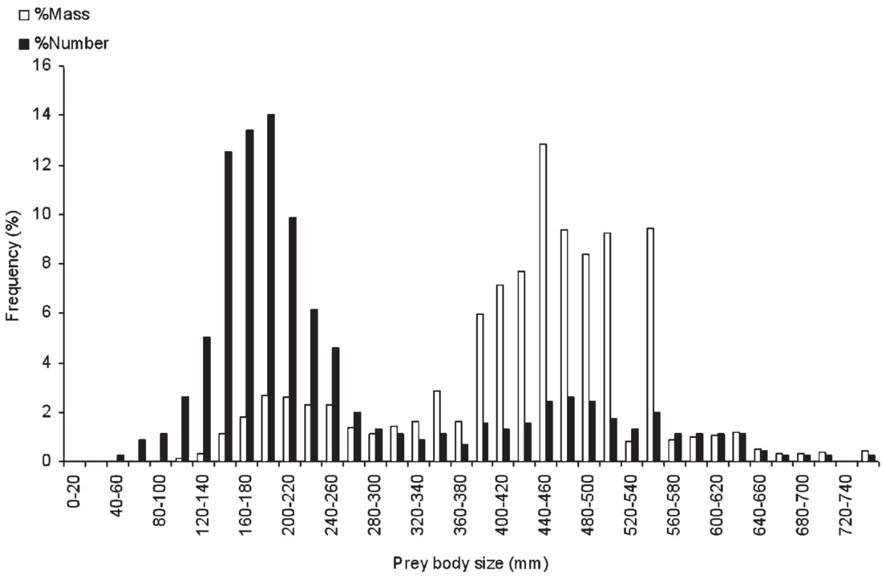

Fig. 2. *Overall prey-size distributions from harbour seal scats expressed as percent number (%N, black bars) and percent mass (%M, white bars). Most prey individuals are less than 300 mm long, but the bulk of ingested biomass comes from prey individuals over 300 mm.*

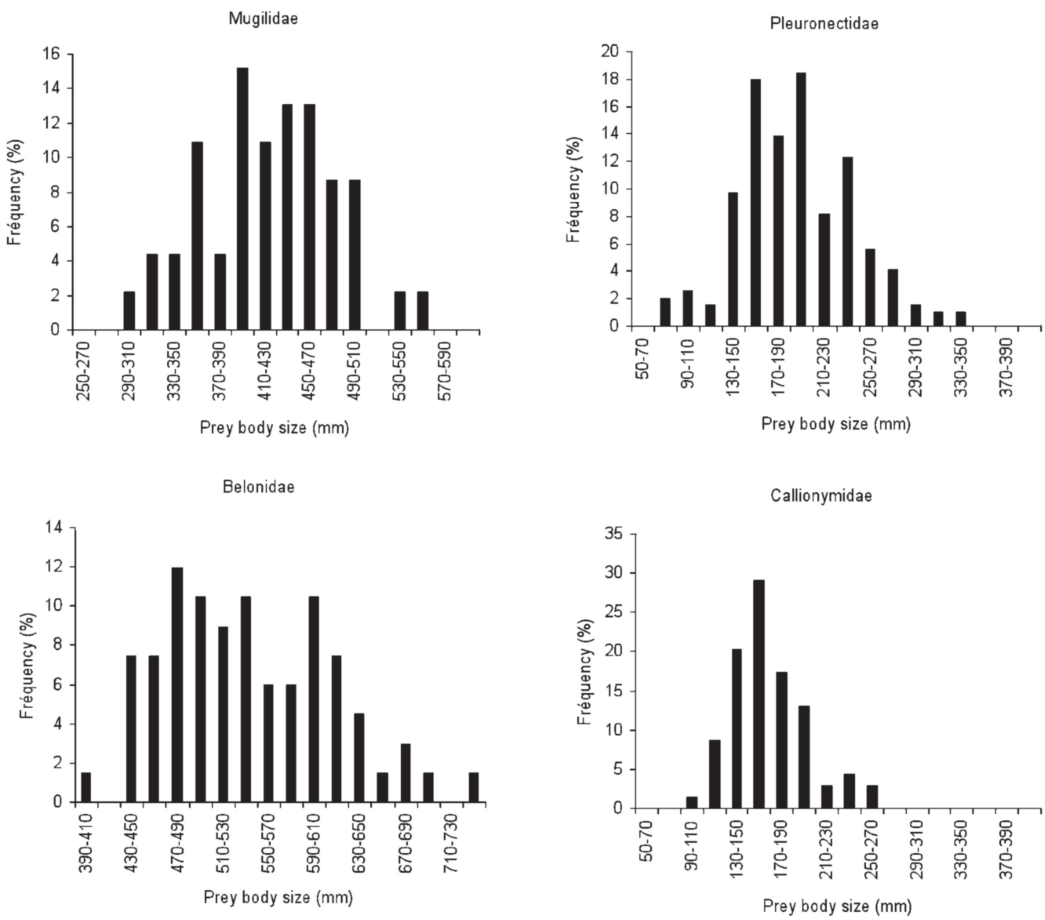

Fig. 3. *Body size distributions expressed as percent number for the main prey species identified from harbour seal scats.*

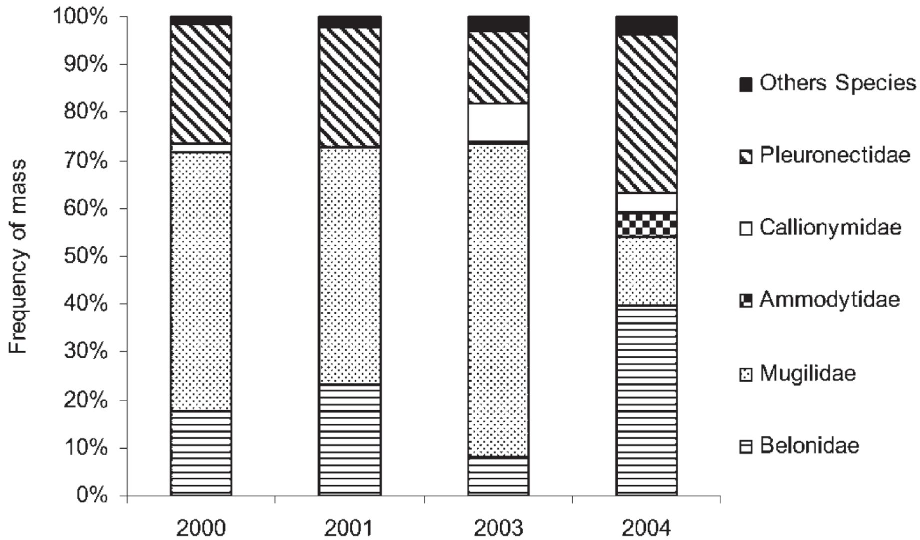

Fig. 4. *Annual dietary preferences of harbour seals in Baie des Veys in the summers 2000 (N=30), 2001 (N=27), 2003 (N=35) and 2004 (N=22).*

reviewed studies from European study sites which applied a similar methodology to ours and provided diet preferences by mass, and thus assumed to offer comparable data. The data used were the proportion by mass of every prey family. For all of these studies when it was feasible, data were split by season or by year and/or by sites in order to express the maximum of variability.

RESULTS

The diet of harbour seals in northern France was composed solely of fish; no cephalopods or large crustaceans were found. Four hundred and fifty otoliths were recovered from at least 14 different fish species. These accounted for a total reconstructed biomass of about 68 kg. However, only a few species constituted a significant proportion of the harbour seal diet (Table 1). The diet by mass was dominated by mullets, with 49% by mass (95% CI: 32–65), representing 26% of the frequency of occurrence and 10% by number (95% CI: 5–17). Plaice (presumably *Pleuronectes platessa* but confusions with very similar otoliths of *Platichthys flesus* or with other pleuronectids cannot be excluded), although the most commonly occurring species (49%) and the most numerous prey (42% by number; 95% CI: 28–55), was second by mass with a total contribution of 24% by mass (95% CI: 14–34) due to its shorter body size (Fig. 2). Garfish *(Belone belone)* was the third most important prey, with 19% by mass (95% CI: 8–33) and 14.2% by number (95% CI: 6–24). Finally, dragonets *Callionymus* spp. were the fourth most important prey, reaching 15% by number (95% CI: 5–27) but only 4% by mass (95% CI: 1–8) because of its small individual body mass (less than 38 g on average).

The average prey individual body size was 262 mm in length and 273 g in mass. The overall prey size distribution ranged from a 50 mm long and 1 g body mass goby to a garfish of 742 mm or a mullet of 1.5 kg. Prey items from 50 to 300 mm long accounted for 74% by number of the diet but larger prey, from 300 to 600 mm long accounted for 81% by mass of the diet (Fig. 3).

Year-to-year variations in diet composition appeared to be fairly limited (Fig. 4). Years 2000, 2001 and 2003 were very similar apart from *Callionymidae* which was more important in 2003. Only year 2004 departed from the general composition with a higher proportion of garfish (40% by mass), a lower contribution of mullets (less than 15% by mass) and the presence of sand-eels in measurable amounts (5% by mass).

The geographical variability of the diet, assessed by a CAs of the present data incorporated in a selection of the main previous studies available, revealed a good homogeneity within each main area and a low overlap between these areas (Fig. 5). Sand-eels mostly prevail in the diet of the harbour seal in eastern

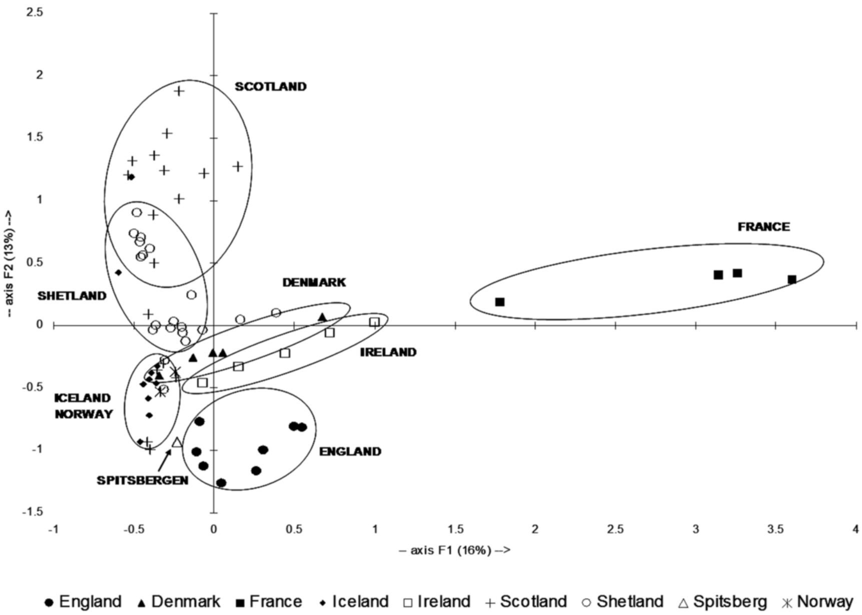

Fig. 5. *Plots of correspondence analysis from the diet composition in mass of harbour seal across its European distribution.*

Scotland, including part of the Shetland islands, whereas gadids are predominant elsewhere with important secondary prey taxa such as flatfish in Ireland, flatfish and clupeids in Denmark and flatfish and small benthic species in England. The harbour seal diet in France as described here was shown to be at the margin of all previously described diet compositions, as a result of the unprecedented importance of the mullet in its diet.

DISCUSSION

General

The diet of harbour seals in *Baie des Veys* was based on a narrow range of fish species. Two demersal species, mullets and plaice, and one pelagic species, the garfish, represented together more than 90% of the consumed biomass. No cephalopods or crustaceans were present in the diet. However, there are several biases inherent to scat analysis (Pierce and Boyle 1991) and the results of this study have to be seen in the light of the following limitations. *Baie des Veys* is home to only a limited number of individuals, which constitutes one of the southernmost permanent harbour seal colonies in the Northeast Atlantic, and therefore gathering very large collections of samples is not possible over a realistic period of time. Scat analyses reflect the food composition during the day prior to sampling, indicate prey size ranges, and quantify species' dietary composition. Extensive literature has reported on biases associated with prey-specific differential transit times in the digestive tract and differential erosion patterns of diagnostic parts (*e.g.* Bigg and Fawcett 1985, Grellier and Hammond 2005, Yonezaki *et al.* 2003). These biases which affect the probability that a prey eaten be recovered, and the ability to back-calculate original prey body mass, are fully acknowledged here. In spite of these limitations, the present study provides original quantitative data from a previously undocumented area, located at the southern limit of the European distribution of harbour seals. These results contribute to baseline data for the assessment of the role of the species in local ecosystems and the potential for interactions with fisheries and they allow comparisons with other sites within the Northeast Atlantic range of the species.

Potential for interactions with local fisheries

Baie des Veys is subject to local fishery activities with about 20 to 40 small fishing boats using nets, longlines and pots; a few larger trawlers occasionally exploit the external part of the bay. In the summer, recreational fishing is also important. The diet of harbour seals in

Table 1. Harbour seal diet in Baie des Veys from scat content analysis for the period 2000 to 2004 (N=121).

	Occurrence		Number	Body length (mm)		Body mass (g)		Biomass
	%O	N	%N (95% CI)	Mean ± SD	Min-Max	Mean ± SD	Min-Max	%M (95%Ci)
Gadidae								
Trisopterus spp	10.3	19	4 (1.1–7.6)	144 ± 41	79–210	42 ± 31	8–105	1.2 (0.3–2.3)
Merlangius merlangus	1.3	1	0.2 (0–0.7)	75	75	2	2	0 (0–0.01)
Pollachius spp	1.3	1	0.2 (0–0.7)	264	264	156	156	0.2 (0–0.8)
Belonidae								
Belone belone	15.4	67	14.2 (6–24)	543 ± 76	394–742	196 ± 92	63–507	19.2 (7.8–32.5)
Serranidae								
Dicentrachus labrax	1.3	1	0.2 (0–0.7)	363	363	268	268	0.4 (0–1.3)
Carangidae								
Trachurus trachurus	1.3	1	0.2 (0–0.7)	254	254	150	150	0.2 (0–0.8)
Mugilidae								
Undetermined mullets	25.6	47	10 (4.8–16.8)	423 ± 59	305–555	704 ± 283	255–1,489	48.6 (31.8–65.2)
Trachinidae								
Trachinus draco	2.6	5	1.1 (0–2.9)	172 ± 11	162–185	64 ± 13	53–80	0.5 (0–0.5)
Ammodytidae								
Undetermined sandeels	7.7	37	7.9 (0.7–20)	188 ± 29	99–243	17 ± 7	3–33	0.9 (0–2.8)
Callionymidae								
Undetermined dragonets	10.3	69	14.7 (5.2–27)	169 ± 34	104–260	38 ± 26	7–129	3.8 (1.1–8.2)
Gobiidae								
Undetermined gobies	1.3	1	0.2 (0–0.7)	50	50	1	1	0 (0–0)
Pleuronectidae								
Undetermined pleuronectids	48.7	195	41.5 (28–55)	195 ± 50	74–348	83 ± 74	3–452	23.7 (14.2–34.1)
Soleidae								
Undetermined soleids	9.0	13	2.8 (0.7–5)	189 ± 36	109–234	66 ± 33	11–118	1.3 (0.2–2.7)
Species A	1.3	3	0.6 (0-–2)	–	–	–	–	–
Undetermined fish	9.0	10	2.1 (0.7–4)	–	–	–	–	–

Baie des Veys is generally composed of species of no, or low, commercial value. Only plaice is limited by a quota, but no fishery targets this species in this part of the Channel. Also, 90% by number of the plaice eaten by seals had an estimated length lower than 27 cm, the commercial length for this species (Fig. 3). Highly valued species targeted by professional and/or recreational fisheries such as the sea-bass, *Dicentrarchus labrax*, are absent. Hence at present, the potential for competition with local fisheries seems very limited. However, more information (*e.g.* fish abundance, patterns of fish migration, trophic links between fish species) is needed to quantify the indirect impact of both consumers (seals and fisheries) on the resources of *Baie des Veys* and the effect on the species exploited by the other; for example, the co-exploitation of the same prey by seals and by high commercial value species. A further step should assess spatial overlap with local fisheries by the use of telemetry data to map harbour seal foraging areas.

Geographical variations of the diet

The diet of harbour seals at *Baie des Veys* appears to differ from the diets described around the British Isles and other core areas of the Northeast Atlantic. Among the 3 main prey species found in Normandy, only plaice has been commonly found in the species' diet elsewhere. Despite their broad distribution in European coastal waters, mullets have never been reported to be of any importance in the food of the harbour seals. Garfish, a large epipelagic species, had only been found as an occasional prey in the Shetland islands (Brown *et al.* 2001). Little is known about the biology and abundance of this latter species, but it is suggested that it would follow the migratory patterns of Atlantic mackerel, *Scomber scombrus* (Muus and Nielsen 1999). Thus, garfish could be locally abundant in the summer and constitute a profitable prey for seals at this season.

Ecological implications

These dietary differences could express a higher ecological plasticity in marginal populations. However, geographical and temporal variations in the diet could also imply that harbour seals are opportunistic feeders, whose diet would merely reflect prey availability around haulout sites. Instead, it could be suggested that this predator could maximise its energy gain by selecting prey types. Some degree of prey selection in the harbour seal has already been suggested because some prey were shown to be over-represented in the diet compared with their availability in the environment or, to the contrary, abundant species to be absent or under-represented (Olsen and Bjørge 1995, Thompson *et al.* 1996). Along the same lines, fish preferences were tested with dead fish offered to seals in floating cages; seals showed preference for certain species and rejected others (Lunneryd 2001). Finally, the proximate fish composition could shape harbour seal dietary preference. Trumble and Castellini (2005) suggested that a mixed diet composed of prey with contrasted lipid and protein contents increased digestible energy intake. These results on captive seals helped interpret dietary results obtained in the wild, which generally show a mixture of fat and lean fish such as clupeids and gadids (*e.g.* Härkönen and Heide-Jørgensen 1991, Brown and Pierce 1998, Berg *et al.* 2002) or sand-eels and flatfish (*e.g.* Thompson *et al.* 1996, Hauksson and Bogasson 1997, Brown and Pierce 1998), or as in the present study, mullet, garfish and flatfish. Hence, among the fish community living around its haulout sites, the harbour seal would appear to be opportunistic in terms of prey species taxonomic composition but fairly specialized in terms of prey species quality.

CONCLUSION

The study provides the first quantitative analysis of the harbour seal diet along the French Channel coast. The results differ from all published studies from locations in the core of the species' European distribution, with mullet accounting for about half of ingested prey biomass. Overall diet composition suggests low potential for interaction with fisheries. A further step for conservation purposes should be the use of telemetry data to map harbour seal foraging areas and associated predation pressure in order to assess spatial overlap with local fisheries. In terms of foraging ecology, comparing habitat and resource use by harbour seals with fish species' spatial availability may help in understanding possible prey selection processes.

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Appendix 1. Dietary data of harbour seal across its European distribution from scat analysis used to provide the CAs.

Country	Locality	Year	Period	Ref	Diet composition																		
					Gadidae	Osmeridae	Clupeidae	Scombridae	Belonidae	Carangidae	Mugilidae	Anarhichidae	Ammodytidae	Cottidae	Callionymidae	Gobiidae	Zoarcidae	Scorpaenidae	Pleuronectidae	Scophthalmide	Soleidae	Others Specie	Cephalopdos
Spitzbergen	Prins Karls Forland	1998	Aut	a	63	0	0	0	0	0	0	6	0	26	0	0	0	0	3	0	0	3	0
Iceland	West coast	1992/93	Aut/Win	b	57	13	15	0	0	0	0	1	1	0	0	0	0	1	0	0	0	13	0
Iceland	West coast	1992/93	Spr/Sum	b	70	0	2	0	0	0	0	4	14	0	0	0	0	2	0	0	0	9	0
Iceland	West-fjords	1992/93	Aut/Win	b	54	1	19	0	0	0	0	18	1	0	0	0	0	4	0	0	0	3	0
Iceland	West-fjords	1992/93	Spr/Sum	b	62	1	6	0	0	0	0	5	7	0	0	0	0	6	0	0	0	14	0
Iceland	Northwest	1992/93	Aut/Win	b	48	6	9	0	0	0	0	2	7	0	0	0	0	12	0	0	0	16	0
Iceland	Northwest	1992/93	Spr/Sum	b	49	3	0	0	0	0	0	8	13	0	0	0	0	20	0	0	0	6	0
Iceland	Northeast	1992/93	Aut/Win	b	54	2	1	0	0	0	0	3	1	0	0	0	0	25	0	0	0	14	0
Iceland	Northeast	1992/93	Spr/Sum	b	48	0	0	0	0	0	0	37	0	0	0	0	0	12	0	0	0	3	0
Iceland	South	1992/93	Aut/Win	b	19	43	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	4	0
Iceland	South	1992/93	Spr/Sum	b	1	0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	9	0
Norway	Vesteraalen	1994	Sum	c	64	0	24	0	0	0	0	0	0	0	0	0	0	0	7	0	0	5	0
Norway	Sandoy	1996/99	All	d	85	0	10	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Denmark	Skagerrak	1989	Sum	e	52	0	19	0	0	0	0	2	6	0	0	0	3	0	16	0	0	2	0
Denmark	Skagerrak	1989	Aut	e	62	0	28	0	0	0	0	0	0	0	0	1	8	0	1	0	0	0	0
Denmark	Skagerrak	1980	Sum	f	17	0	1	0	0	0	0	0	9	0	0	0	0	0	74	0	0	0	0
Denmark	Skagerrak	1977/78	All	f	51	0	8	0	0	0	0	0	8	0	0	0	0	0	24	0	0	9	0
Denmark	Skagerrak	1978/79	All	f	52	0	9	0	0	0	0	0	6	0	0	0	0	0	28	0	0	6	0
Scotland	Shetland / Mousa	1994	Sum	g	56	0	13	1	6	0	0	0	22	0	0	0	0	0	1	0	0	0	1
Scotland	Shetland / Southeast	1996	Jan	h	69	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	1	4
Scotland	Shetland / Southeast	1996	Feb	h	87	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	6	0

Appendix 1. Dietary data of harbour seal across its European distribution from scat analysis used to provide the CAs.

					Diet composition																		
Country	Locality	Year	Period	Ref	Gadidae	Osmeridae	Clupeidae	Scombridae	Belonidae	Carangidae	Mugilidae	Anarhichidae	Ammodytidae	Cottidae	Callionymidae	Gobiidae	Zoarcidae	Scorpaenidae	Pleuronectidae	Scophthalmide	Soleidae	Others Specie	Cephalopdos
Scotland	Shetland / Southeast	1996	Mar	h	42	0	0	0	0	0	0	0	56	0	0	0	0	0	0	0	0	0	1
Scotland	Shetland / Southeast	1996	Apr	h	29	0	3	0	0	0	0	0	64	0	0	0	0	0	0	0	0	7	0
Scotland	Shetland / Southeast	1995	May	h	21	0	1	0	0	0	0	0	67	0	0	0	0	0	0	0	0	3	2
Scotland	Shetland / Southeast	1995	Jun	h	22	0	32	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	1
Scotland	Shetland / Southeast	1995	Jul	h	60	0	16	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	1
Scotland	Shetland / Southeast	1995	aug	h	49	0	24	0	5	0	0	0	16	0	0	0	0	0	0	0	0	2	1
Scotland	Shetland / Southeast	1995	Sep	h	40	0	6	0	34	0	0	0	15	0	0	0	0	0	0	0	0	1	0
Scotland	Shetland / Southeast	1995	Oct	h	70	0	2	0	8	0	0	0	17	0	0	0	0	0	0	0	0	0	1
Scotland	Shetland / Southeast	1995	Nov	h	56	0	3	0	9	0	0	0	12	0	0	0	0	0	0	0	0	0	15
Scotland	Shetland / Southeast	1995	Dec	h	87	0	0	0	1	0	0	0	10	0	0	0	0	0	0	0	0	0	3
Scotland	Shetland / Mousa	1995	Spr	i	22	0	20	0	0	0	0	0	51	0	0	0	0	0	4	0	0	2	1
Scotland	Shetland / Mousa	1996	Spr	i	2	0	48	0	0	0	0	0	49	0	0	0	0	0	0	0	0	0	1
Scotland	Shetland / Mousa	1997	Spr	i	30	0	8	0	0	0	0	0	60	0	0	0	0	0	1	0	0	0	1
Scotland	Shetland / Mousa	1994	Sum	i	56	0	12	0	7	0	0	0	18	0	0	0	0	0	1	0	0	0	1
Scotland	Shetland / Mousa	1995	Sum	i	50	0	19	0	14	0	0	0	13	0	0	0	0	0	0	0	0	1	1
Scotland	Shetland / Mousa	1996	Sum	i	44	0	28	0	6	0	0	0	7	0	0	0	0	0	2	0	0	2	3
Scotland	Shetland / Mousa	1997	Sum	i	37	0	18	0	22	0	0	0	11	0	0	0	0	0	3	0	0	4	2
Scotland	Hebrides	1993	Sum	j	47	0	2	1	0	37	0	0	1	0	0	0	0	0	0	0	0	12	0
Scotland	Hebrides	1994	Spr	j	80	0	0	0	0	0	0	0	2	0	0	0	0	0	5	0	0	10	3
Scotland	Hebrides	1993	Aut	j	39	0	29	0	0	0	0	0	4	0	0	0	0	0	2	0	0	26	0
Scotland	Hebrides	1994	Sum	j	68	0	20	6	0	0	0	0	1	0	0	0	0	0	0	0	0	2	3

Appendix 1. Dietary data of harbour seal across its European distribution from scat analysis used to provide the CAs.

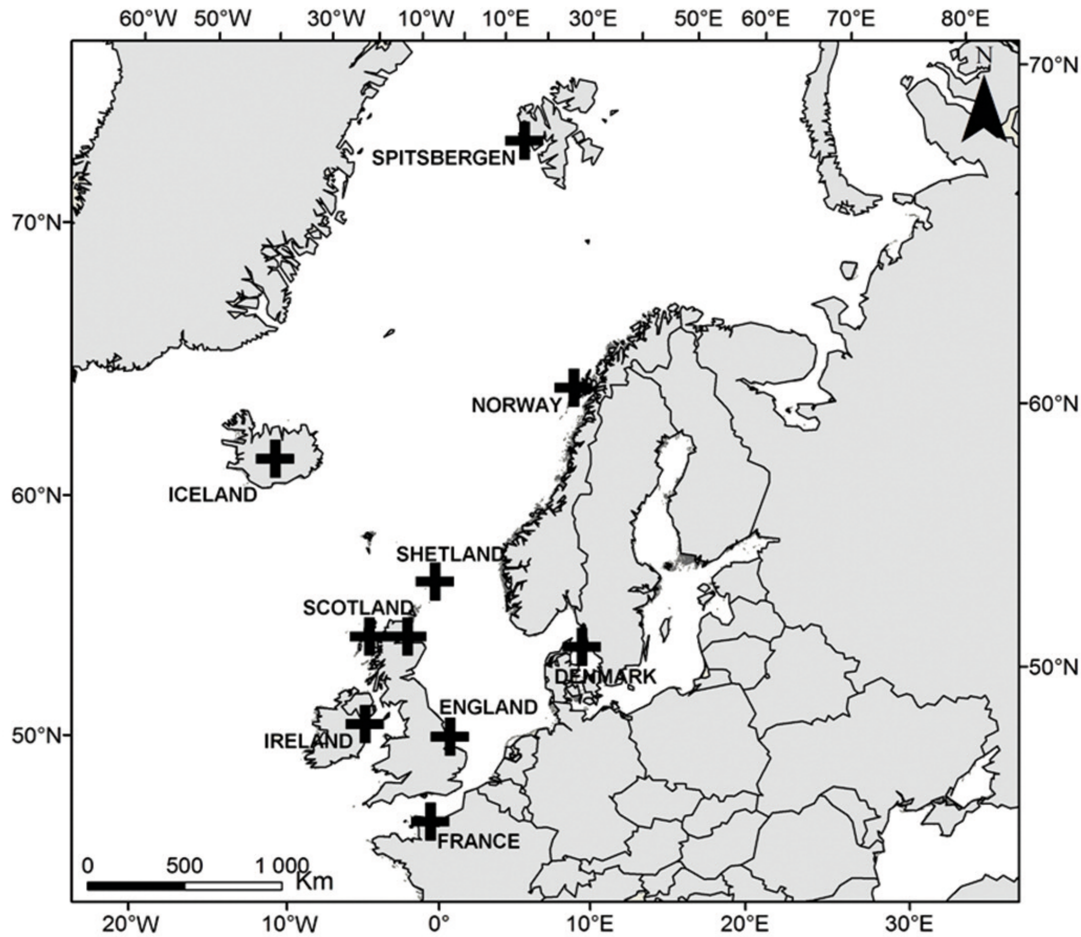
					Diet composition																		
Country	Locality	Year	Period	Ref	*Gadidae*	*Osmeridae*	*Clupeidae*	*Scombridae*	*Belonidae*	*Carangidae*	*Mugilidae*	*Anarhichidae*	*Ammodytidae*	*Cottidae*	*Callionymidae*	*Gobiidae*	*Zoarcidae*	*Scorpaenidae*	*Pleuronectidae*	*Scophthalmide*	*Soleidae*	*Others Specie*	*Cephalopdos*
Scotland	Hebrides	1994	Aut	j	47	0	10	2	0	36	0	0	1	0	0	0	0	0	0	0	0	4	0
Scotland	Moray Firth	1988/89	Win	k	2	0	92	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0
Scotland	Moray Firth	1992	Sum	l	4	0	4	0	0	0	0	0	64	0	0	0	0	0	11	0	0	0	15
Scotland	Moray Firth	1989	Sum	m	2	0	12	0	0	0	0	0	86	0	0	0	0	0	0	0	0	0	0
Scotland	Moray Firth	1989/90	Win	m	3	0	1	0	0	0	0	0	91	0	0	0	0	0	1	0	0	2	3
Scotland	Moray Firth	1990	Sum	m	2	0	1	0	0	0	0	0	44	0	0	0	0	0	9	0	0	4	41
Scotland	Moray Firth	1990/91	Win	m	20	0	3	0	0	0	0	0	60	0	0	0	0	0	6	0	0	0	4
Scotland	Moray Firth	1991	Sum	m	3	0	2	0	0	0	0	0	20	0	0	0	0	0	11	7	0	0	64
Scotland	Moray Firth	1991/92	Win	m	43	0	1	0	0	0	0	0	49	0	0	0	0	0	4	0	0	0	3
Scotland	Moray Firth	1992	Sum	m	5	0	3	0	0	0	0	0	65	0	0	0	0	0	7	1	0	0	20
Scotland	Moray Firth	1991-93	Sum	n	5	0	0	0	0	0	0	0	0	0	0	0	0	0	19	1	0	1	30
Scotland	Moray Firth	1991-93	Sum	n	6	0	2	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	18
Scotland	Moray Firth	1989	Sum	o	3	0	2	0	0	0	0	0	68	0	0	0	0	0	19	0	0	5	4
Ireland	Dundrum Bay	1995	All	p	15	0	6	0	0	0	0	0	0	0	0	0	0	0	76	0	0	3	0
Ireland	Dundrum Bay	1996	All	p	52	0	5	0	0	0	0	0	0	0	0	0	0	0	34	0	0	9	0
Ireland	Dundrum Bay	2000	All	p	77	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	6	0
Ireland	Dundrum Bay	1995	All	p	3	0	0	0	0	0	0	0	0	0	0	0	0	0	96	0	0	1	0
Ireland	Dundrum Bay	2000	All	p	40	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	5	0
England	The Wash	1990	Aut	q	61	0	1	0	0	0	0	0	3	9	3	6	0	0	8	0	6	4	0
England	The Wash	1991	Win	q	48	0	3	0	0	0	0	0	1	4	0	37	0	0	4	0	2	2	0
England	The Wash	1991	Spr	q	17	0	0	0	0	0	0	0	4	2	23	9	0	0	11	0	14	22	0

Appendix 1. Dietary data of harbour seal across its European distribution from scat analysis used to provide the CAs.

Country	Locality	Year	Period	Ref	Diet composition																		
					Gadidae	Osmeridae	Clupeidae	Scombridae	Belonidae	Carangidae	Mugilidae	Anarhichidae	Ammodytidae	Cottidae	Callionymidae	Gobiidae	Zoarcidae	Scorpaenidae	Pleuronectidae	Scophthalmide	Soleidae	Others Specie	Cephalopdos
England	The Wash	1991	Sum	q	29	0	0	0	0	0	0	0	4	1	38	2	0	0	20	0	3	3	0
England	The Wash	1991	Aut	q	57	0	1	0	0	0	0	0	1	24	2	6	0	0	4	0	5	1	0
England	The Wash	1992	Win	q	41	0	1	0	0	0	0	0	1	5	4	28	0	0	3	0	16	2	0
England	The Wash	1992	Spr	q	29	0	0	0	0	0	0	0	3	6	17	9	0	0	8	0	24	5	0
England	The Wash	1992	Sum	q	18	0	0	0	0	0	0	0	3	3	26	11	0	0	32	0	4	4	0
France	Baie des Veys	2000	Sum	r	1	0	0	0	18	0	54	0	0	0	2	0	0	0	25	0	0	0	0
France	Baie des Veys	2001	Sum	r	0	0	0	0	23	0	50	0	0	0	0	0	0	0	25	0	2	0	0
France	Baie des Veys	2003	Sum	r	2	0	0	0	8	0	65	0	0	0	8	0	0	0	15	0	0	1	0
France	Baie des Veys	2004	Sum	r	1	0	0	0	40	1	14	0	5	0	4	0	0	0	33	0	1	0	0

Period – All: all the year; Sum: summer; Aut: autumn; Win: winter; Spr: spring; Jan to Dec: January to December / Réf. – a: Anderson *et al.* 2004; b: Haukson and Bogasson 1997; c: Berg *et al.* 2002; d: Bjørge *et al.* 2002; e: Härkönen and Heide-Jorgensen 1991; f: Härkönen 1987; g: Brown and Pierce 1997; h: Brown and Pierce 1998; i: Brown *et al.* 2001; j: Pierce and Santos 2003; k: Thompson *et al.* 1991; l: Thompson *et al.* 1996; m: Tollit and Thompson 1996; n: Tollit *et al.* 1998; o: Pierce *et al.* 1991; p: Wilson *et al.* 2002; q: Hall *et al.* 1998; r: Spitz *et al.* 2010 (this study).

Appendix 2. *Map of the localisation of the used studies to provide the CAs.*



SCOTLAND covers mainland and Hebrides islands, Shetland islands at more northern latitude were isolated.