ICES Journal of Marine Science, 61: 1195–1200 (2004)
doi:10.1016/j.icesjms.2004.06.012

Mitigation of seal-induced damage in salmon and whitefish trapnet fisheries by modification of the fish bag

Esa Lehtonen and Petri Suuronen

Lehtonen, E., and Suuronen, P. 2004. Mitigation of seal-induced damage in salmon and whitefish trapnet fisheries by modification of the fish bag. – ICES Journal of Marine Science, 61: 1195–1200.

During the past decade, seal-induced gear and catch damage has increased dramatically in the Baltic Sea. The problems are most severe in the coastal trapnet fisheries for salmon (*Salmo salar*) and whitefish (*Coregonus lavaretus*), where grey seals (*Halichoerus grypus*) in particular frequently visit the traps. There is an acute need for gear modifications and other solutions that can prevent seals from entering the fish bag of the traps. Modifications that have been tested in Finland include a wire grid installed in the funnel of the trap and a fish bag made of extra-strong netting material. In comparative fishing experiments conducted in 2001 in the Gulf of Finland the grid was made of 2-mm steel wires with 175-mm spacing. The average undamaged salmon catch per haul in the fish bag of modified trapnets was significantly higher (70%) than that of traditional traps (Mann–Whitney, $p < 0.01$). In the whitefish experiments, the average undamaged catch of whitefish per haul was 16% higher in modified trapnets than in traditional traps, but the difference was not significant (Mann–Whitney, $p > 0.05$). These results indicate that the wire grid did not prevent fish from swimming into the fish bag. Experiments also suggest that the wire grid and the extra-strong netting prevented seals from entering the bag. However, on some occasions seals were able to tear the fish through the netting. Underwater observations confirmed that the wire grid kept adult seals outside the bag while salmon and whitefish could be seen entering through the grid into the bag.

Keywords: catch damage, grey seal, modifications, salmon, trapnet, whitefish, wire grid.

Received 19 June 2003; accepted 26 April 2004.

E. Lehtonen and P. Suuronen: Finnish Game and Fisheries Research Institute, PO Box 6, FIN-00721 Helsinki, Finland. Correspondence to P. Suuronen: tel: +358 2057511; fax: +358 205751201; e-mail: petri.suuronen@rktl.fi.

Introduction

During the past decade, grey seal (*Halichoerus grypus*) populations have expanded rapidly in the northern Baltic Sea and, consequently, seal-induced gear and catch damage has increased dramatically, particularly in the coastal trapnet fisheries for salmon (*Salmo salar*) and whitefish (*Coregonus lavaretus*). The damage, however, varies considerably from one region to the next (Lunneryd and Westerberg, 1997; Westerberg and Stenström, 1997; Westerberg *et al.*, 2000; Lunneryd, 2001; Kreivi *et al.*, 2002). In 2001, more than 40% of salmon catches were damaged by seals in the Finnish trapnet fishery in the Bothnian Sea, whereas in the coastal areas of the Gulf of Finland and Bothnian Bay the corresponding figure was on average only 10–20%. Seal-induced damage in whitefish catches has not been as pronounced as in salmon catches, but with the present growth of seal stocks the problem is becoming serious also in the whitefish fishery.

The wings, chambers, and fish bag of a traditional salmon trapnet in the Gulf of Finland are made of relatively thin and elastic nylon twine of 130–160 mm full (stretched) mesh size. The leader netting of the gear is made of stiff and large mesh polyethylene netting. The gear is light, inexpensive, and easy to handle, and its catching performance is good. However, it is vulnerable to seal attacks because of its catching principle and because seals can readily enter all parts of the gear. The traditional whitefish trapnet, on the other hand, is made of relatively thick netting of ca. 80 mm stretched mesh size. Fish are not caught in the meshes but instead are trapped in the fish bag. However, as in case of a salmon trapnet, the netting material and the open funnel construction of a whitefish trap allow seals freely to enter fish bag, attack the catch, and transport fish away from the bag.

Considerable research efforts allocated in the northern Baltic Sea to deter and keep seals away from fishing gears have included the use of acoustic alarms and modifications of the gears (e.g. Westerberg and Stenström, 1997; Lunneryd, 2001; Lunneryd *et al.*, 2002, 2003). So far, the most promising gear modification has been invented by a commercial fisherman in Sweden (the so-called push-up trapnet; see Lunneryd, 2001). The basic principle behind preventing seal attacks in the fish bag of a push-up trap is the double netting held under tension with the help of a rigid aluminium frame. Seals cannot enter the inner netting wall of the bag because of the outer seal-safe protection netting. The main problem with this design, however, is its complicated construction and high price. In regions where seals are very common but catch potential is high, this construction is a potential solution, regardless of expense. In areas where seal attacks are less common, a cheaper alternative could be a more economic solution even when seal protection would not be perfect.

The aim of this study was to develop and test a practical and inexpensive fish bag modification that would effectively prevent seals from entering the bag while allowing fish to swim into it. The concept uses a wire grid in the funnel to prevent seals entering the bag and netting material that a seal cannot tear apart.

Material and methods

The study was conducted in 2001 in the Gulf of Finland near the city of Kotka (ICES Subdivision 32) in close cooperation with local fishermen. The salmon trapnet trials were conducted with five modified and five conventional trapnets in June–August. The whitefish trials were conducted in September–November with four modified and four conventional trapnets.

The modified salmon trapnet included a wire grid installed in the funnel of the trap and large fish bag ($16 \times 8 \times 5$ m) made of extra-strong Dyneema netting (Figure 1). The grid was made of tightened 2-mm steel wires with 175-mm spacing. The shape and size of the grid frame was similar to the entrance of a conventional funnel. The frame of the grid was made of stainless steel and was buoyant. The stretched mesh size of the Dyneema netting was 80 mm and twine thickness was ca. 1 mm (no. 210/23). The design, mesh sizes, and netting materials of the leader net, wings, and chambers in the modified trapnets were similar to those of a conventional trap. The only difference between the gears was the construction and netting material of the fish bag, and the existence of a wire grid.

Bag length of a conventional salmon trapnet is 12 m, maximum width 8 m, and depth ca. 5 m, and it narrows towards the end. Hence, the overall volume of the traditional fish bag is less than half of that of the modified fish bag. The full mesh size in the traditional fish bag is 130–140 mm and the netting is elastic nylon (PA 210/30), i.e. fish are caught in the meshes. Seals can freely enter the traditional bag, either through the netting (by tearing a hole) or through the funnel. The chambers and the wings of salmon trapnets are made of nylon netting (PA 210/30) with a stretched mesh size of 130–160 mm. The leader netting is made of twisted polyethylene (PE 2.0–2.2 mm) of 600–700 mm full mesh size.

The modified fish bags used in the whitefish study were the same as those used in the salmon study. The fish bag of a traditional whitefish trapnet has a similar design (shape), but is smaller than that of modified traps and is made of stiff polyethylene netting (thickness 1.0–1.6 mm). The stretched mesh size in the fish bag was 80 mm both in modified and in traditional trapnets.

A paired set-up was used as a means of making a reliable comparison of seal damage and catching performance between modified and conventional gears, i.e. one conventional and one modified trap were set-up close to each other as a pair. The location of traps in each pair was chosen randomly. In the salmon experiment, the average distance of gears within a pair was 540 m (variation 200–1400 m), whereas the average distance between the pairs was 2200 m (variation 1000–4000 m). The gears were hauled daily. In total, there were 241 hauls with modified and 242 hauls with conventional salmon traps. In the whitefish experiments, the average distance within a pair was 900 m (variation 500–1400 m). The average distance between pairs was 2300 m (variation 800–3500 m). In total, there were 173 hauls with modified and 180 hauls with conventional whitefish traps. A non-parametric Mann–Whitney test was used in the statistical analysis of the data.

The catch of salmon and whitefish in all parts of the experimental gears was weighted and measured in length, and seal damage was registered. All fish that had any type of seal-induced damage, large or small, were classified as seal-damaged. The potential catch damage caused by seabirds was not separated from seal-induced damage. The maximum width of all fish caught in trapnets was

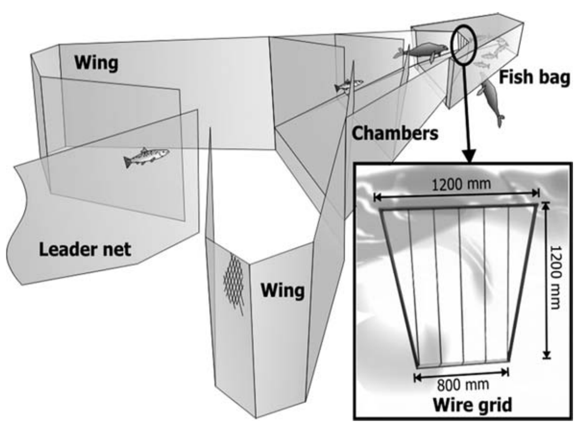

Figure 1. A salmon and whitefish trapnet equipped with a wire grid in the funnel of the fish bag. The grid is made of vertical 2-mm steel wires and its buoyant frame is constructed of stainless steel.

measured separately to assess the optimal wire spacing of the grid.

The behaviour of fish and seals near the wire grid in a modified trapnet was observed over a period of ca. 2 weeks with an underwater (light-sensitive, wide-angle lens) camera installed on the frame of the grid. The distance between the camera and the grid was 1.2 m. The camera was inside the bag and pointed towards the funnel viewing the incoming fish and seals that appeared near the grid. Owing to turbulent water the viewing distance was only up to 2 m in good visibility conditions.

Results

Catches and catch damage

In modified salmon trapnets the total salmon catch was 3989 kg, whereas in conventional traps the total catch was 2156 kg (Table 1). There was a small by-catch of sea trout, rainbow trout, and whitefish (250 kg in total). The average salmon catch per haul was significantly higher in modified traps (16.6 kg) than in conventional traps (8.9 kg) (Mann−Whitney, $p < 0.01$).

In the modified salmon traps, the total salmon catch caught in the fish bag was 2350 kg, whereas in conventional traps it was 1361 kg (Table 2). Hence, ca. 60% of the total (observed) salmon catch was captured in the fish bag in both trapnet types. The rest were captured in the chambers and wings; these fish were caught in the meshes (often tangled), as were most of the fish captured in the conventional fish bags.

The total quantity of salmon not damaged by seals was 2726 kg in the modified trapnets and 1491 kg in the conventional trapnets (Table 1). The total salmon catch damaged by seals was about 31% in both gear types. The total undamaged salmon catch in the fish bag of modified trapnets was 1489 kg, whereas that of traditional trapnets was 881 kg (Table 2). The 70% difference between the average catch per haul in modified (6.2 kg) vs. conventional (3.6 kg) fish bag is significant (Mann−Whitney, $p < 0.01$).

The mean weight of salmon caught in the traps was 6.1 kg (range 0.5−17.3 kg); mean length was 82 cm (range 40−115 cm). The average size of salmon caught was the same in both gear types. The maximum body width of salmon caught in the experimental gears was on average 94 mm (range 30−173 mm).

In the whitefish trials, a total of 5981 kg were caught in modified trapnets, and 5451 kg in conventional traps (Table 3). In addition, there were minor by-catches of salmon, sea trout, and rainbow trout (90 kg in total). The whitefish catches were taken almost solely in the fish bag in both gear types. No meshing of fish was observed in any parts of the gears. The average whitefish catch per haul (34.6 kg in modified and 30.3 kg in conventional traps) did not differ significantly between gear types (Mann−Whitney, $p > 0.05$). Of the total whitefish catch, about 5% were damaged. The average undamaged whitefish catch per haul in the modified trapnets (33.4 kg) did not differ significantly from that of the conventional traps (28.7 kg) (Mann−Whitney, $p > 0.05$). The mean weight of whitefish caught was 0.7 kg in both gear types. The maximum body width of whitefish caught in the experimental gears was on average 50 mm (range 25−65 mm).

Underwater observations of fish and seal behaviour

In the underwater observations, salmon and whitefish were seen entering through the wire grid into the fish bag. On some occasions, individual salmon were seen hesitating before swimming through the wire grid. In particular, sudden gear movements caused by high waves appeared to disturb the fish and occasionally may have prevented or delayed them from entering through the grid into the bag.

Table 1. Salmon catch, catch per haul, and the quantity of undamaged salmon in the modified and conventional salmon trapnets (whole gear).

Trapnet type	No. of hauls	Catch (kg)	Catch/haul (kg)	Undamaged catch (kg)	Share of undamaged catch (%)
Modified	58	1044	18.0	677	65
Conventional	55	332	6.0	222	67
Modified	52	534	10.3	359	67
Conventional	55	444	8.1	259	58
Modified	56	1 241	22.2	1 153	93
Conventional	60	464	7.7	436	94
Modified	56	671	12.0	375	56
Conventional	57	819	14.4	553	68
Modified	19	499	26.2	162	32
Conventional	15	97	6.5	21	22
In total: modified	241	3 989	16.6	2 726	68
In total: conventional	242	2 156	8.9	1 492	69

Table 2. Salmon catch, catch per haul, and the quantity of undamaged salmon caught in the fish bag of modified and conventional salmon trapnets.

Trapnet type	No. of hauls	Catch (kg)	Catch/haul (kg)	Share of total trapnet catch (%)	Undamaged catch (kg)	Share of undamaged catch (%)
Modified	58	426	7.3	40	273	64
Conventional	55	231	4.2	69	122	53
Modified	52	476	9.2	89	336	70
Conventional	55	340	6.2	77	182	54
Modified	56	502	9.0	40	475	95
Conventional	60	242	4.0	52	235	97
Modified	56	531	9.5	79	281	53
Conventional	57	511	9.0	62	340	67
Modified	19	415	21.8	83	125	30
Conventional	15	38	2.5	39	2	6
In total: modified	241	2 350	9.8	59	1 489	63
In total: conventional	242	1 361	5.6	63	881	65

A few underwater observations were made of seals exploring the wires of the grid and then turning around; they thus remained outside the fish bag. No observations were made of young seals (pups). Only on a few occasions were fish observed swimming inside the fish bag to escape through the wire grid out from the bag.

Gear damage induced by seals

The occurrence of gear damage varied substantially depending on time and location. Gear damage was at its highest during peak catches. The most common type of gear damage was a minor tearing of netting, i.e. a few bars of the net were damaged. Gear damage was most common in the chambers and in the fish bag of the conventional traps. New damage was registered on average in 14% of the daily hauls. No serious net damage was registered in the Dyneema fish bags. Clearly, the use of extra-strong Dyneema netting prevented seals from entering the bag by tearing a hole in it.

Discussion

This study indicates that a wire grid installed in the funnel of a trapnet does not prevent fish from swimming into the fish bag. Although self-evident, the fishermen who participated in this study were sceptical about the catching efficiency of a trap equipped with such a wire grid. The underwater observations confirmed that salmon and whitefish could easily swim through the grid wires into the bag.

The spacing of the grid wires is critical: the space must be large enough to allow fish to swim into the bag with ease but small enough to prevent seals entering through the space. A gap of 175 mm appears suitable for salmon; the maximum measured body width of salmon was 173 mm (a

Table 3. Whitefish catch, catch per haul, and the quantity of undamaged whitefish caught in the modified and conventional whitefish trapnets.

Trapnet type	No. of hauls	Catch (kg)	Catch/haul (kg)	Undamaged catch (kg)	Share of undamaged catch (%)
Modified	54	3 309	61.3	3 183	96
Conventional	59	2 280	38.6	2 160	95
Modified	38	925	24.4	887	96
Conventional	34	573	16.9	534	93
Modified	36	502	13.9	490	98
Conventional	55	2 216	40.3	2 146	97
Modified	45	1 245	27.7	1 214	98
Conventional	32	381	11.9	333	87
In total: modified	173	5 981	34.6	5 774	97
In total: conventional	180	5 451	30.3	5 173	95

17 kg salmon). Obviously, a larger salmon would not be able to swim through a gap of 175 mm. However, the share of salmon of this size in the population is very small. For whitefish, a substantially smaller gap might work just as well (maximum body width measured was 65 mm), but this requires further testing.

Our results suggest that the grid with a gap of 175 mm prevents seals from entering the bag. Nevertheless, they also show that seal protection in the fish bag of the modified traps was not completely satisfactory. Damaged salmon were frequently recorded in the fish bag of the modified traps. On some occasions, seals were able to get at the fish swimming inside the fish bag by lifting the bottom netting of the bag, by chasing the fish into a netting corner, and then tearing them through the netting. In fact, we could find some clear marks on netting of modified bags where seal had apparently beaten a fish through the netting (there was some tearing of twine and fish mucus). This kind of behaviour may be prevented, or at least mitigated, by using a special anchoring system, or a double netting in the bag. Furthermore, some fish may have been damaged by seals hunting them in the wings and chambers; damaged fish may have been able to escape into the bag. No observations of such behaviour were made. A special problem may have occurred when young seals (pups) attempted to enter the fish bag through the wires. Our indirect observations indicate that pups are small enough to squeeze through a gap of 175 mm. It is obvious that a pup inside a fish bag can destroy the whole salmon catch. Reducing the wire spacing would prevent pups from entering the bag but might also cause substantial catch losses, at least in the case of larger salmon. Clearly, the overall design, installation, and wire spacing of a grid needs more investigation.

The quantity of seal-damaged fish observed and registered in this study is an underestimation of the total damage, because many damaged or partly eaten fish may have been rinsed out of the traps without trace. Damaged fish might have been lost, in particular from the conventional bags because of the larger mesh size. Moreover, seals may have brought fish out from the fish bag of the conventional traps, which according to fishermen is a common behaviour pattern but one that is difficult to estimate. Taking all these factors into account, the total catch damage presented in this study is a clear minimum estimate, particularly in the case of conventional traps.

The total salmon catch in the modified trapnets was almost twice that in the conventional trapnets. It is noticeable that the salmon catch taken from the wings and chambers of the modified trapnets was also about twice that in the conventional traps, which may indicate that there were more fish around the modified traps. However, the location of traps within each pair was chosen randomly, i.e. the location of conventional traps could not have been any less favourable than that of modified traps. Therefore, the difference in (observed) catches may indicate that there were more seals around the conventional traps. This could have occurred because of the easy access of seals to the fish bag, where the major part of the catch was. Consequently, these seals were hunting the same fish that were caught in the wings and chambers. Hence, a seal-safe fish bag may at least to some extent reduce seal attacks also in the other parts of the gear by reducing the overall interest of seals in moving and hunting around such gear.

The overall catch damage was substantially smaller in the whitefish study than in the salmon study and may explain why the overall catch quantity did not differ markedly between modified and conventional gear types. It was noticeable that in one gear pair the modified trap gave a very low catch compared to the conventional trap (see Table 3). This was probably due to blockage of the modified trap by gillnets set out very close by other fishermen. Nevertheless, even if this pair were dropped from the analysis, the difference in catches would not be significant.

Finally, it is obvious that seals can attack fish in the wings and chambers of a trapnet long before fish enter the bag, but that this behaviour can likely be mitigated by the use of proper netting materials, mesh sizes, and designs (see, e.g. Lunneryd *et al.*, 2003). The design should prevent the meshing of fish and facilitate their fast entrance into the fish bag where they can most easily be protected from seal attacks.

Acknowledgements

Special thanks are expressed to fishers Antero Halonen, Paula Halonen, and Arja Lillberg, who made this work possible by dedicating their expertise to the study. We are grateful to Fisheries Director Asko Niemi (Employment and Economic Development Centre of South-Eastern Finland) for arranging funding and for other support. We send special thanks to fishing master Raimo Riikonen for his valuable technical assistance during the study. Useful assistance in data handling and analysis was given by Pekka Korhonen, Tarja Alapassi, and Mika Kurkilahti. Vesa Tschernij (ICONEX Ltd) prepared the drawing of a trapnet.

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