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Feeding Preferences of Harbour Seals (*Phoca vitulina*) Specialised in Raiding Fishing Gear

Sara J. Königson,[1] Karl E. Lundström,[2] Malin M. B. Hemmingsson,[1] Sven-Gunnar Lunneryd,[1] and Håkan Westerberg[1]

[1]*Swedish Board of Fisheries, Box 423, 401 96 Göteborg, Sweden*
[2]*University of Gothenburg, Department of Marine Ecology, Tjärnö Marine Biology Laboratory, 452 96 Strömstad, Sweden*

Abstract

The Swedish eel (*Anguilla anguilla*) fishery has suffered an increase both in damage to fishing gear and in catch losses caused by harbour seals (*Phoca vitulina*). Eel fyke nets, which are the principal type of fishing gear used, tend to incidentally catch species like cod (*Gadus morhua*), flounder (*Platichthys flesus*), and eelpout (*Zoarces viviparus*). These are species known to be important in the harbour seals' diet. This raised the issue of whether it is the eels or the by-caught species, which attract harbour seals to attack fyke nets. To examine this question, trials were made with experimental fyke nets in three geographically separated areas within the Archipelago of Göteborg. In each area, fyke nets with two bags each were baited with eels in one bag and cod, flounder, or eelpout in the other. In all three areas, the harbour seals showed a clear preference for eels in the fyke nets. The results indicated that certain harbour seals specialise in foraging at fyke nets and have developed different feeding preferences compared to other seals. Knowledge about harbour seals' behaviour around fishing gear is important and will be useful in the development of seal-safe fishing gear to prevent damage caused by harbour seals.

Key Words: Harbour seal, *Phoca vitulina*, eel, *Anguilla anguilla*, prey preference, foraging specialisation, fyke net, Kattegatt, Skagerrak, seal-fisheries conflict

Introduction

The eel (*Anguilla anguilla*) is one of the most economically important species in the Swedish fishery. Traps, pound nets, and fyke nets are the traditional fishing gear used to capture them. Fyke nets were introduced to Sweden at the beginning of the 20th century, and remain the principal type of fishing gear used for catching eels on the west coast. Typically, a fisherman uses around 400 fyke nets, emptying them approximately every third day. Generally, the eel fishery is carried out in shallow areas at depths of 1 to 4 m, mainly in the inner archipelagos, between April and November. An eel fyke net is 60- to 120-cm high with one or two fish bags connected by a 5- to 10-m leading net.

Damage to eel fishing gear became more frequent in the late 1980s. Characteristically, the damages were in the fish bags, where the fish gather, and consisted of small holes and tears from 10 to 20 cm in length (Königson et al., 2003). Occasionally, eels were pulled out through the mesh and bitten in half. According to Königson et al. (2003), harbour seals (*Phoca vitulina*) are responsible for most of the damage. In this study, underwater filming for 521 h in an area close to the study area confirmed that harbour seals raid fyke nets, whereas no cormorant (*Phalacrocorax carbo*) attacks were documented. During the same study, 150 h of visual observation, only harbour seals were seen close to the fyke nets. Lunneryd (2001) also concluded that harbour seals were the main scavengers when studying seal preference in a baited cage. Grey seals (*Halichoerus grypus*) also occurred in the area, but only very rarely (Härkönen & Lunneryd, 1990). Cormorants are also known to cause damage in the eel fisheries (Engström, 1998), but the scratch marks usually associated with cormorant damages were absent here. Cormorants are not believed to cause the bigger tears in the fyke nets which often occurred in this study.

The harbour seal damage has become a major problem in the west-coast eel fishery, with an estimated catch loss of 18% or more (Königson et al., 2003). Different ways to mitigate the conflict have been tried. A key question is whether the harbour seals raid the gear to catch eels or if the presence of other by-caught species is the main attractant. Several studies of the diet of harbour seals have concluded that their most important prey items are herring (*Clupea harengus*), species of the cod family, and flatfish; eels are rarely eaten

(Härkönen, 1987; Härkönen & Heide-Jørgensen, 1991; Lunneryd, 2001). The catch in fyke nets is mixed, including several species other than eels, such as cod (*Gadus morhua*), flounder (*Platichthys flesus*), and eelpout (*Zoarces viviparus*). If those species are the target for the harbour seal attacks, then should mitigation concentrate on eliminating the by-catch? This is the question this study addressed.

Materials and Methods

Fieldwork was carried out in the Archipelago of Göteborg in the Kattegat Sea during the 2001 and 2003 fishing seasons. In 2001, the research period was from May until November, and it was from September until November in 2003. In 2001, six fyke nets were placed in two geographically separated areas (Areas 2 & 3 of Figure 1). In 2003, three fyke nets were placed in Area 1, and another three fyke nets were placed in Area 2 (Figure 1). All the areas in the study were subject to a high frequency of damage. The fyke nets in each area were placed within 100 m of each other. The netting was nylon (min. mesh-size of 22 mm and twine gauge of 4 [210D/12 ply]). Each fyke net consisted of two fish bags connected by a leading net with a length of about 6 m. They were placed close to shore in shallow water at a depth of 1 to 4 m. All the fyke nets were baited with live, freshly caught fish in both fish bags, with eels in one fish bag and either cod, flatfish, or eelpout in the other (Figure 2). The entrances of the fyke nets were blocked so that no other fish could swim into the fish bag and so that none of the confined fish could escape. On occasions when there was not enough cod, flatfish, or eelpout to bait one of the fish bags, only fyke nets baited with eels and the available fish were set out. The fish used as bait were themselves caught in fyke nets and always in good condition. Between

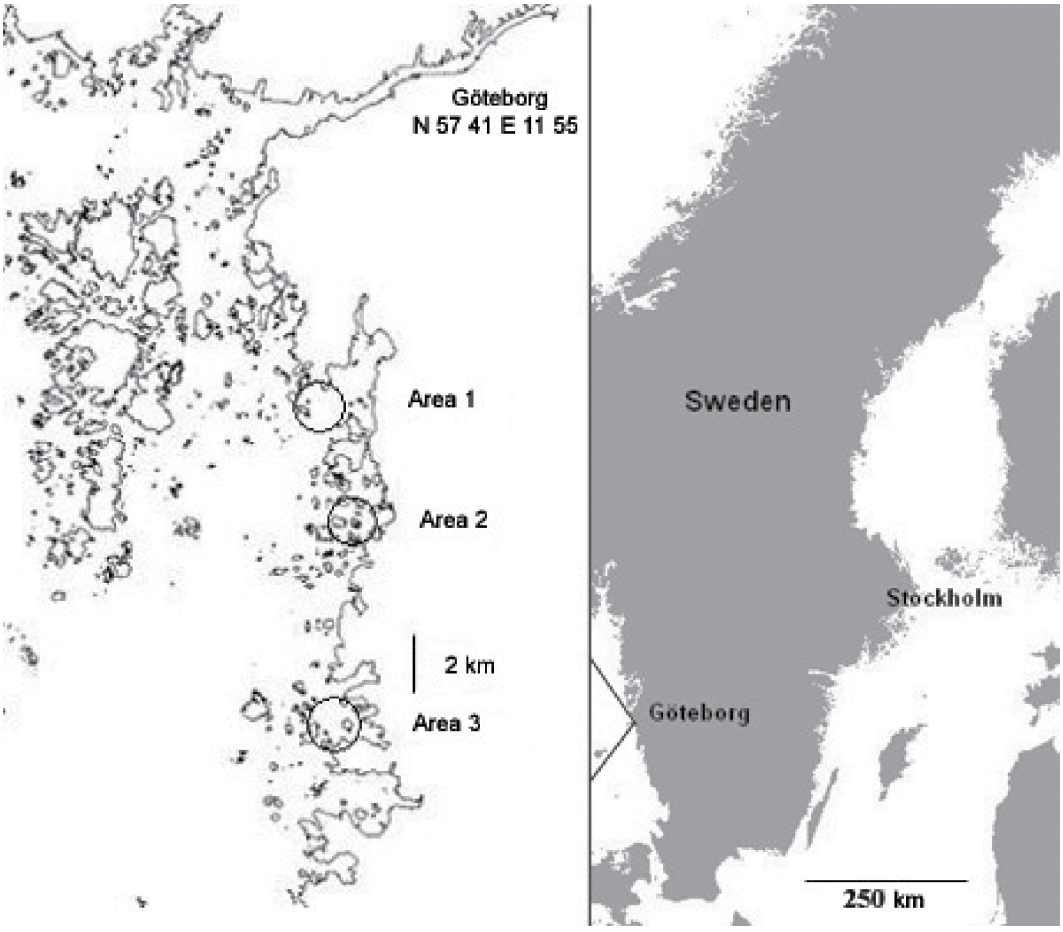

Figure 1. Map showing the three study areas south of Göteborg, Sweden; three baited fyke nets were placed in each area. Areas 2 and 3 were used in 2001 and Areas 1 and 2 in 2003.

three and five fish were placed in each fish bag. The baited fyke nets were inspected and refilled with fresh fish approximately every second day. At each inspection, tears and holes in the fyke nets or damage on the fish were noted. Any damaged gear was repaired immediately.

Whenever one of the fish bags in the fyke net showed damage, the species of fish that was in the bag was recorded. Occasions when both fish bags were damaged were omitted from the statistical analysis as they do not indicate a choice made by the harbour seals. The seals' prey species preference was tested statistically using a binomial test (Sokal & Rohlf, 1995).

Results

In total, the experimental fyke nets were examined 152 times in the three areas during 2001 and 2003, and 840 fish bags were checked. Harbour seal damage was documented on approximately 30% of the occasions when the areas were visited, except for Area 2 in 2003, where the damage frequency was very low (Table 1).

Altogether, for the three areas during 2001 and 2003, the baited fyke nets were damaged on 119 occasions. On 105 of those occasions, the harbour seal(s) only damaged one of the baited fish bags (Table 2; Figure 3).

When choices were made, eel was the species chosen on 97%, 97%, and 89% of the occasions for eel-cod, eel-flounder, and eel-eelpout, respectively. The preference for eels over the other species of bait fish was statistically significant ($p < 0.05$) for all species in Area 2 in 2001, Area 3 in 2001, and Area 1 in 2003. In Area 2 in 2003, the seal visit frequency was very low, and no statistically significant results were obtained.

Discussion

The prediction that seals prefer eels when raiding fyke nets clearly was confirmed. Fish bags containing eels had a much higher damage frequency than the other fish bags. On almost every occasion of damages, the seal(s) chose eel (only the fish bag containing eel was damaged). In the few cases when both fish bags were damaged, a choice also could have been made, as one fish bag could have been attacked prior to the other. It is impossible to tell in which order the bags were attacked,

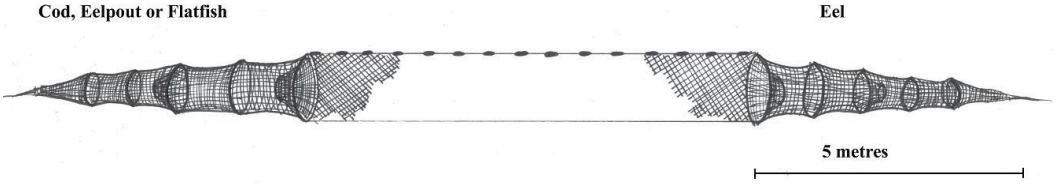

Figure 2. Schematic drawing of a fyke net; one fish bag in the fyke net was baited with eels and the other with either cod, eelpout, or flatfish.

Table 1. Number of areas, fish bags examined, and damage frequencies (i.e., occurrence of harbour seal damage on any of the fish bags in the area)

Location	Year	No. of times area was checked	No. of fish bags inspected	Damage frequency (%)
Area 2	2001	49	294	29
Area 3	2001	55	276	34
Area 1	2003	26	140	34
Area 2	2003	22	130	9

Table 2. Number of times differently baited fyke nets were checked and found damaged, number of choices the harbour seal(s) made, and the number of occasions eel was chosen

Fyke nets' bait	No. of times fyke nets were checked	No. of times fyke nets were damaged	No. of preferred choices	No. of times when eel was chosen
Eel-Cod	137	42	34	33
Eel-Flounder	136	34	33	32
Eel-Eelpout	147	43	38	34

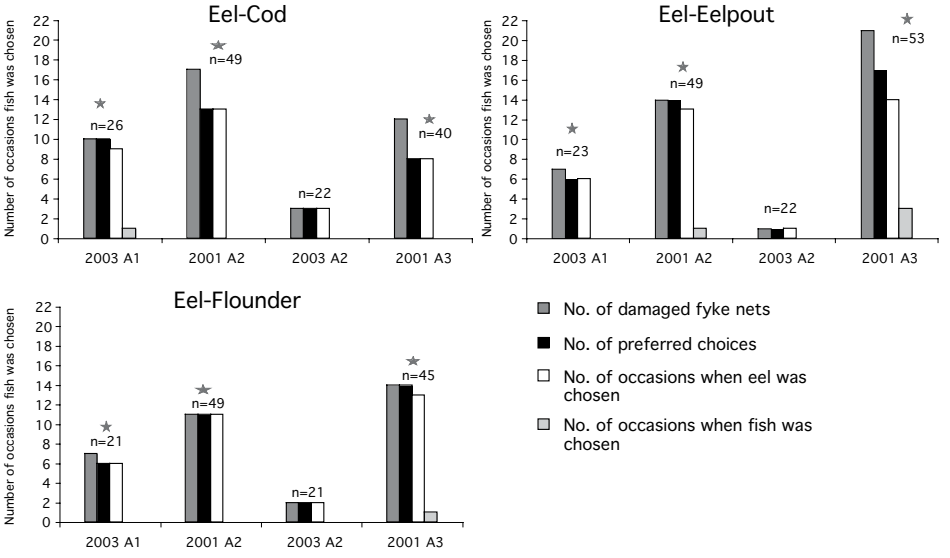

Figure 3. Number of damaged fyke nets and number of preferential choices made by harbour seals; white bars indicate the number of occasions the fish bag baited with eels was chosen, and light-grey bars indicate when the adjacent fish bag with another fish species was chosen. *n* equals the number of occasions the fyke nets were examined in each area. A statistically significant preference ($p < 0.05$) for eels is indicated by a star.

however; therefore, those occasions have been excluded from the analysis.

Several studies have shown that harbour seals feed on a variety of prey. The main prey species are herring, codfish, and flatfish; however, a scat analysis during a 3-y study in Skagerrak identified 40 different species (Härkönen, 1987; Härkönen & Heide-Jørgensen, 1991). Eels were very rarely represented in that study, and it was concluded that eels were only exceptionally preyed upon by harbour seals. Lunneryd (2001) conducted a study in which harbour seals were offered several different species of dead fish in net cages placed close to haul-out areas. The harbour seals in this case also showed a preference for herring, codfish, and flatfish. Eel and eelpout were included in the experiment, but they were rejected most of the time. Five-bearded rockling (*Ciliata mustela*), bullrout (*Myoxocephalus scorpius*), and small labrids were always rejected. These studies showed that eel was a minor part of the diet or that it was actively rejected by harbour seals, which is contrary to the result of the present investigation.

Prey selection by harbour seals was described by Tollit et al. (1997). They pointed out that faecal samples were unlikely to reflect a random sample of the population. One reason is that harbour seals making short foraging trips are more likely to be represented in scat studies than harbour seals performing longer trips. Tollit et al. (1998) also discussed the problems of interpretation of scat data due to the lack of information on the individual producing the faecal sample. This prevents more detailed analysis of individual variations in dietary composition. To obtain more information, we need to study individual harbour seals or at least certain areas more thoroughly and in greater detail.

The earlier studies mentioned above that were performed in Swedish waters (Härkönen, 1987; Härkönen & Heide-Jørgensen, 1991; Lunneryd, 2001) were carried out in haul-out areas. Haul-out areas are places where a large part of the population rests and socialises. The choice of study location—an area where eel fishery is common—could have affected our results. Harbour seals that forage in these areas were shown to strongly prefer eels, contrary to what is seen in a random sample from haul-out sites. A hypothesis is that certain harbour seals specialise in foraging by raiding fyke nets and that they come back repeatedly to the same areas to forage. As a consequence, they developed different feeding preferences compared to other harbour seals.

Individual harbour seals have a regular pattern of visiting the same feeding areas and then returning to the haul-out sites (Bjørge et al., 1995; Tollit et al., 1998). Tollit et al. (1998) found that individual harbour seals used different foraging habitats and suggested that this might indicate an individual specialisation in certain prey and foraging techniques. An earlier foraging experience could encourage individuals to return to feeding grounds that were previously successful. The specialised foraging of the seals leads to the development of

a certain technique of damaging fyke nets to catch the trapped fish.

The theory that by-caught species provoke the attacks on fyke nets is rejected by the present study. Reducing by-catch is important for other reasons. It will not solve the problem of harbour seal-damage to eel fyke nets, however. The economic loss due to seal damage in the Swedish eel fishery on the west coast was estimated to be €200,000 for the year 2001 (Königson et al., 2003). The assumption was that 18% of the eel catch was lost or damaged, based on studies comparing the catches from damaged and undamaged fyke nets and the frequency of seal damages reported in the fishery logbook system. The fisherman's cost for modifying and repairing the fishing gear is not included. The sum probably represents a considerable underestimate because including seal damage reports in their logbooks is voluntary. It is, therefore, very important to find ways to mitigate the conflict.

If the harbour seals that raid eel fyke nets are specialised, this has several implications for possible technical mitigation measures. The most effective way of reducing harbour seal damage in general is the development of seal-safe fishing gear. Any refinement (such as stronger material in the fish bags) which makes it difficult for harbour seals to get hold of the fish will decrease the incentive for the individual seal to specialise, as the effort to get a reward increases. In the case of eel fyke nets, we also suggest that finding a way of concealing the presence of trapped eels in the fish bags, and thereby removing the harbour seals' interest in the first place, might be a way forward. If some form of culling is to be considered as a way of alleviating the conflict, such interventions should focus on harbour seals foraging in the immediate vicinity of the fishing gear, as those harbour seals probably are specialists. Seen from a wildlife management point of view, this would be a more appropriate action than taking random measures against the whole population.

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Literature Cited

Bjørge, A., Thompson, D., Hammond, P., Fedak, M., Bryant, E., Aarefjord, H., et al. (1995). Habitat use and diving behaviour of harbour seals in a coastal archipelago in Norway. In A. S. Blix, L. Walloe, & O. Ulltang (Eds.), *Whales, seals, fish and man* (pp. 211-223). Amsterdam: Elsevier.

Engström, H. (1998). Conflicts between cormorants (*Phalacrocorax carbo L.*) and fishery in Sweden. *Nordic Journal of Freshwater Research*, *74*, 148-155.

Härkönen, T. (1987). Seasonal and regional variations in the feeding habits of the harbour seal, *Phoca vitulina*, in the Skagerrak and the Kattegat. *Journal of Zoology*, *London*, *213*, 535-543.

Härkönen, T., & Heide-Jørgensen, M. P. (1991). The harbour seal *Phoca vitulina* as a predator in the Skagerrak. *Ophelia*, *34*(3), 191-207.

Härkönen, T., & Lunneryd, S. G. (1990). Knubb-och gråsälen i Kattegatt-Skagerrak (Harbour and grey seals in the Kattegat and Skagerrak areas). *Fauna och Flora*, *85*, 129-139. (In Swedish with an English summary).

Königson, S., Lunneryd, S. G., & Lundström, K. (2003). Sälskador i ålfisket på svenska västkusten: En studie av konflikten och dess eventuella lösningar (The seal-fisheries conflict on the west coast of Sweden: An investigation of the problem and its possible solutions). *Fiskeriverket Informerar* (FINFO), *9*, 1-24. (In Swedish with an English summary). Available from the National Board of Fisheries, Box 423, 401 26 Göteborg, Sweden and online: www.fiskeriverket.se/publikationer/finfo/finfo03_9.htm. Retrieved 17 April 2006.

Lunneryd, S. G. (2001). Fish preference by the harbour seal (*Phoca vitulina*), with implications for the control of damage to fishing gear. *ICES Journal of Marine Science*, *58*(4), 824-829.

Sokal, R. R., & Rohlf, F. J. (1995). *Biometry* (3rd ed.). New York: W. H. Freeman and Co. 887 pp.

Tollit, D. J., Greenstreet, S. P., & Thompson, P. M. (1997). Prey selection by harbour seals, *Phoca vitulina*, in relation to variations in prey abundance. *Canadian Journal of Zoology*, *75*. 1508-1518.

Tollit, D. J., Black, A. D., Thompson, P. M., Mackay, A., Corpe, H. M., Wilson, B., et al. (1998). Variations in harbour seal *Phoca vitulina* diet and dive-depths in relation to foraging habitat. *Journal of Zoology, London*, *244*, 209-222.