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Fish preference by the harbour seal (*Phoca vitulina*), with implications for the control of damage to fishing gear

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This study compares food preference for different fish species by harbour seals in a seal colony off the northwest coast of Sweden. Seals were offered several different species of dead fish in net cages and showed a preference for herring, gadids and flatfish. Other fish such as eel and eelpout were mostly rejected. Five-bearded rockling, bullrout and small labrids were always rejected. Seal visits occurred at only 30% of the total number of feeding opportunities, in spite of the fact that seals were constantly present in the area. The temporal and spatial aggregation of the pattern of seal visits to the cages was not randomly distributed. This study suggests that only a minority of the seals in the area used the baited cages and that the feeding preferences could be a result of specialised prey selection. This has important implications for the choice of appropriate management options to control seal damage of fishing gear. It is predicted that it may be a more successful and efficient option to focus on those individual seals found in the vicinity of the fishing gear, rather than to carry out random culling amongst the whole population.

Keywords: harbour seal, food preference, by-catch, eel fishery.

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Introduction

Along the Swedish west coast the conflict between of harbour seals (*Phoca vitulina*) and fishermen is an increasing problem (Westerberg *et al.*, 2000). The conflict involves competition for fish between seals and man and, more importantly, damage to fishing gear, especially in the eel fishery. This fishery, which is the only remaining coastal fishery left after a severe depletion of demersal fish during the last two decades (Lagenfeldt & Svedäng, 1999), mainly involves the use of small unbaited fyke nets. The fishery is conducted in shallow areas at depths of 1–4 m. By-catch is common, especially of juvenile cod (*Gadus morhua*), flatfish, wrasse sp. and eelpout (*Zoarces viviparus*), which can surpass the number of eels (*Anguilla anguilla*) retained by the gear several times over (Swedäng, 1999).

Fishing gear damage occurs with a spatial variability not always correlated to the distance to harbour seal colonies (haul-outs) and with a temporal variability peaking during late spring and early autumn, with increased damage after windy periods (Westerberg *et al.*, 2000). Seals damage fyke nets by tearing a hole from the outside in the end (the bag) of the fyke net. The size of the hole can be from a few meshes (20 mm) up to 300 mm. This means an economic loss for the fisherman both in terms of lower catches and time and money spent in repairing gear. The total direct economical loss is estimated to be around one million Swedish krona (110 000 Euros) for approximately 50 fishermen, and is increasing at a high rate (Westerberg *et al.*, 2000). The harbour seal is thought to be responsible for the bulk of the damage, although there are also indications that the cormorant (*Phalacrocorax carbo*) could cause similar holes (Engström, 1998).

The harbour seal is the only numerous seal species in Kattegat-Skagerrak. The mean number of seals counted during three aerial surveys in 2000 was 9700 (Härkönen, T. pers. comm.).

The study area, a haul-out area, is situated in the southwest Koster Islands in the northern Skagerrak off the Swedish west coast (Figure 1). The highest concentration of harbour seals occurs during the breeding, mating and moulting seasons between May and

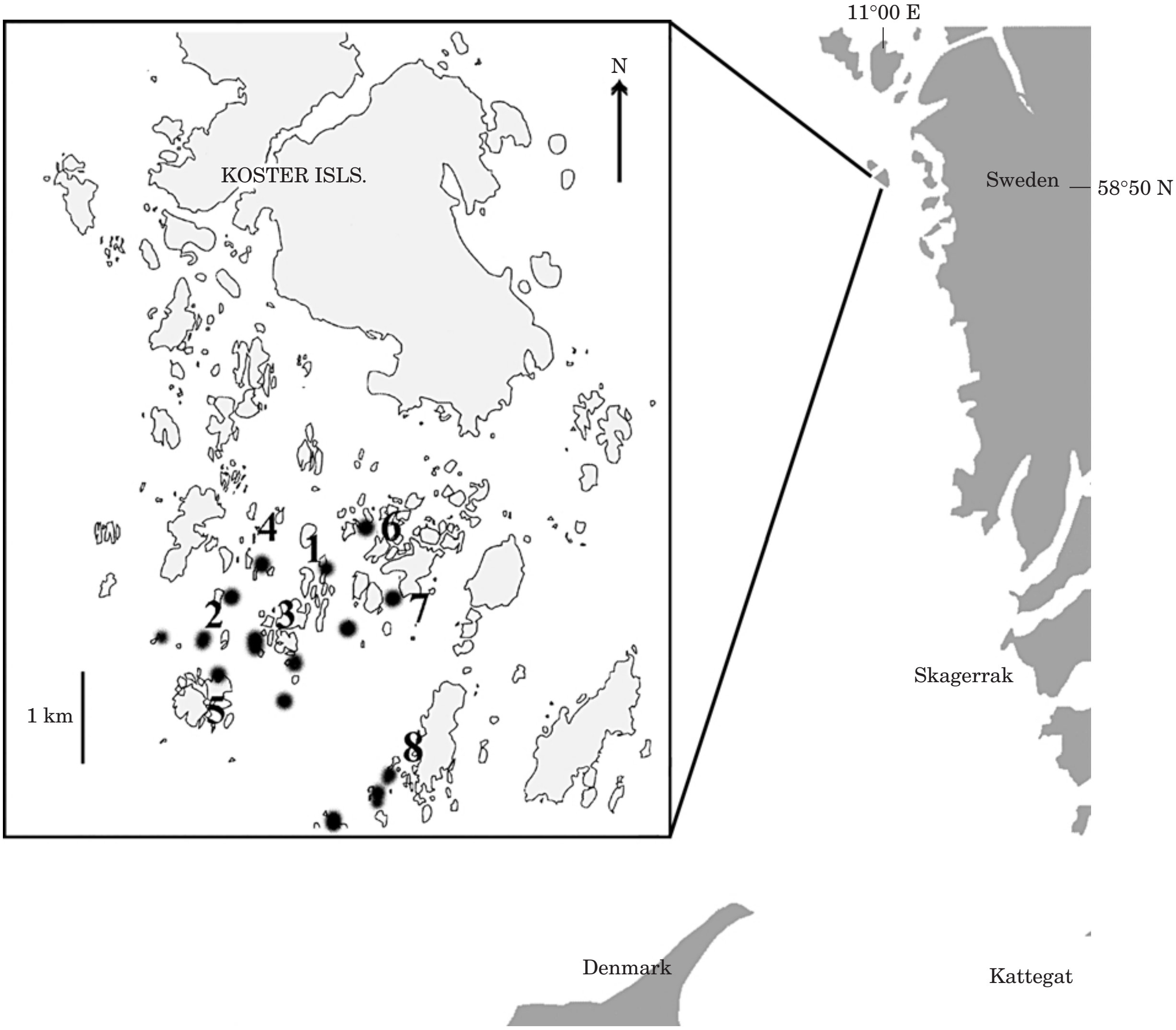

Figure 1. Map of the study area with feeding stations and haul-outs indicated with dark grey spots.

September, when up to several hundred seals gather on the shore. During the summer period, haul-out times vary markedly between the sexes and among different age groups (Härkönen *et al.*, 1999). During the rest of the year the seals are more dispersed, but some of the skerries in the area are frequently used as haul-out places between feeding trips, under suitable weather conditions (Härkönen, 1987b).

The study was initially designed with a view to testing different seal deterrent methods by first habituating wild seals to take food from feeding stations. However, because of the unexpected nature of the seals' reactions to the baiting trials, the experiment was redesigned to include information about seal behaviour in relation to the eel fyke-nets, and to test food preferences.

Materials and methods

Baiting procedure

Eight feeding stations (Figure 1) were chosen near to the most frequently used harbour seal haul-out locations. The experiment was performed during four periods: 8 May–30 July and 3 October–7 December 1997, and 4 May–8 June and 28 August–29 November 1998, for a total of 276 d. At each station, one or two cages were suspended at a depth of at least 1.5 m from the surface and in water around 5–7 m deep, without contact with the bottom. The cages consisted of a metre long tube-shaped net with a diameter of 0.5 m, with a stainless steel frame keeping both ends open. Fish up to 50 cm in

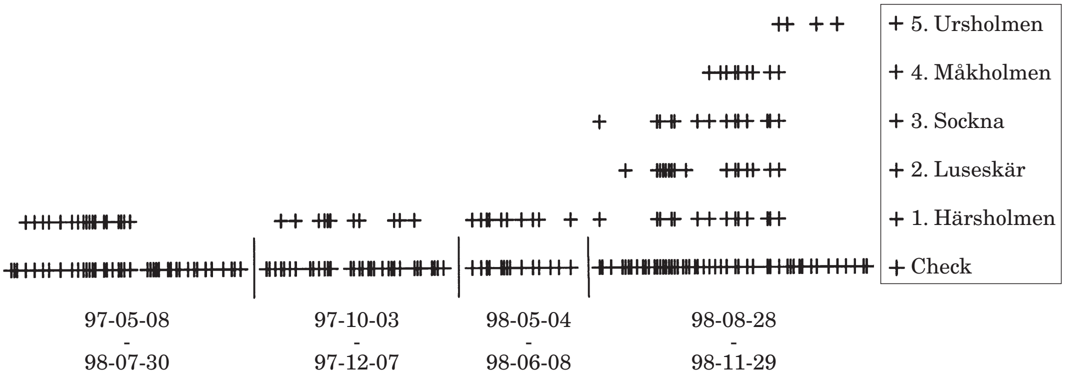

Figure 2. Results for seal visits to station 1 during the whole period of the experiment 1997–1998, and for five stations during autumn 1998.

length were used as bait. Fish were kept frozen for use in the experiment for a period of up to four months. Herring (*Clupea harengus*) or blue whiting (*Micromesistius poutassou*) were initially used as bait because they were readily available from the commercial fishery. One to five whole specimens of each species were threaded through the mouth on a steel ring and hung in the centre of the cage. The bait was inspected and renewed at irregular intervals, but typically every second day. If the cages could not be inspected for a period of three to four days, only occasions when the condition of the bait allowed a clear interpretation of a visit (removal of the bait) or a non-visit were included in the data. Seals visited the cages on 38 of the occasions on which herring and blue whiting were presented together in the same cage. The blue whiting was rejected only once, while herring was never rejected. Based on these observations, herring and blue whiting were considered to have the same preference level and were used as control, against which other fish species were compared. During 1998 and sporadically in 1997 twelve other fish species were added to the cages in various combinations with herring or blue whiting. An unexplained removal of fish from two stations occurred four times during a time span of 14 d in October 1998. In these incidents, all the fish [blue whiting, eels and bullrout (*Myoxocepahulus scorpius*)] were removed completely without any remains of the head left on the baiting rings. These cases of bait removal were not regarded as seal visits, because the pattern of removal was totally different from the other observations. The significance level of rejection between fish species was calculated using a standard probability distribution (binomial distribution). An one-sample run test of randomness was used to test if the sequence of observations of bait removal could be explained by randomness, at a p-level of 0.05 (Siegels and Castle, 1988).

Results

Seal visits

The total number of trials was 580. However, in 48 cases, inspections of the bait could not be interpreted as the presence or absence of a visit from a scavenger since the previous baiting, and these were excluded. Of the remaining 532 trials, 122 were done with herring alone, 98 with blue whiting alone, 38 with herring and blue whiting together, and 274 with herring or blue whiting together with other species. The time until the fish fell off the ring owing to decay varied from 3 d to more than a week, depending on species, thawing procedure and water temperature. Herring was the species most susceptible to decay, with the fastest decomposition of the jaw bone ligaments. Usually the head was left on the ring if a fish was eaten.

The condition of the bait on inspection was interpreted as a seal visit on 162 occasions, or 30% of the trials. Seal visits were clumped into separate time periods. An example of this is seen at station 1, which was baited for the entire length of the experiment (Figure 2). The one-sample run test shows that the pattern of visits are significantly different from a random distribution of visits in time, except for station 5 during autumn 1998 ($p<0.01$). An uneven spatial distribution is also indicated in the pattern shown by stations 1 to 5 during autumn 1998 (Figure 2).

No correlation was found between the probability of a seal visit and the water temperature, which ranged from 3–19°C. Neither wind direction, wind strength nor air pressure (measured 8 km from the study area) influenced the tendency of seals to take the bait. The freshness of the bait did not influence the result in any obvious way, since fish that were reused from an earlier baiting were eaten with the same frequency as fresher fish. On 32

Table 1. Summary data of fish species offered at eight different feeding stations during four periods in 1997 and 1998. These include: length class of the fish, number of times offered, number of times when a seal was considered to have visited the cage and number of times when a seal was considered to have visited the cage as shown by removal of herring or blue whiting, where other fish species were offered at the same time. Significance level p for rejection of the species compared with control was calculated from a binomial distribution.

Fish species	Length (cm)	No. of times offered	No. of removal	No. of times control removed	% rejection	Significance of rejection
Eel *Anguilla anguilla*	33–48	52	1	20	95	p<0.01
Herring *Clupea harengus*	18–25	239	99	—	—	—
Blue whiting *Micromesistius potassou*	24–38	331	83	—	—	—
Gadids*	10–30	48	14	18	22	n.s.
Five-bearded rockling *Ciliata mustela*	20–25	16	0	8	100	p<0.01
Bull-rout *Myoxocepahulus scorpius*	15–23	59	0	24	100	p<0.01
Corkwing wrasse *Crenilabrus melops*	10–16	20	0	10	100	p<0.01
Eelpout *Zoarces viviparus*	19–27	40	1	18	94	p<0.01
Mackerel *Scomber scombrus*	32–42	13	4	5	20	n.s.
Flatfish**	18–27	26	4	6	33	n.s.

*Saithe *Pollachius virens*, Whiting *Merlangius merlangus* and Cod *Gadus morhua*.
**Plaice *Pleuronectes platessa*, Flounder *Platichtys flesus* and Dab *Limanda limanda*.

occasions, one-day-old untouched blue whiting were left in place and complemented with fresh blue whiting. On seven of these occasions, the stations were visited during the following day and in none of these cases were the older fish left untouched. There was even an example of fish up to four days old being completely consumed apart from the head.

Preference test

In the course of the trials, neither herring nor blue whiting were ever rejected in favour of another species that was offered simultaneously. The number of comparisons between some less-used species and the reference species were too few for a thorough test so cod, whiting (*Merlangius merlangus*), saithe (*Pollachius virens*) respective plaice (*Pleuronectes platessa*), flounder (*Platichtys flesus*) and dab (*Limanda limanda*) were pooled together. A conclusion from Table 1 is that there were no rejections of gadids, mackerel or flatfish. In contrast, eel, five-bearded rockling, corkwing wrasse, bullrout and eelpout were less preferred species.

Discussion

Seals, mink (*Mustela vision*) and cormorants are possible predator species present in the study area which might feed from baited cages. The otter (*Lutra lutra*) is extinct in the coastal region. The characteristic way in which our bait fish were taken, leaving the head or jawbones behind, excludes mink and cormorant since they do not leave the heads of large fish. Cormorants swallow fish whole and observations of mink indicate that they bring bigger fish to the shore and tear them into smaller pieces using their teeth and claws. Neither cormorant nor mink were observed in the vicinity of the cages, but harbour seals were often observed close to the cages. Grey seals (*Halichoerus grypus*) also occur in the area, but only very rarely (Härkönen and Lunneryd, 1990), so the harbour seal is probably the main scavenger. Fish such as shark or cod that at least theoretically could eat bait fish are more or less extinct from the area as adults. Decapods (Arthropoda) could not reach the cages suspended in mid-water, and schools of amphipods which might have eaten the dead fish would have left the vertebrae.

Harbour seals feed on a variety of prey, yet the key species are rather few. In the Skagerrak, at least 40 species have been identified by scat analysis during a three year sampling period (Härkönen, 1987a; Härkönen and Heide-Jørgensen, 1991). Seven key species: herring, sprat (*Sprattus sprattus*), cod, blue whiting, whiting, Norway pout (*Trisopterus esmarcki*) and lemon sole (*Microstomus kitt*) contributed over 10% by the weight of the total diet at different periods of time. Other species which have occasionally contributed up to 10% of the dietary composition include sand eels (*Ammodytidae*), and long-rough dab (*Hippoglossoides platessoides*). It has been concluded by many authors that the harbour seal is an opportunistic predator which prefers the most temporally abundant species within its geographical range (Brown and Pierce, 1997; Härkönen, 1987a; Olsen and Bjørge, 1995; Thompson *et al.*, 1996). Prey selection is however proposed by Tollit *et al.* (1997). These authors found that the most abundant species did indeed contribute most of the diet, but that the relative abundance of the remaining species showed less correlation to their contribution to the seal diet.

The pattern of food removal in this study, showing a preference for cod, herring and flatfish with a rejection of other species, largely tallies with the composition of the harbour seal diet determined from the analysis of otoliths found in the area (Härkönen, 1987a; Härkönen and Heide-Jørgensen, 1991). Fish which are normally found in shallower waters with vegetation, such as eels, five-bearded rockling, wrasse and cottids, were rejected in this study. These species also occur in very low frequencies or were absent from the otolith studies, with the single exception of eelpout. The eelpout, a common species in shallow areas, constituted 0–8.1% of the seals' diet during different sampling periods (Härkönen and Heide-Jørgensen, 1991). Eelpout is also occasionally found as a rather common prey species in other areas (e.g. Tollit *et al.*, 1997). The difference between studies may be due to differences in individual seals' preferences for eelpout or to a seasonal shift in their availability as a prey species.

Telemetry studies of harbour seals' feeding patterns have shown that, at least on a limited time scale, individual seals have a regular pattern of visiting specific feeding areas, to which they return after visits to the haul-out sites (Bjørge *et al.*, 1995; Tollit *et al.*, 1998). Specialising in different habitats and prey species might allow individual seals to feed more efficiently. In this study, seals were always observed in the area but the bait was removed in only 30% of trials. This indicates that rather few animals actually took food from the cages. An explanation as to the rejection of the eelpout, from the perspective of prey specialisation amongst seals, could be that none of the seals that were accustomed to eating eelpout happened to visit the cages.

As the individual lengths of the fish were not measured, the issue could have been confused by a size preference on behalf of the seals, e.g. that a seal preferred a larger blue whiting compared with a small wrasse. However, harbour seal are known to feed on fish with a variety of lengths, from whiting of a few centimetres length to ling (*Molva molva*) with a length of 90 cm (Brown and Pierce, 1998).

Another question raised in this study was whether the composition of the prey species trapped in the fyke nets could explain the damage to the gear. Is it the by-catch of other species rather than the eels which attract the seals? In this study, seals rejected eels as food, which suggests that damage may result first and foremost from the seals' attraction to prey other than eels. Therefore finding a way to reduce the by-catch could mean a lower frequency of raided fyke nets. However, fishermen have reported on several occasions finding half-eaten eels inside the fyke nets. Eel otoliths have also been found in small numbers in dietary investigations (Härkönen, 1987a; Härkönen and Heide-Jørgensen, 1991). It is therefore clear that some seals do eat eels, but it could be a very small fraction of the seal population which is responsible.

The irregular pattern of visits to the cages with marked clumping in distinct time periods suggests that only a few of the seals in the local population approached the cages and actually took the bait, and then continued to visit the cages. I suggest that when those individuals disappeard from the haul-out area, none of the other seals in the area were similarly attracted to the bait, or if they were, it was apparently too difficult for inexperienced seals to learn to remove the bait.

The pattern of visits in this study correlates with the reported pattern of damage in the eel fishery, with distinct temporal peaks in raiding during late spring and early autumn. This raises the question of whether an individual foraging specialisation could explain the pattern of damage in the eel fishery. If individual foraging specialisation has lead to the elaborate technique of tearing fyke nets to catch the trapped fish then the variability of damage over time is easier to understand. Even if there is a need for more thorough investigations of individual seal feeding strategies, it is predicted from this study that management options directed towards animals in the vicinity of the gear would be more effective in limiting damage to fyke nets than random actions directed at the whole population.

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