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Food remains in a harp seal, *Phoca groenlandica*, stranded in the Netherlands

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Summary

Food remains in stomach, intestines and faeces of a harp seal that stranded on the Dutch coast were examined. In total, 100 fish-otoliths were found, representing at least 52 fish. The most important prey species was whiting (*Merlangius merlangus*), of which about 6 kg had been eaten by the seal. Seven other species of fish were identified, indicating opportunistic feeding behaviour. Two of these do not normally occur in inshore waters, suggesting that the seal had ingested these prey at a distance of at least 75 km from the stranding location. Other prey may have been eaten anywhere between this location and the stranding site.

Introduction

Harp seals *Phoca groenlandica* are pelagic seals of the pack-ice zone. They live in the North Atlantic and Arctic Oceans, from Newfoundland to the Barents and White Seas (Pedersen, 1974; Ronald *et al.*, 1982; King, 1983). Harp seals migrate south in winter, but in the eastern Atlantic most remain north of Iceland, with only some stragglers reaching the North Sea. Since 1978 considerable numbers yearly invade northern Norway in winter and spring, with numbers peaking in 1987 and 1988. In these two years, the harp seals also ventured unusually far south along the Norwegian west-coast (Haug *et al.*, 1990; Øritsland, 1990).

Until 1986, harp seals had never been recorded in the Netherlands (Wolff, 1981; J. S. van de Kamp, in litt.). In 1987, 1988 and 1990 however, a small number of harp seals (less than 5 per year) stranded on the Dutch coasts. These strandings appear to be associated with the presence of unusually large numbers of harp seals in coastal waters of Finnmark, north Norway. Food shortage in their home-waters may explain this movement of the seals, but the stranded animals on the Dutch coasts did not seem to have fared much better. Most died, and their stomachs were found empty on autopsy, except for nematodes, some pebbles and some plastic (J. S. van de kamp and L. Vedder, Seal Centre Pieterburen, pers. comm.).

Since food remains had never been retrieved from any of the stranded seals, it is not known whether harp seals that end up in the southern North Sea are still able to hunt, and if so, what they feed on. Some stranded alive however, and were in good enough condition to be treated successfully in the Seal Centre at Pieterburen indicating that they had not starved beyond recovery. This paper provides the first information on the food eaten by a harp seal in Dutch waters.

Methods

In the afternoon of 15 March 1990, a harp seal stranded on the beach near Den Helder, The Netherlands (ca. 53°N). The animal died during the night, but first it defecated, and the solid parts of the faeces (about $10 \times 4 \times 4$ cm) were collected. A small, but unknown quantity of more fluid faeces was lost. The seal body was kept deep-frozen, and was thawed for autopsy on 11 April 1990.

Since the production of faeces seemed indicative of a recent meal, this material was examined. The faeces were put in a 2 litre measuring glass, under gently steaming water, and teased apart by hand. The running water made the jar overflow, taking with it small, buoyant and floating particles. Heavy particles, like fish-otoliths, fish bones and eye-lenses remained on the bottom of the jar, and could easily be recovered. The same method has been used by Haug *et al.* (1990) on the stomachs of harp seals, by Havinga (1933) on harbour seals *Phoca vitulina*, and by Piersma (1988) on grebes (Aves, Podicipedidae).

After about 1 hour of treatment, the faeces were reduced to particles of less than 0.5 cm cross section, and all visible otoliths were removed from the bottom of the jar. Since it was felt that small (e.g. clupeoid) otoliths could still be present, the remaining debris were treated with an ultrasonic disintegrator (20,000 Hz; 75 Watt), to break the faeces-particles further down. Before the disintegrator was used, first a test run was done with two herring,

Clupea harengus, otoliths, showing that these fragile otoliths were not extensively damaged by the process.

On 26 April 1990 the stomach and intestines, that were kept frozen after the autopsy, were thawed, cut open, and the contents were removed by scraping and washing. These were put into the same 2 litre jar and treated as mentioned above (the stomach contained ca. 100 grams wet weight of nematodes, which were first removed with pincers).

Results

The faeces produced 27 otoliths, 17 whiting *Merlangius merlangus*, one cod *Gadus morhua*, one sole *Solea solea*, two dab *Limanda limanda*, three long rough dab *Hippoglossoides platessoides*, two four-bearded rockling *Enchelyops cimbrius*, and one dragonet *Callionyme* spec. The faeces further contained a few fish bones (no skulls), and 32 fish eye-lenses. In the stomach nine whiting otoliths were found. The intestines contained 59 whiting, one sole, two dragonet, *Callionyme lyra*, and two northern rockling *Cilita septentrionalis* otoliths. The fragile tips of all gadoid otoliths were missing, or at least eroded. Therefore, otolith-width was taken as a measure of prey size (cf. Camphuysen, 1990). Whiting otoliths were measured with vernier callipers to the nearest 0.1 mm. Of all other otoliths, lengths were measured to the nearest 0.1 mm with a micrometer mounted on a binocular dissecting microscope. In the sole, the largest possible diameter was taken as otolith length.

In order to estimate fish length from otolith length, several otolith reference collections were used, all based on fishes caught in the area where the harp seal had stranded. For whiting, Camphuysen (1990) gives the equation relating otolith width to fish length:

$\ln(F_{mm}) = 3.86 + 1.15^* \ln(OW)$; $n = 75$; $r = 0.99$, where: F_{mm} is total fish length in mm, and OW is otolith width in mm.

For the four-bearded rockling, dragonet, dab and long rough dab the NIOZ reference collection was used. The equations relating otolith length to fish length are:

$\ln(F_{cm}) = 1.446 + 1.180^* \ln(OL)$; $n = 19$; $r = 0.98$ (Rockling),
$\ln(F_{cm}) = 1.360 + 1.390^* \ln(OL)$; $n = 70$; $r = 0.97$ (Dragonet),
$\ln(F_{cm}) = 1.271 + 1.117^* \ln(OL)$; $n = 202$; $r = 0.97$ (Dab),
$\ln(F_{cm}) = 1.328 + 1.042^* \ln(OL)$; $n = 26$; $r = 0.97$ (Long Rough Dab),

where: F_{cm} is total fish length in cm, and OL is otolith length in mm.

For the sole, A. Rijnsdorp of the Netherlands Institute for Fishery Investigations kindly produced the equation:

$\ln(OD) = 1.177 + 0.942^* \ln(F_{cm})$; $n = 114$; $r = 0.97$, where: OD is largest diameter of otolith in 0.05 mm.

The cod otolith was very worn and difficult to measure. Comparison with reference otoliths, indicated a fishlength of about 20 cm. The northern rockling is a little known fish in the North Sea, and very few reference otoliths have been collected. However, the two otoliths of this species found in the seal (1.6 and 1.4 mm long) very closely resembled a pair in the collection of P. A. M. Gaemers of the National Museum of Natural History. They belonged to a fish of 7 cm, weighing 5 gram.

In total, 85 whiting otoliths were found, 43 from the left and 42 from the right side of a fish's head (Fig. 1). Therefore, the seal had eaten at least 43 whiting. The state of the otoliths was examined before fish size was calculated. Although gadoid otoliths withstand erosion during passage in a seal's stomach relatively well, they may be "reduced up to 45% in lateral thickness during their passage through the gut" (Prime, 1979; Jobling & Breiby, 1986). The otoliths in the present case also showed considerable wear. They were ranked "1" (original structure still present, though faded); "2" (outline smooth, with at most remnants of original lobes still protruding); or "3" (very worn and thin). For want of a better estimate it was considered that otolith width in the class 1 otoliths had been reduced to 90% of the original size; in class 2 otoliths to 80%, and in class 3 otoliths to 70%, and otolith width was accordingly adjusted. Since the magnitude of this adjustment may not be precise, the original photograph of the otoliths is presented in Figure 2. With the present adjustments fish lengths of the whiting were calculated to have ranged from 18.2 to 32.8 cm. (Fig. 3). Note that a fish length is given for every otolith, i.e. the true total number of fish involved is about half the number of otoliths recorded.

The two sole otoliths were probably a pair, even though one was found in the intestines and one in the faeces. They measured 5.1 and 5.2 mm, and were slightly worn (class 1). The corresponding fish length is 35.4 cm. All other otoliths were also considered to have been reduced to 90% of their original size. The dab otoliths were one single of 4.1 mm and an apparent pair of 2.7 and 3.0 mm. The (pair of) long rough dab otoliths measured 3.2 and 3.3 mm. Corresponding lengths of these three flatfishes is 19.4, 12.9, and 14.4 cm, respectively. The four-bearded rockling otoliths measured 3.5 and 3.7 mm and are considered a pair. The corresponding fish length is 21.5 cm. The *Callionymus lyra* otoliths in the

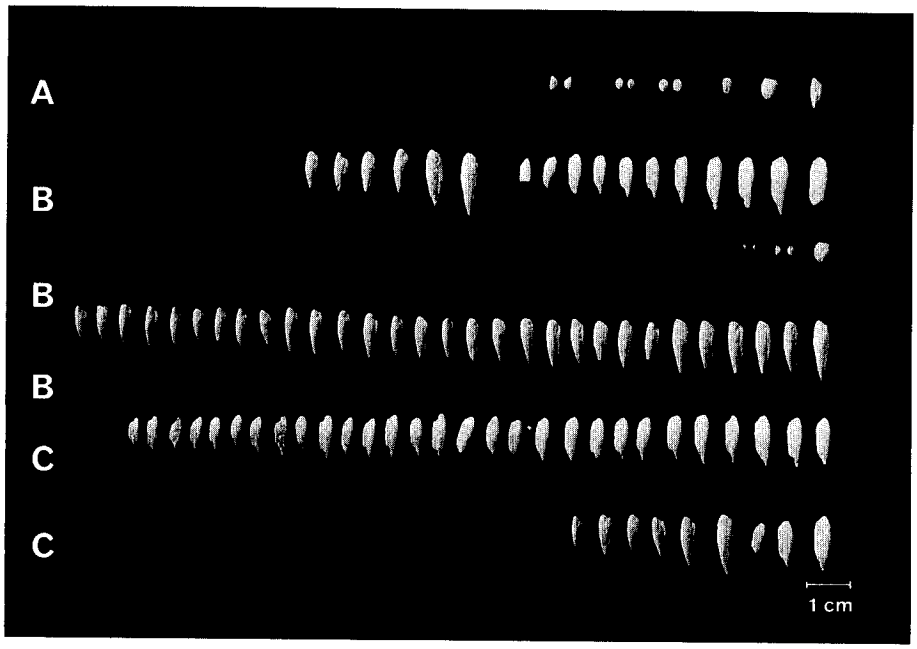

Figure 1. Overview of the otoliths found in the stranded harp seal. Stomach (top row, marked A): 9 whiting otoliths. Intestines (rows marked B): 59 whiting, one sole, and pairs of dragonet and northern rockling otoliths. Faeces (bottom rows, marked C): 17 whiting, one cod, one sole, one dab, pairs of long rough dab, dab, four- bearded rockling otoliths, one very small dragonet spec. otolith was also found, but was not photographed.

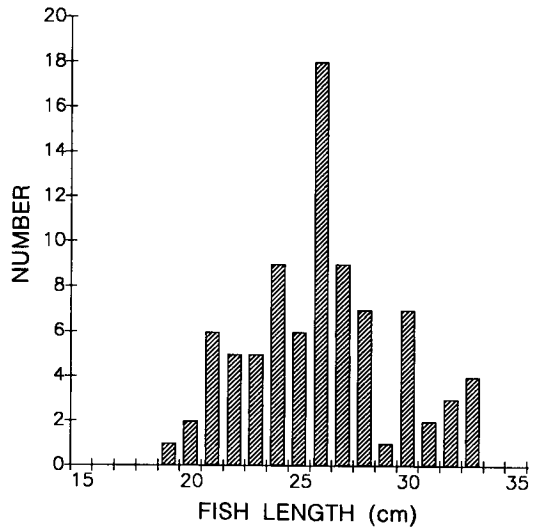

Figure 2. Length-frequency distribution of the whiting, calculated from otoliths-widths, corrected for wear. Note that each fish has two otoliths, and should ideally be represented twice.

intestines (2.8 and 2.9 mm) were also considered a pair. Finally, the *C.* spec. otolith in the faeces measured 1.1 mm. This *C.* spec. otolith is further treated as belonging to *C. lyra.* The dragonets measured 19.1 and 5.1 cm. It is possible, that the smaller round-fishes were in fact prey of the larger whiting. If the whiting had eaten them shortly before being eaten in turn by the seal, the seal would also have digested the little fish, which were of little significance anyway. Whiting thus was the most important prey species found in this harp seal by number (82.7%) of 52 fishes found, see Fig. 4a.

For calculating fish mass from the estimated fish lengths, Coull *et al.* (1989) and Netherlands Institute for Sea Research (NIOZ, unpublished) were used. Fish mass in grams relates to fish length in cm following the general equation:

$$W = A*L^B$$

The relevant values for A and B are given in Table 1. For each prey species, total fish mass was calculated. The calculated contribution of the different groups to the seal's diet in mass is depicted in Fig. 4b. Whiting is the most important prey (89% on the basis of mass), but the sole (488 gram) was the largest fish ingested.

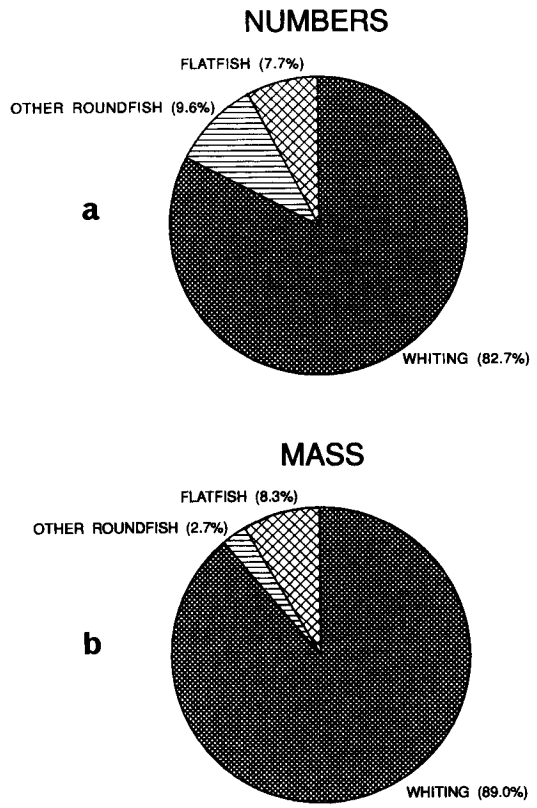

Figure 3. The diet of the stranded harp seal. A: proportions on the basis of numbers of fish. B: proportions based on mass.

Table 1. Values for the parameters A and B in the equation $W = A*L^B$, for the species of fish found in the stranded harp seal. (1): from Coull *et al.*, 1989; (2): NIOZ-data, unpublished.

Fish Species	A	B
Whiting (1)	0.0102	2.9456
Cod (1)	0.0197	2.8571
Four-bearded Rockling (1)	0.0035	3.1062
Dragonet (2)	0.0262	2.4415
Sole (1)	0.0036	3.3133
Dab (2)	0.0056	3.1660
Long Rough Dab (2)	0.0016	3.4802

Discussion

The diet of harp seals in their home waters has been studied by several authors. In an overview by Ronald *et al.* (1982), they are reported to eat mainly fish, with capelin, *Mallotus villosus*, herring, and cod, being the most common prey. In northern Norway the harp seals were found to feed opportunistically. In stomachs of drowned seals many different fish species, among them flatfishes were found, as well as some invertebrates. The most important prey species were cod and other gadoids, and herring and capelin (Haug *et al.*, 1990). Therefore, it is not surprising that the harp seal that stranded near Den Helder had eaten whiting, some flatfish and several other species of fish. Most of the fish species eaten by the harp seal are common demersal fish in waters around Den Helder in winter. Truly pelagic species were not taken, although both herring and sprat, *Sprattus sprattus*, are common in the southern North Sea in winter. Clupeoid otoliths are relatively quickly eroded by the acidic digestive secretion of a predator (Prime, 1979; da Silva & Neilson, 1985; Jobling & Breiby, 1986; Murie & Lavigne, 1986), but the retrieval of other small otoliths indicates that clupeoids should have been found in this seal, had it been feeding on herring or sprat. Moreover, Thompson *et al.* (1991) found numerous otoliths in the faeces of harbour seal and they argue that digestion of these otoliths in free-living seals may be less rapid than previously considered.

The harp seal appears to have been hunting over the sea floor for whiting, taking other bottom-dwelling fish opportunistically. Most fish could have been taken close to the location of stranding. Also the presence of otoliths in the stomach indicates foraging close by. Only the long rough dab and the rockling occur further offshore, at least at a distance of 75–100 km north of the stranding location (J.IJ. Witte, NIOZ, pers. comm.). The presence of these otoliths in the seal thus seem indicative of offshore feeding of the seal on its way to Den Helder. To explain both the presence of otoliths in intestines and faeces that must have taken at a considerable distance from Den Helder and the presence of otoliths in the stomach, one must assume that the animal swam south after a meal at a distance of at least 75 km north of Den Helder, and taking more fish on its way, before it stranded. In general, seal stomachs become empty shortly after feeding has stopped, but it may take more than 12 hours before the intestines are empty (Havinga, 1933; Härkönen, 1986; Jobling & Breiby, 1986; Murie & Lavigne, 1986). The stress of stranding appears to have stopped the emptying of the gastro-intestinal tract, however. This may be inferred from the presence of otoliths in the stomachs at the time of death, and from the presence of fish bones and eye-lenses in the faeces, but complete absence of these items in the digestive tract, indicates abnormally long exposure to the gastric acid (see also Murie & Lavigne, 1986).

The numbers and sizes of fish considered to have been taken by the harp seal are subject to several

sources of error. Härkönen (1986) lists the studies on otoliths in seals, and warns that only about 86% of gadoid otoliths are usually retrieved. Although some otoliths were retained for a long time in the seal's body, some other otoliths may have been excreted at sea or on the beach, or lost with the unrecovered faeces at the seal centre. At least 2 gadoid, 1 dragonet, and 1 dab otolith were missing. Therefore, the total number of otoliths found provide only an impression of the seal's diet during its last one or two days alive.

The sizes and masses of the fish may be severely biased if the correction factors for wear are too far out of order. The calculated total mass of 7112 gram, or 7.9% of this seal's body mass (ca. 90 K) fits within the range of values for food intake given in the literature. Reported values for daily fish consumption in seals range widely, from less than 2% to over 10% of the body mass per day (see: Havinga, 1933; Markussen *et al.*, 1990; Kastelein *et al.*, 1990; Murie & Lavigne, 1986). Acknowledging the uncertainties in the present calculations on the amount of food ingested, the 100 otoliths found in the stranded seal still show that harp seals may feed in the southern North Sea, after a long migration.

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References

Camphuysen, C. J., 1990. Dieet, leeftijd en geslacht van de Zeekoet *Uria aalge* in de Nederlandse Noordzee in het voorjaar. *Sula* **4:** 41–54.

Coull, K. A., A. S. Jermyn, A. W. Newton, G. I. Henderson, & W. B. Hall, 1989. Length/weight relationships for 88 species of fish encountered in the North East Atlantic: 1–81. Scottish Fisheries Research Report Number 43–1989, DAFS, Scotland.

Havinga, B., 1933. Der Seehund (*Phoca vitulina* L.) in den Holländischen Gewässern. Tijdschr. Ned. Dierk. Ver., Ser. 3, **3:** 79–111.

Härkönen, T., 1986. Guide to the otoliths of the bony fishes of the Northeast Atlantic: 1–256. Danbiu Aps., Hellerup.

Haug, T., A. B. Krøyer, K. T. Nilssen & K. I. Ugland, 1990. Harp seal (*Phoca groenlandica*) invasions in North Norwegian coastal waters: a preliminary report on age composition and feeding habits. ICES C.M. 1990/N: **6:** 1–24.

Jobling, M., & A. Breiby, 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. *Sarsia* **71:** 265–274.

Kastelein, R. A., P. R. Wiepkema, & N. Vaughan, 1990. The food consumption of grey seals (*Halichoerus grypus*) in human care. *Aquatic Mammals* **15:** 171–180.

King, J. E., 1983. Seals of the world: 1–240. Brit. Mus. (Nat. Hist.), Univ. Queensland Press, St. Lucia.

Markussen, N. H., M. Ryg & N. A. Øritsland, 1990. Energy requirements for maintenance and growth of captive harbour seals, *Phoca vittulina*. *Can. J. Zool.* **68:** 423–426.

Murie, D. J. & D. M. Lavigne, 1986. Interpretation of otoliths in stomach content analyses of phocid seals: quantifying fish consumption. *Can. J. Zool.* **64:** 1152–1157.

Øritsland, T., 1990. Seals in the Northeast Atlantic and interactions with fisheries. Comité Arctique International commentary, February 1990: 10–13.

Pedersen, A., 1974. Die Nordpolaren Robben: 1–64 Die Neue Brehm Bücherei, Wittenberg, Lütherstadt pp.

Piersma, T., 1988. Body size, nutrient reserves and diet of red-necked and slavonian grebes *Podices grisegena* and *P. auritus* on Lake IJsselmeer, The Netherlands. *Bird Study* **35:** 13–24.

Prime, J. H., 1979. Observations on the digestion of some gaboid fish otoliths by a young Common Seal. ICES C.M. 1979/N: **14:** 1–3. Marine Mammals Committee.

Ronald, K., P. J. Healey & H. D. Fisher, 1982. The harp seal, *Pagophilus groenlandicus*.: 267–293 in: Mammals in the Seas, Volume IV: Small Cetaceans, Seals, Sirenians and Otters. FAO Fisheries Series, No 5, Rome.

Silva, J. da & J. D. Neilson, 1985. Limitations of using otoliths recovered in scats to estimate prey consumption in seals. *Can J. Fish. Aquat. Sci.* **42:** 1439–1442.

Thompson, P. M., G. J. Pierce, J. R. G. Hislop, D. Miller & J. S. W. Diack, 1991. Winter foraging by common seals (*Phoca vitulina*) in relation to food availability in the inner Moray Firth, N.E. Scotland. *J. Anim. Ecol.* **60:** 283–294.

Wolff, W. J. 1981. Marine Mammals of the Wadden Sea: 7–14 in: P. J. H. Reijnders & W. J. Wolff (Eds.): Final Report of the section 'Marine Mammals' of the Wadden Sea Working Group, Balkema, Rotterdam.