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A large-mesh salmon trap: a way of mitigating seal impact on a coastal fishery

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A new design for a salmon trap aimed at minimizing damage to catch and gear caused by grey seals was tested. The traditional trap design used in the northern Baltic permits an efficient hunting strategy by seals, whereby chased fish entangle themselves in the side panels and can then easily be taken, with associated damage to the net. The side panels of the test trap (excluding the fish chamber) are made of large-mesh (400 mm) netting compared to ≤200 mm in traditional traps. This should allow seal-chased and panicking salmon to pass through, while less stressed individuals should still be guided efficiently towards the fish chamber. Trials with the two trap types were performed at the mouth of the river Indal (northern Sweden) in a comparative test programme. Catches of salmon and trout in the test trap were larger than in the standard trap. We estimated that 65% of the potential catch was lost in the standard trap owing to seal predation, while escape rate through the large meshes in the test trap was 52%. The standard trap had a total of 269 holes owing to seal damage, while only six holes were found in the test trap. Seal activity in and around the standard trap was up to 16 times higher compared with the test trap and decreased considerably during the following year when only large-meshed traps were used in the area. We suggest that seals are difficult to deter from fishing gear as long as they get a reward in terms of food and propose that a strategy that deprives seals of a reward will make the gear uninteresting to them and may have long-term mitigation effects.

Keywords: conflict, fishery, grey seal, mitigate, predation, salmon, trap.

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Introduction

Seal damage to catch and to fishing gear has increased severely in Swedish coastal fisheries during the last two decades. Of the three seal species present in the Baltic Sea, the grey seal (*Halichoerus grypus*) is causing most of the damage and the fishery most severely affected is the set trap fishery for salmonids (*Salmo salar*, *Salmo trutta*, *Coregonus lavaretus*) in the northern Baltic. Westerberg *et al.* (2000) estimated that up to half of the potential total catch is lost to seals. The large traps used are set for prolonged periods (several weeks) and emptied at a varying frequency (once per week to five times daily). Seals may enter the traps either via the main entrance, over the net panels or through a hole torn in the side of the fish chamber and chase fish into the netting, and then tear them loose, often damaging the net.

Trials with deterrent techniques (sounds) have generally given poor or inconclusive results (Jefferson and Curry, 1996). A device that has been tried in the Baltic trap fishery with some success is an acoustic harassment device of Norwegian design (Lofitech Ltd.; Westerberg *et al.*, 1999). However, this device still needs technical improvement and is too expensive (€2500) to be generally applicable for mitigation, except perhaps at the most profitable fishing sites.

In general, other means of seal deterrence tried have had limited success, because seals soon adapt their behaviour to find some way of getting at the fish. This happened for instance when stronger materials and/or entrance gates were used in the fish chamber (Westerberg and Stenström, 1997). However, even if those fish reaching the chamber can be protected, the problem with seals using the rest of the trap as an aid for hunting fish inside the gear continues to exist and may still lead to considerable losses. Moreover, the more or less continuous presence of seals around a trap may deter fish, thereby further reducing the catch.

To overcome these problems, we sought a trap design that would discourage seals from even gathering near it.

The basic idea was to allow fish to escape through the side panels of the entrance part if chased, to prevent seals from getting a reward so that they would lose their motivation for staying around the trap. Earlier experiments had shown that a large mesh size may be used without the trap losing its function to guide fish in the desired direction (Lunneryd *et al.*, 2002). Therefore, we designed a test trap with large meshes of coarse twining in the entrance part and with improved panel construction to eliminate blind corners, with two objectives in mind: (1) to keep the herding effect but allow seal-chased fish to escape; and (2) to make the trap an unprofitable hunting ground and thereby discourage seals from visiting it.

To investigate whether these objectives could be met by the design, we compared a test trap with a traditional (standard) trap under experimental conditions and tested the following predictions: (1) damage to the test trap is less; (2) seals visit the test trap less frequently; and (3) catches in the test trap at least equal those in the standard trap.

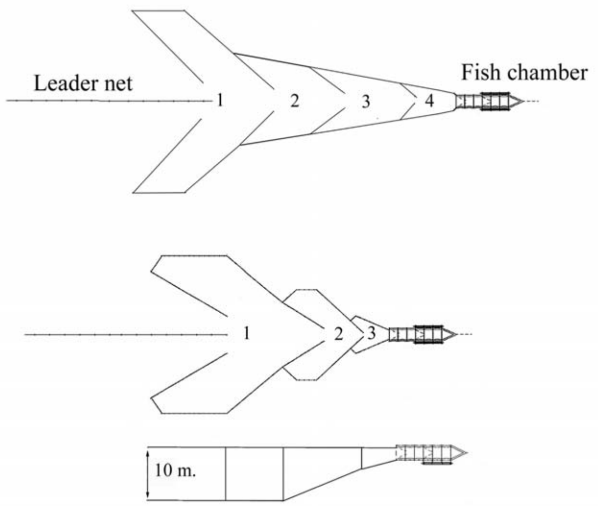

Figure 2. General outline of the standard (top) and test (bottom) traps used.

Materials and methods

Data collection

The mouth of the river Indal, 20 km north of Sundsvall in northern Sweden, was chosen as the test area (Figure 1). The river forms a delta that flows into a deep bay, 20 km from the open sea. To compensate for hydroelectric dams blocking access to the original spawning grounds, 325 000 salmon and trout smolts are released into the river annually. Adult fish are trapped as they return to the river system from the open sea. The fishery for migrating salmonids in the river mouth is of local importance, both economically and culturally. With the recovery of the Baltic grey seal population from low numbers in the period 1960–1980 (Hårding and Härkönen, 1999), grey seals have recently begun to appear around the traps and their numbers are growing. From around 1995, they have brought severe damage to the fisheries and yields have decreased sharply. In 1999, one of two salmon traps in the river mouth did not catch a single undamaged salmon during the whole season.

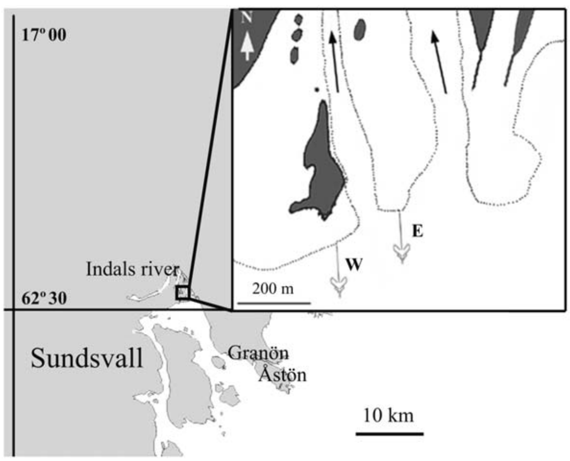

Figure 1. Map of the delta of the river Indal showing trap locations (E and W) and main migration routes for salmonids (arrows) and 3 m depth contours (dotted lines).

During summer 2000, a large-mesh test trap was compared directly with a traditional (standard) trap and follow-up studies were carried out in the same area during 2001. Figure 2 shows the general layout of the two traps. Both had a 100 m long leader net (stretched mesh size, 400 mm), fastened at one end to the main entrance of the first section of the trap and at the other to a pole near the shore. They further consist of a series of funnel-shaped sections with gradually smaller openings until these finally lead into a seal-safe fish chamber. The entrance has a rigid frame with double netting to keep the seals well away from the live fish collecting in the chamber, while the fish are not discouraged from entering. The leader net as well as the whole trap are buoyed to float at the surface. Local depth was around 30 m. The test trap was somewhat smaller, with one section less than the standard trap. It also had a different configuration where the sections joined together, so as to avoid narrow pockets where chased salmon might get stuck.

The first two sections of both traps were made of polyethylene (gauge of 1.6 mm) and had a stretched mesh size of 400 and 200 mm, respectively. Section 3 of the test trap and sections 3 and 4 of the standard trap had a mesh size of 100 mm, but the netting was made of Dynema (1 mm gauge) and 1.5 mm nylon, respectively.

The two traps were placed at traditional trap sites on opposite sides of one of the two main channels of the river delta (positions E and W; Figure 1), which represent the main upstream migration routes. The experimental period in 2000 was split into three separate trials lasting from 24 June to 9 July, 10 July to 3 August, and 6 to 31 August, respectively. After each period, all holes in both traps were repaired. Moreover, trap positions were swapped between the second and third trial periods.

Both traps were generally emptied every second day during the trials and catch was recorded by species and individual gutted weights. The side panels were checked daily for entangled fish or remains from seal attacks. Each fish caught was measured (total length) and weighed, and external damage was recorded. Accessible parts (side panels and the bottom section in front of the fish chamber) were occasionally checked for damage. When repairs were made, records were taken of the size and positions of any holes. The deeper parts (i.e. bottoms of front sections) were checked only after the traps were taken ashore at the end of each trial period. To estimate how many fish were taken by seals, each new hole in the side panels was assumed to represent one entangled fish lost. To avoid double counting, holes in the bottom parts were excluded, because these might have been caused by seals feeding on the remains of fish that had been torn loose from the side panels.

During trial periods 2 and 3, visual observations of seals surfacing between diving bouts were made daily (weather conditions permitting) at irregular intervals between 5 AM and 7 PM. These observations covered an area of 400×300 m comprising both traps. Binoculars ($8\times$) were swept continuously back and forth over the area at an even pace from a position on the shore during 15 min.

Seal activity at the traps was recorded at intervals with a digital video recorder (Sony DCR-TRV890E) fastened to the outer end of the fish chamber, mounted 1 m above water level and directed shoreward. The camera covered the trap and approximately 50 m of the leader net nearest to the trap. In addition, underwater observations were made during the third trial period with the aid of two Mariscope video cameras (one for each trap) connected to a video splitter and a time lapse video recorder (Hitachii VT-L1100ER). The frame rate was set to 12 s^{-1}.

In 2001, traps of the same test design were adopted by some local fishermen, and we were able to observe the progress of their operations. Two such traps were placed in the same location as we had used in 2000, and we carried out binocular studies of seal activity here during July 2001. Further observations were made at new locations in the outer part of the bay, where a large-meshed trap was sited off the island of Granön (10 km from the river mouth), while the standard trap used in 2000 was now sited 15 km away, off the island of Åstön. Those traps were placed on their own, with no other traps present within 1 km.

Modelling

To analyse the experimental data, a simple, linearized model was used. The catch per effort (C) of a trap will depend on fish abundance (F) and on a gear efficiency function (E). F may vary as a function of time (t) but is assumed to affect the catch rates in both traps equally. E is assumed to be constant in time, but dependent on a position variable (x) and other parameters that are specific for the particular gear type. We thus have:

$$C(x,t) = F(t) * E(x) \tag{1}$$

E is further separated into a site-dependent factor (P^*), an intrinsic factor depending on gear design (K_1) and a factor which depends on the effect of seals on the catch process (K_2). K_1 and K_2 are considered constants that are specific for the two gears in the experiment and the general level of seal activity in the area, which we assume to have been roughly constant during the whole experimental period. The absolute values of K_1 and K_2 cannot be measured. Instead, we factor out the part of these constants that is common to both gears and incorporate this part into a new site factor (P). The remainder of K_1 is then replaced by a gear escape coefficient (L), which expresses the relative capturing efficiency of the test trap compared to the standard trap. The remainder of K_2 is expressed as a seal loss coefficient (S), which represents the relative amounts of fish that are caught or scared away by seals when present. With those changes we now have:

$$E(x) = P(x) * (1 - L) * (1 - S) \tag{2}$$

The three trial periods represent three successive experiments: an initial period ($t = a$) when seals are supposed to have been active at both the traps, a period ($t = b$) when the seals should have abandoned the experimental trap ($S = 0$) and concentrate at the standard trap, and a period ($t = c$) when trap positions had been switched but when the seals are supposed to adjust rapidly to the new situation such that again $S = 0$.

Identifying the two gear positions (E and W; Figure 1) by $x = e$, we get the following three catch equations for the experimental trap by trial period (a, b, c):

$$C(a,e) = F(a) * P(e) * (1 - L) * (1 - S) \tag{3}$$

$$C(b,e) = F(b) * P(e) * (1 - L) \tag{4}$$

$$C(c,w) = F(c) * P(w) * (1 - L) \tag{5}$$

The corresponding equations for the standard trap are:

$$C(a,w) = F(a) * P(w) * (1 - S) \tag{6}$$

$$C(b,w) = F(b) * P(w) * (1 - S) \tag{7}$$

$$C(c,e) = F(c) * P(e) * (1 - S) \tag{8}$$

All six C are known from observations. By dividing Equation (3) by (6), (4) by (7), and (5) by (8), we eliminate F(a), F(b) and F(c), while P(w)/P(e) can be regarded as a single variable, so that the equation system can be solved for S and L.

Results

Trap data

During the three trial periods, the two traps were emptied 7, 13 and 10 times, respectively, yielding a total of 622 salmonids belonging to four species (Table 1). Salmon dominated the catch, followed by sea trout. During trial b, the test trap caught significantly more salmon and trout than the standard trap (Figure 3), but the difference over the three periods combined was not significant. Also, their mean weights were not significantly different. In contrast, significantly more whitefish were taken in the standard trap (Mann−Whitney U-test, $p < 0.05$). Because only large fish were observed entangled or eaten by seals, salmon and trout are regarded as their main target and the other two species were excluded from the analyses.

Over the entire period, a total of 187 tears and holes (size range, 0.005−3.25 m^2; total area damaged, 30.7 m^2) were found in the side panels of the standard trap while only two holes classified as large (>1.5 m^2) were found in the side panels of the outer section of the test trap. The holes in the standard trap were distributed throughout all sections (32, 25, 68, and 60 for sections 1−4, respectively) and mostly situated in the top 4 m of the panels (average depth, 1.6 m). In addition, 82 holes with sizes up to 1.5 m^2 were found in the bottom panels, compared to four small holes (<0.3 m^2) in the bottom of the test trap. In the standard trap, remains of 38 large fish were found entangled, distributed evenly over the three periods (Table 1), compared to none in the test trap.

Assuming no escapees through the meshes in the standard trap and no losses caused by seal predation in the test trap, the estimated gear-escape coefficient (L) for the test trap was a 52% loss of the potential catch, while the estimated relative seal-loss coefficient (S) in the standard trap was 65%.

Seal observations

During 123 out of the 153 binocular observation sessions in 2000, one to four seals were spotted, all being identified as grey seals. The seals appeared to operate individually and with one exception when three seals fought over a salmon, there were no signs of social interactions. During trial b, 85% of the observations were close (approximately 50 m) to the standard trap (position E) and very few (2%) near the test trap (position W). After swapping trap positions, the difference during trial c was less pronounced. Seals were still commonly observed around position E with the test trap (34% of all observations). At position W, the number of observations increased to 24% after the standard trap had been set up there.

The number of seals sighted during above-water video recordings was significantly higher around the standard trap than around the test trap (Table 2; $p < 0.01$ for pooled data from both periods, Mann−Whitney U-test). Sub-surface video observations in trial c indicated a 16× higher underwater activity of seals inside the standard trap than in the test trap. In the former, seals swam on average at a frequency of 0.92 h^{-1} into the last section before the fish chamber during 105 h of recording. The corresponding figure for the test trap was 0.04 h^{-1} during 106 h of recording.

Observations in July 2001 at the river mouth showed significantly lower seal activity (t-test, $p < 0.01$) compared with those during 2000, while catch rates of salmon and

Table 1. (A) Catch in number (n) and mean gutted weight (w in kg) by species and (B) number (n) of entangled salmon and trout found, number of holes, and estimated numbers and percentage catch of salmon and trout lost in the standard (S) and test (T) trap during each trial period.

		Trial a (24/6−9/7)		Trial b (10/7−3/8)		Trial c (6/8−31/8)		Total	
		S	T	S	T	S	T	S	T
(A) Reported catch									
Species									
Salmon (*S. salar*)	n	52	44	64	133	56	55	172	232
	w	8.8	10.9	7.7	7.0	5.0	4.5	7.2	7.2
	s.e.	1.2	1.6	1.0	0.6	0.7	0.6	0.6	0.5
Trout (*S. trutta*)	n	11	3	36	80	6	–	53	83
	w	2.5	2.3	3.9	4.2	2.7	–	3.3	4.1
	s.e.	0.7	1.4	0.6	0.5	1.01	–	0.5	0.5
Whitefish (*C. lavaretus*)	n	–	–	27	17	71	8	98	25
Grayling (*T. thymallus*)	n	–	1	–	–	–	–	–	1
(B) Losses									
Fish remains	n	15	–	12	–	11	–	38	–
Holes in side panels	n	26	–	75	–	86	–	187	–
Salmon and trout	n	41	–	87	–	97	–	225	–
	%	40	–	47	–	61	–	50	–

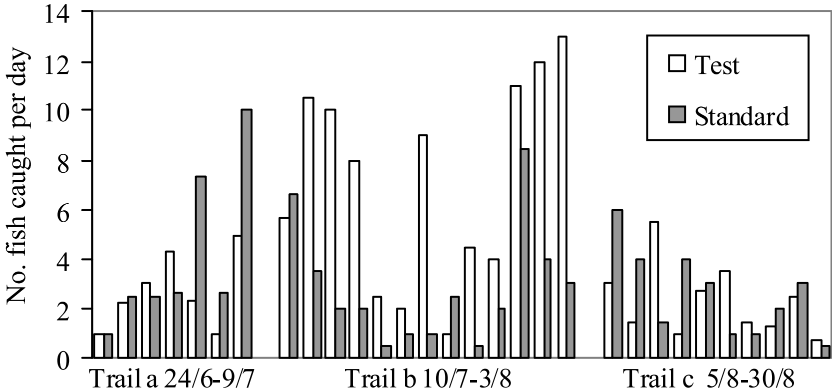

Figure 3. Catch rates of salmon and trout combined during consecutive checks of the two traps for the three trial periods.

trout were comparable between years (Figure 4). Catch rates in the standard trap at Åstön were similar in the river mouth area in 2000 and 2001, but the seals were observed much more frequently than in the river mouth in 2001. No seals were observed during 8.25 h at the Granön site, but this turned out to be a poor fishing location with only three salmon caught in a whole month.

Feeding observations

Seals were observed feeding on salmon or trout on 15 occasions during 39.5 h of binocular observations (0.4 h^{-1}). Twelve of these incidents occurred close to the standard trap or in-between the two traps, while three occurred around the test trap. Video observations above water revealed a similar pattern: seals were seen eating a fish inside the standard trap at a frequency of 0.1–0.3 h^{-1} and never in the test trap (Table 2). During 2001, seals were seen feeding on four fish during ca. 15 h of observation time at the standard trap at Åstön (0.3 h^{-1}) and none during ca. 11 h of observations at the test traps in the river mouth.

Discussion

The first prediction that seals cause less damage to the test trap was clearly confirmed. For fishermen, a reduction from 268 holes in the standard trap to six holes in the test trap means a substantial reduction in costs and labour for maintenance, because repair work on the standard trap took over a week. The life expectancy of the test trap should also be substantially higher.

The second prediction that seals visit the test trap less was confirmed by the above-water and sub-surface video recordings. The binocular observations yielded less convincing patterns. While seals surfaced more frequently around the standard trap during the second trial period, when the two traps had been in the same location for quite some time, the pattern emerging during the third period after swapping trap locations was less clear. This suggests that there may be a learning time involved, particularly after seals have got used to finding their food at a particular location. Nevertheless, the video recordings suggest that even though seals may visit the area around the test trap, they are less likely to enter the trap itself.

Table 2. Frequencies of seal observations (surfacing in-between dives; N ± s.e.) and feeding events (seals surfacing with a new fish; F) during above-water video recordings (n, number of recordings) inside and close to the mouth of the standard (S) and test (T) trap.

	Trial b		Trial c	
	S	T	S	T
n	14	8	17	14
N (h^{-1})	4.1 ± 2.3	0.2 ± 0.2	1.6 ± 0.5	0.2 ± 0.2
F (h^{-1})	0.13	0	0.32	0

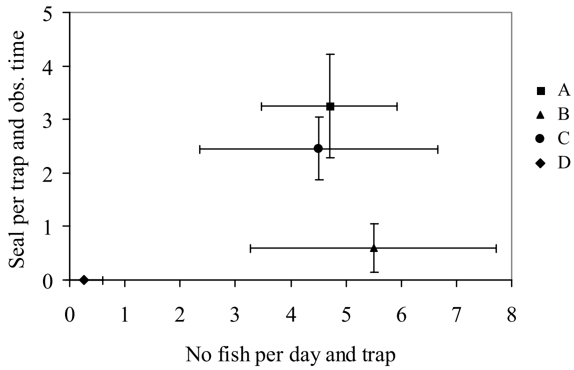

Figure 4. Mean catch rates (with 95% confidence intervals) of salmon and trout combined in relation to mean number of seals seen surfacing per trap during 15 min of binocular observation at different locations. (A) average, test + standard trap, Indal river mouth, 2000 – n = 104; (B) average, two test traps, Indal river mouth, 2001 – n = 43; (C) standard trap, Åstön, 2001 – n = 59; (D) test trap, Granön, 2001 – n = 33.

Finally, total catches in the test trap (341 fish) exceeded catches in the standard trap (323 fish), despite its smaller size and having one section less. However, there were species-specific differences. The catch of salmon and trout in the test trap (315) was in fact 40% higher than in the standard trap (225). In contrast, the number of whitefish in the test trap was 75% lower.

Our model estimated that 52% of the salmon and trout entering the test trap may have escaped through the mesh. It is not possible to distinguish between losses related to forced escapes owing to seals hunting in the trap, and losses owing simply to fish finding their way through the larger meshes. The calculated loss (260 fish) over a time-span of 88 days corresponds to 0.2 lost fish per hour. This figure is of the same order of magnitude as the average number of seals observed inside the trap by above-water video recordings (Table 2). The losses can thus be explained mainly by the presence of seals. Previous experiments with ultrasonic tagged whitefish showed that non-stressed fish were reluctant to pass through large-meshed nets, even up to a stretched mesh size of 1.6 m (Lunneryd *et al.*, 2002). Similar observations on herring and cod show that other species are also reluctant to pass through very large meshes in trawl nets or in the bag of purse-seines. Only when fish are physically constrained or severely stressed, they may panic and try to pass through the netting (Misund and Aglen, 1992).

The differences in mean weight of salmon and trout caught in the two traps were not significant. This indicates that smaller fish do not escape through the larger meshes more readily than larger fish do. It is not clear if the lower catch of whitefish was related to the smaller size of fish or a different behaviour relative to trap construction (Toivonen and Hudd, 1993).

At the level of seal activity observed in 2000, the estimated losses owing to seal predation in the standard trap (65%) were higher than losses owing to fish escaping from the test trap (52%). It seems quite possible that if traditionally only large-meshed traps had been employed in the fishery, the number of seals attracted to the area might have been even smaller and therefore losses even fewer. This is supported by the reduced seal activity (expressed as seals surfacing between dives) observed in the river mouth area in 2001 (when only large-meshed traps were employed), which was only 15% of the value in 2000. Although there were still seals around, no successful pursuits were observed.

Around the standard trap at Åstön 15 km from the river mouth, seal activity in 2001 was similar to the value observed during 2000 in the river mouth. The absence of seals around the large-meshed but unproductive trap sited at Granön indicates that seals are not randomly distributed around traps, but rather gather around traps that actually catch salmon.

This experiment shows that it is possible to reduce the seal problem in trap fisheries considerably by adapting the design. Minimizing the rewards for seals when entering the traps seems to be of utmost importance, even if this causes some loss of fish to the fishermen, because preventing habituation and demotivating seals from visiting the gear are the primary ingredients for finding a solution. The dynamics of the interactions between seals and fisheries are such that marine mammals adapt quickly to new countermeasures taken by fisheries. Therefore, a proactive approach must be taken in developing new measures rather than a merely defensive approach. In-depth understanding of the behaviour of both the predators and the target fish should be sought and used creatively, instead of persisting with fishing gear that merely serves as a dinner table for predators.

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