Salmonids and grey seals (*Halichoerus grypus*)

Mitigation in pontoon traps

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Cover: Aerial view of pontoon trap for salmon and whitefish, Alnö, Sweden.
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Abstract

In the 1970's, the seal populations of the Baltic Sea Area were at historically low levels. They have recovered and increased since then. The increase of the seal populations is a success for the management of the Baltic Sea Area environment. It has also meant an increase in number of interactions with coastal fisheries. Seals take fish and damage fishing gear. Three studies were carried out with the purpose of contributing to a sustainable fishery and fewer interactions between seals and fishers.

The first study compared the effect two different Seal Exclusion Devices (SEDs) had on the catch and on seal visits. The SEDs used were a diamond mesh SED and a square mesh SED, with the frame rotated 45°. They were compared with a control, an open frame. The expectation was that using SEDs would reduce the number of seal visits, increase the catch and deter larger fish from entering. Larger salmons (*Salmo salar*) were caught in the traps with selection panels. For brown trout (*Salmo trutta*), there was no difference in size of fish between the SEDs. Neither of the SEDs had any effect on total catch or catch per unit effort. The number of seal visits were too low to be able to draw any conclusions regarding presence of seals.

The second study examined the efficiency of selection panels in a pontoon trap for salmon and whitefish. One control and two experimental traps were used. The mesh in the control trap had 35 mm bar length. The selection panel was square mesh with 50 mm bar length. In one of the experimental traps, the selection panel covered 30 % of the inner netting. In the other, it covered 100 %. The results showed that proportionally more fish of commercial size were caught in traps with selection panels. Using selection panels contributes to a sustainable fishery.

The third study analysed a series of visits by seals in the middle chamber of a herring pontoon trap. Visiting seals were filmed in the middle chamber. Roughly, 1 400 visits by 12 seals were recorded. Of all visits, 3.5 % were overlapping visits, i.e. two seals inside the middle chamber at the same time. Forty simulations of random visits were performed resulting in an average of 7.1 % overlapping visits. There was a significant difference between the actual overlapping visits and the simulated. This suggests that the seals avoided swimming in when another seal was present.

Keywords: grey seal, coastal fisheries, mitigation, Seal Exclusion Device, selection panel, overlapping visits

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Laxfiskar och gråsälar (*Halichoerus grypus*): Begränsande och lindrande av interaktioner mellan sälar och yrkesfisket

Abstrakt

På 1970-talet var sälpopulationerna i Östersjön och Bottenhavet på historiskt låga nivåer. De har återhämtat sig och ökat sedan dess. Ökningen är en framgång för förvaltningen av sälpopulationerna i Östersjöområdet. Det har även medfört en ökning i interaktioner med det kustnära yrkesfisket. Sälar tar fisk och skadar fiskeredskap. Tre studier har genomförts med syftet att bidra till ett hållbart fiske och minska antal interaktioner mellan sälar och yrkesfisket.

Den första studien jämförde påverkan två olika sälgrindar hade på fångsten och på besök av säl. Två sälgrindar användes, en med diamantmaska och en med fyrkantsmaska där ramen roterades 45°. De jämfördes med en kontroll (öppen ram). Det förväntade resultatet var att användandet av en sälgrind skulle reducera antal besök av säl, öka fångsten, samt även att stora fiskar skulle avhållas från att simma in. Större laxar (*Salmo salar*) fångades i fällor med selektionspanel. Det var inga skillnader i storleken av öring (*Salmo trutta*) mellan fällorna med de olika sälgrindarna och kontrollen. Ingen av sälgrindarna påverkade utfallet av den totala fångsten i kg fisk eller i antal fångad fisk. Antal besök av säl var för lågt för att kunna dra några slutsatser.

Den andra studien undersökte effektivitetsgraden av två selektionspaneler i en push-up fälla för lax och sik (*Coregonus maraena*), d v s hur stor andel icke-kommersiell sik simmade ut genom panelerna. En kontrollfälla och två experimentfällor användes. I kontrollfällan användes garn med 35 mm stolpe. Selektionspanelen bestod av fyrkantsmaska med 50 mm stolpe. I en av experimentfällorna, bestod 30 % av innergarnet av selektionspanel. I den andra var det 100 %. Resultaten påvisade att det fångades proportionellt mer fisk av kommersiell storlek i fällorna med selektionspaneler. Selektionspaneler i push-up fällor bidrar till ett hållbart fiske.

Den tredje studien analyserade en serie av besök av säl som gjordes i vatthuset i en push-up fälla. De besökande sälarna filmades när de simmade in och ut ur vatthuset. Ca 1 400 besök av 12 individer filmades. Av alla besök var det 3.5 % som var överlappande besök, d v s två sälar var samtidigt inne i vatthuset. Fyrtio simuleringar av slumpmässiga besök gjordes. Det resulterade i en signifikant skillnad med 7.1 % överlappande besök. Detta indikerar att sälarna undviker att simma in när en annan säl är närvarande.

Nyckelord: gråsäl, kustfiske, lindra interaktioner, sälgrind, selektionspanel, överlappande besök

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Dedication

To my Mother and Father and my Mom and Dad

We shall not cease from exploration, and the end of all our exploring will be to arrive where we started and know the place for the first time.

T.S. Eliot

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Calamnius, L.*, Lundin, M., Fjälling, A., & Königson, S. (2018). Pontoon trap for salmon and trout equipped with a seal exclusion device catches larger salmons. *PLoS ONE*, 13(7), e0201164. https://doi.org/10.1371/journal.pone.0201164

II Calamnius, L.*, Hillström, L., Fjälling, A. and Lundin, M. Square mesh panels in a pontoon trap reduces bycatch of young whitefish (*Coregonus maraena*). Manuscript.

III Calamnius, L.*, Lundin, M., Königson, S. and Fjälling, A. Visits of grey seals (*Halichoerus grypus*) into a fish trap overlap less than expected. Manuscript.

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The contribution of Linda Calamnius to the papers included in this thesis was as follows:

I Main applicant, conceptualisation of the study concept and design, collection of data, statistical analyses and interpretation thereof, writing the manuscript.

II Co- applicant, part conceptualisation of the study concept and design, full collection of data, part statistical analyses and interpretation thereof, part writing the manuscript.

III Main applicant, conceptualisation of the study concept and design, collection of data, statistical analyses and interpretation thereof, writing the manuscript.

Glossary and explanations

(including abbreviations and acronyms)

adapter	In pontoon traps*, the chambers between the wings* and the final parts of the pontoon trap.
Baltic Sea Area	The internal waters south and eastwards of the parallel at Skaw in Skagerrak, 57° 44.43'N.
biota	Living organisms.
bycatch	Discarded catch plus incidental catch.
carrying capacity	The number of individuals in a population(s) that the ecosystem can sustain.
coastal fisheries	Fishery conducted in coastal waters. The boats are often under 12 m.
diamond mesh	Mesh shaped like the diamond in a deck of playing cards. The geometric term is rhomb. All sides are equally long. Opposite angles are congruent.
fish chamber	The final part of the pontoon trap*. The pontoons are placed under this chamber. When they are filled with air from a compressor, the fish chamber is lifted to the surface. The catch is harvested by opening a hatch in the bottom of the fish chamber.
Hanseatic League	A commercial and defensive confederation of guilds in the Middle Ages. It was present in 200 cities in 7 countries.
HELCOM	The governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area, known as the Helsinki Convention.
leading net	In pontoon traps*, the net which extends from land to the wings. It leads the migrating fish into the wings of the trap.
LIFE	Low Impact Fuel Efficient.

middle chamber	In pontoon traps*, the chamber preceding the fish chamber*.
overlapping visit	Two seals in the middle chamber at the same time.
PCB	Polychlorinated biphenyls. An organochlorine. It is classified as a persistent organic pollutant.
pinniped	Commonly known as seals. Includes earless seals (e.g. all Baltic seal species), eared seals (e.g. sea lions) and walrus. The word has Latin origin and means ‘fin-foot’.
pontoon trap	A fishing trap developed by a Swedish commercial fisher and innovator in the early 2000’s, to mitigate the conflict between fishers and seals. It can be adapted to target different fish species of different sizes.
Program Seals & Fisheries	Project for developing a sustainable coastal fishery and a viable seal population by e.g. developing seal-safe fishing gear with good catchability
square mesh	Mesh shaped as a square. All sides are equally long and all angles are perpendicular.
Swedish Agency for Marine and Water Management	In Swedish – Havs- och vattenmyndigheten. A government agency responsible for the use of Sweden’s marine and freshwater environments. Located in Gothenburg.
Swedish Board of Fisheries	In Swedish – Fiskeriverket. A government administrative authority for the management of and utilization of fishery resources. It ceased to be an authority in 2011. The operation was transferred to the Swedish Agency for Marine and Water Management* and to the Department of Aquatic Resources at the Swedish University of Agricultural Sciences.
Swedish Environmental Protection Agency	In Swedish – Naturvårdsverket. Located in Stockholm. Public agency responsible for environmental issues.
Swedish Museum of Natural History	In Swedish – Naturhistoriska riksmuseet, located in Stockholm. It has the world’s oldest specimen bank for documenting and tracking pollutants. Responsible for the environmental monitoring of many organisms, including seals.
Wings	In pontoon traps*, the first ‘chamber’ of the pontoon trap.

* Word, abbreviation or acronym explained in the glossary

1 Introduction

1.1 The Baltic Sea Area

The Baltic Sea Area includes the Kattegat, the Sound, the Western Baltic, the Baltic Proper, the Bothnian Sea, the Bothnian Bay, the Gulf of Finland and the Gulf of Riga (cf. HELCOM, 2014; Lääne et al., 2005). Nine countries are bordering the Baltic Sea Area; Sweden, Denmark, Finland, Estonia, Latvia, Lithuania, Russia, Poland and Germany.

The biota of the Baltic Sea Area includes a total of 2 730 species (HELCOM, n.d.). Of these, 230 are fishes or lampreys and 5 are mammals. Three of the mammals are seals. They are the grey seal (*Halichoerus grypus*), the ringed seal (*Pusa hispida*) and the harbour seal (*Phoca vitulina*). The remaining biota are invertebrates and aquatic plants (HELCOM, n.d.). Around 50 of the fish species are commercially caught (Schroeer et al., 2012). The largest fisheries are for herring (*Clupea harengus*), sprat (*Sprattus sprattus*), cod (*Gadhus morhua*), European plaice (*Pleuronectes platessa*) and salmon (*Salmo salar*). The Baltic Sea is productive due to a high nutrient content (Håkanson, 2003).

1.2 A brief history of fish, fisheries and seals

Fish and seals in the Baltic Sea Area have historically been important resources for the people living along its shores. They have provided food and material for clothing and tools. The fish and seal populations have been and are subject to various fluctuations, e.g. predation, fishing effort, hunting, environmental toxins and other environmental stressors (MacKenzie et al., 2002).

1.2.1 Fish and fisheries

For the early settlers along the shores of the Baltic, the availability of fishing grounds were probably a reason for many settlements (Kaiser & Terberger, 2000). The exploitation of aquatic resources such as fish and marine mammals, was probably mostly conducted in coastal waters, since hunting or fishing in open waters were too risky (Glykou, 2014). It was also more easily accessible. Fish bone remains of marine species have been found in archaeological sites, dating from the Viking Age (800 – 1050 AD) in Denmark, Sweden, Estonia, Germany and Poland (Enghoff, 1999).

One of the first trades to reach an industrial level was the herring fishery in the 13th century (Sahrhage & Lundbeck, 1992). The populations around the Baltic grew and more cities were founded along its shores. The Hanseatic League (12th to 16th century) founded a large part of its wealth on the herring fisheries, exporting Baltic herring to England, Flanders and France (Sahrhage & Lundbeck, 1992).

From the middle of the 19th century, until the beginning of the 20th century the landings of fish in Sweden were dominated by herring, cod and flounder (*Platichthys flesus*: Ojaveer et al. 2007). At the beginning of the 20th century, the Baltic fisheries consumed around 1 % of the primary production and marine mammals around 5 %. In the late 1980's the corresponding numbers were around 10 % of the primary production for the fisheries and less than 0.1 % for the seal populations (Elmgren, 1989). The seals consumption of fish has most likely increased with the increasing seal populations. A recent study compared the total 'consumption' of fish by fisheries, birds and seals in the Baltic. On a large scale, including both the coastal and offshore consumers, the fisheries consumed 79 % of the fish, seals consumed 11 % and birds consumed 10 %. On a smaller scale, the coastal consumers, the consumption of fish was instead estimated to be 29 % for the fisheries, 57 % for the seals and 14 % for the birds (Hansson et al., 2018).

The coastal fisheries provide local communities with locally produced, high quality fish which most often is used for human consumption. They are an important part of a sustainable fishery and decreases the dependency on imported fish. Present-day coastal fisheries are often small operations, carried out by single fishers (Königson & Lunneryd, 2012). The fishing is not only an important source of income for the fishers themselves, but also a valuable source of locally produced food. The fishers often smoke or marinate the fish and sell it directly to the consumer. It is a colourful part of the coastal communities and has a high touristic value (Schroeer et al., 2012).

Further developments and improvements of the conditions for the coastal fishers would be an incentive for new generations to deliver locally produced food to local consumers, thereby contributing to a more sustainable food consumption in the near future (Königson & Lunneryd, 2012).

1.2.2 Seals and sealers

From the first settlers to the late 19th century, seals were considered a valuable resource (Eriksson, 2004). They were valued for their meat, blubber, bones and fur. In a coastal village dated 2600 BC on Gotland, seal meat was found to be the most prevalent food in the diet of its human population (Eriksson, 2004). The blubber was turned into seal oil, which was a prized export product. It was shipped to other European countries from the late middle ages until the end of the 19th century when it was replaced with cheaper alternatives (Edlund, 2000). Seal oil was used in soap, paints (Harding & Härkönen, 1999) as fuel in oil lamps and was deemed to have healing properties for both humans and livestock (Tengström (1747) in Edlund, 2000).

At the beginning of the 20th century it was estimated that the populations of the three species of seals in the Baltic were 90 000 for the grey seal (Harding et al., 2007), around 200 000 for the ringed seal (Harding & Härkönen, 1999) and around 5 000 for the harbour seal (Härkönen et al., 2005). Seals had until the late 19th century been regarded as a valuable resource, but were beginning to be viewed as a nuisance by fishers. They were competitors for fish and caused damage to fishing gear (Schwarz et al., 2003). Around the turn of the 20th century, fishers in Germany called for an eradication of seals with the Prussian authorities (Schwarz et al., 2003). The consensus was the same in other countries surrounding the Baltic. Bounties were introduced in the early 20th century by Sweden, Finland, Denmark and Germany (Harding & Härkönen, 1999; Schwarz et al., 2003). In the same period, the heavy muzzleloader was eventually replaced by the lighter Mauser rifle (Edlund, 2000). The Mauser was faster to load and had, with a scope, a longer shooting range (Edlund, 2000). The result was a decline of the seal populations. By 1920 seal hunters were complaining about smaller harvests (Harding & Härkönen, 1999). Due to a continued excessive culling there followed a rapid decline of the Baltic grey seal population to about 20 000 in the 1940's (Harding et al., 2007).

The seal populations continued to decrease between World War II and until the 1970's. By 1970 it was estimated that there remained 3 000 grey seals, 5 000 ringed seals (Harding et al., 2007) whereas fifty harbour seals were counted at Kalmar Strait (Karlsson et al., 2007). The reason for the decline of the grey seal and the ringed seal were the pesticides DDT and PCB (Bergman et al., 2002; Elmgren, 2001; Kokko et al., 1999). These substances reduces the reproductive abilities in the female seals by partial or complete occlusion of their uterine horns

(Helle, 1980) and caused a population crash (Harding et al., 2007). For the harbour seal the reason for its population decline was most probably an extensive hunt (Swedish Agency for Marine and Water Management, 2014).

As a means to aid the recovery of the seal populations, HELCOM recommended in 1988 that a ban on hunting seals in the Baltic Sea Area, should be enforced by the contracting parties, i.e. Sweden, Denmark, Finland, West Germany, East Germany, Poland and the USSR (HELCOM, 1988). In 2006, HELCOM issued a long-term management plan of the Baltic seals to ensure a viable population. This included a recovery of the populations towards carrying capacities and that they would be allowed to disperse to suitable breeding sites (HELCOM, 2013a).

Since the early 2000's, the populations of grey seals have had an annual increase of 8 %, the ringed seal 4.5 % and the harbour seal 9 % (Bäcklin et al., 2016). The recovery of the seal populations is a success story for the management of the Baltic environment. Their health status has improved and the levels of DDT and of PCB are no longer detrimental. The population status of the grey and the harbour seal is at present listed as 'least concern' and the ringed seal as 'vulnerable' (HELCOM, 2013b). The last annual counts of seals in the Baltic proper was 30 000 for grey seals (2017), 10 000 for ringed seals (2018) and 12 300 for harbour seals (2016: M. Ahola, 2018[1]). The true number of seals is estimated to be 1.25 to 2.0 times more than the counted number (Hansson et al., 2018; Swedish Agency for Marine and Water Management, 2014).

It is the grey seal which is considered to cause most problems in the coastal fisheries (Graham et al., 2011). The depredation by the grey seal is estimated to be 75 % of the total depredation by seals in the Baltic (Hansson et al., 2018).

1.3 Interactions between fishers and seals

One of the earlier accounts of how seals affected Baltic fisheries is from the early 18th century (Broman, 1720/1911). Broman mentioned that seals stole fish and damaged the nets of fishers. Another early account is from the journey Carl von Linné made to Lapland (Linné, 1732/1977). Linné described how seals damaged fish and fishing gear. He probably gave one of the earliest accounts of bycatch of seals, when their rear flippers became entangled in the nets (Linné, 1732/1977).

In the early 1990's fishers began to report more frequent encounters with seals (Varjopuro & Salmi, 2006). Since then, several papers have addressed seal

[1]. Personal communication. M. Ahola works as curator at the Swedish Museum of Natural history.

induced damage to fishing gear and catch of the coastal fisheries (Fjälling, 2006; Hemmingsson et al., 2008; Jounela et al., 2006; Kauppinen et al., 2005; Königson et al., 2013; Lehtonen & Suuronen, 2010; Lunneryd et al., 2003; Westerberg et al., 2000; Westerberg, et al., 2007).

As a means to reduce the seal induced damage on fishing gear and catch, a limited culling (removal of problem animals in this instance) for grey seals was introduced in 2001 in Sweden (Swedish Environmental Protection Agency, 2013).

The fishing gear most severely affected by seals are passive fishing gears; gillnets, trap-nets and fyke-nets in fisheries targeting salmonids or cods (Königson et al., 2009; Westerberg et al., 2000, Westerberg et al., 2007). The total cost for the seal induced damage on fishing gear and catch was in 2014 estimated to be 33 million SEK (Swedish Agency for Marine and Water Management, 2014). In addition, there may be significant hidden losses. They can amount to around 60 % of the potential catch (Fjälling, 2005). Hidden losses are mainly fish that are removed by seals from fishing gear without any trace. Hidden losses also includes fish that are deterred by the presence of seals, seal-induced gear damage and repairing or replacing damaged material (Königson et al., 2007). Another hidden loss is increased fuel costs from more frequent checking or relocation of the gear (Swedish Agency for Marine and Water Management, 2014).

1.3.1 Seals ability to learn

The learning ability of pinnipeds is well documented and has been known since the days of the Roman empire (Pliny, 77AD). They quickly exploit weakness in different protective systems in fishing gear and fish farms (Marine and Marine Industries Council, 2002; Nelson et al., 2006). Seals have learned to open doors in fish traps (Lehtonen & Suuronen, 2010), to associate buoys with fishing gear (Fjälling et al., 2007), acoustic fish tags with fish (Stansbury et al., 2015) and sounds of Acoustic Harassment Devices with a potential foraging opportunity (AHD: Nelson et al., 2006). They have also been observed to keep their heads out of the water during AHD pings (Fjälling et al., 2006).

The problem with pinnipeds interacting in fish industries is global, occurring for example in fish farms in Chile (Sepúlveda & Oliva, 2005), trawls in Tasmania and New Zeeland (Chilvers, 2008; Lyle & Willcox, 2008), fish ladders in the Pacific Northwest (Brown et al., 2011), gillnets where they and pinnipeds are present (Cosgrove et al., 2016; Königson et al., 2007; Read et al., 2006) and in fish traps in the Baltic (Lunneryd et al., 2003). Their ability to learn and adapt is considered to be the main obstacle in achieving long term mitigation measures

(Varjopuro, 2011). As long as the seals get a reward (fish), their behaviour is reinforced (cf. Pavlov, 1927; Skinner, 1953) and they will continue their foraging forays into fishing gear (Lunneryd et al., 2003).

The difficulty in designing fishing gear is to maintain a good fishing function while preventing seals from reaching the catch, i.e. extinguishing an unwanted behaviour. It is a continuous arms race between the fishing industry and seals, leading to experiments with a wide variety of mitigation means.

1.3.2 Different mitigation methods

The mitigation methods can be divided into two main groups; non-lethal and lethal. To the non-lethal group belongs acoustic deterrents (cracker shells, ADD’s, AHD’s, sounds of killer whales), aversive stimuli (taste aversion), capture, exclusion, management, tactile harassment, (rubber bullets, cattle prods, electrical deterrent), vessel handling and visual deterrents (killer whale decoys). To the lethal group belongs culling specific individuals or culling by decimating the population. See Appendix A for references.

The different methods have been tried with varied degrees of success. In a meta-analysis, papers addressing the different mitigation methods were reviewed (Calamnius, 2017). Whether the method was perceived as favourable or not, generally varied with the perceived degree of severity of the mitigation method. The higher the perceived degree of severity was, the less proportion of papers were in favour. The same mitigation method could in different papers be viewed either as a possible solution or as not being a possible solution.

When pinnipeds interact with fishing gear there is a risk that they become entangled and dies. This poses both ethical and practical concerns for the affected fishers (Lunneryd et al., 2004).

1.3.3 The pontoon trap – a successful means of mitigation

In the mid 1990’s the Swedish government began to search for long term solutions to mitigate the interactions between the increasing numbers of seals and fishers (Westerberg et al., 2000). Solutions to keep the seals from the fish were needed, while not endangering the seals frequenting the fishing gear. Since 1994 the Swedish Environmental Agency and the Swedish Agency for Marine and Water Management have supported research and development for mitigating the interactions between fishers and seals (Westerberg et al., 2000). This has been effected through the program ‘Seals & Fisheries’, whose long-term goal is a sustainable coastal fishery and a viable seal population. This is achieved by developing mitigation methods based on scientific research by analysing catch data and by observing the behaviour of seals interacting with fishing gear (Fjälling, 2006; Seals & Fisheries, n.d.).

Technical adaptations are generally preferred by authorities over compensation schemes as they seek to provide long term effects (Varjopuro & Salmi, 2006) and are considered to reduce the cause of conflict (Holma et al., 2014). If the technical method works, it provides a long-term solution. Compensation schemes instead offers a short-term solution and are often favoured by the fishers. A successful means of mitigation must keep seals away while still catching fish, be resistant to heavy weather, be easy to use and be compatible with the fisheries goals and conservation policies set by the authorities (Varjopuro & Salmi, 2006). The seals' opportunistic and adaptive nature makes the development of seal safe fishing gear a reactive rather than a proactive undertaking.

The development of the pontoon trap began in the late 1990's (Hemmingsson et al., 2008; Lunneryd et al., 2003). It was invented by an innovator and fishing gear developer and was officially recognized in 2001 as a means to minimize seal induced damage to fish and gear (Hemmingsson & Lunneryd, 2007). The pontoon trap has been in commercial use since the early 2000's.

The pontoon trap (Fig. 1) consists of a leading net, which is attached to land, leading the fish into a series of progressively smaller chambers. The chambers are designed so that it is difficult for the fish to find its way out. The final chamber is the fish chamber, from where the fish is harvested (Fig. 1). The mesh size in the leading net and wings is matched to the target fish. This allows a seal-chased fish to escape through the mesh, whereas a fish that is not alarmed will be guided into the trap (Lunneryd et al., 2002)

The pontoon trap is a further development of models of trap-nets which have been in use since the middle of the 19th century (Varjopuro & Salmi, 2006). The design is similar to that of the Scottish salmon trap. The Scottish salmon trap consists of a series of successive chambers, gradually decreasing in size and funnelling into the next chamber. The funnels function as a non-return device making it difficult for fish to escape (von Brandt, 1984).

The pontoon trap is the most successful mitigation means in the Baltic to this date. It is most commonly used to catch salmon, trout (*Salmo trutta*) and white-fish (*Coregonus maraena*). The success of the pontoon trap can be attributed to its ease of use. Harvesting fish from a pontoon trap takes minutes and does normally not involve any heavy lifting for the fishers. Today, it is an essential part of the fishing gear used by a majority of coastal commercial fishers along the east coast of Sweden. They have been developed for eels (*Anguilla anguilla*), salmonids (*Salmonidae*) and whitefish, herring and vendace (*Coregonus albula*) and perch (*Perca fluviatilis*) and zander (*Sander lucioperca*).

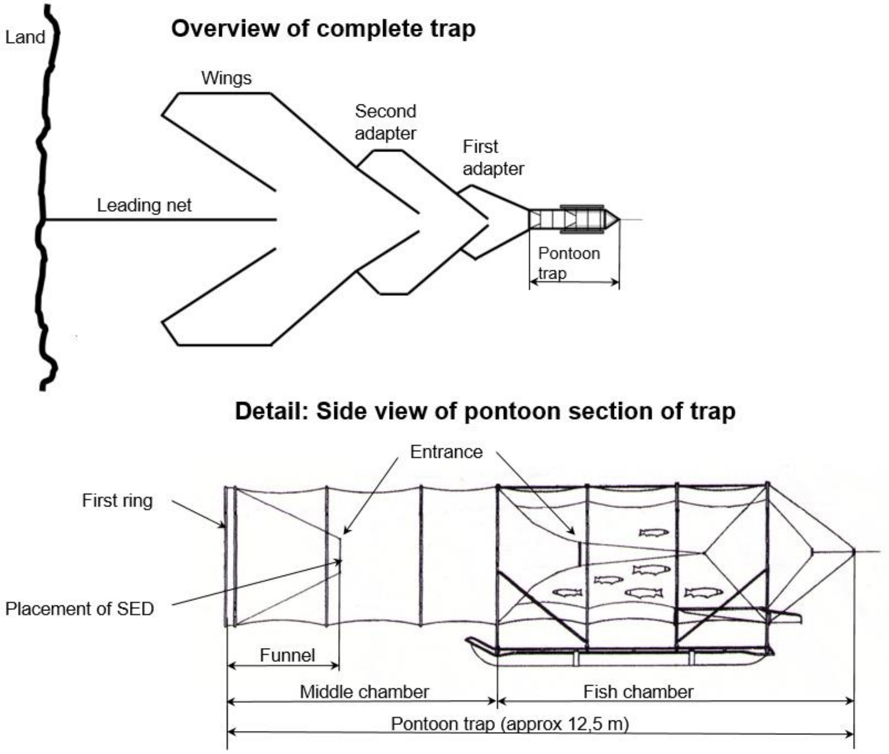

Figure 1. Overview and detail of pontoon trap for salmon and whitefish. The entrance into the middle chamber measures 80 x 80 cm. The entrance into the fish chamber is 40 x 40 cm and has a vertical steel rod placed in the middle to prevent seals from entering. Seals have previously had access to all preceding parts of the trap, including the middle chamber.

There are several advantages with using passive fishing gear such as pontoon traps. The catch is contained in the fish chamber, where it is seal-safe (Königson & Lunneryd, 2012). The fishers consume less fuel per kg caught fish and the fishing method has a Low Impact on the environment and is Fuel Efficient (LIFE: Suuronen et al., 2012). Selection panels can be installed in traps to make them size selective, reducing bycatch of non-commercial target fish (Paper II).

The seals have however learned to find their way into the middle chamber (cf. Fig. 1). A preventive measure to keep seals from this part, led to the construction of two different types of Seal Exclusion Devices (Paper I).

The advantages of pontoon traps have been recognized in other countries in Europe. In 2015, pontoon traps were introduced in the Rumanian part of the Black Sea (M. Lundin, 2018[2]). The purpose was to exclude dolphins from the

[2]. Personal communication. M. Lundin works for Harmångers Machine & Marine, a Swedish manufacturer of pontoon traps.

catch. The pontoon traps have also been used in the river Danube, where the purpose was to exclude pelicans. An important feature for the Rumanian fishers was that it is easy to use, while maintaining a good catch efficiency.

A commercial fisher said that if the pontoon trap had not been invented, there would be no small-scale coastal fisheries in the northern part of the Baltic (K-Å Wallin, 2015[3]).

The seals are setting the pace and fishing gear developers are reactive, rather than proactive in finding new mitigating solutions. Understanding the behaviour of both predator and prey (i.e. seals and fish) will further our knowledge of how to best design innovative fishing gear in the future.

[3]. Personal communication. K.-Å. Wallin is a commercial fisher.

2 Aims of the thesis

The main aims of this thesis are to contribute with new knowledge on how seal-safe and selective modifications to existing fishing gear can contribute to mitigate the interactions between seals and fishers and to a more sustainable coastal fishery. The thesis also describes the behaviour of rogue seals during their exploits into a trap with the aim that the knowledge can be used for the future management of the grey seal population. The main interactions addressed in this thesis are between grey seals and coastal fisheries.

The three themes in this thesis all concern pontoon traps and coastal fisheries in the Baltic Sea and are:

Preventing seals from reaching the catch (Paper I).
Reducing bycatch of non-commercial fish (Paper II).
Behaviour of seals when visiting a pontoon trap (Paper III).

3 Material and methods

This section will give an outline of the materials and methods used in each of the experiments. A detailed description of how the experiments were conducted is found in each of the papers. All presented experiments took place in pontoon traps. The data collected were catch data and recordings of visiting seals in front of a SED (Paper I), catch data (Paper II) and recordings of visiting seals inside the trap (Paper III).

3.1 Paper I

The need for excluding seals from the middle chamber was recognized early after the introduction of the pontoon trap. The first time a SED was used in a pontoon trap in Swedish waters, was in the early 2000's and in the shape of a diamond mesh SED (T. Innala, 2018[4]).

The study for Paper I was conducted at Ljusne, Sweden, using pontoon traps for salmon and brown trout. Ljusne is close to the city of Söderhamn and around 240 km north of Stockholm.

Two different types of SEDs were used. One trap had a diamond mesh. The other had a square mesh SED with the frame rotated 45°. Rotating the square mesh SED results in an approximation of the diamond mesh, facilitating for fish to swim through. In a square frame with diamond mesh, there will be resulting quarter and half mesh. In a square frame with square mesh, there are no quarter or half mesh. All mesh are equally sized and shaped. The SEDs were compared with a control, which was an open frame. The frames with the SEDs and the control were exchanged with an interval of one week. The expectations of using a SED in a pontoon trap was that it would prevent access of seals into the middle chamber and that it would increase the landed catch. It was also expected that

[4]. Personal communication. T. Innala is a commercial fisher.

the SED might prevent larger salmon or brown trout from entering into the middle chamber.

The weight of each salmon and brown trout, total weight of catch per harvest and number of fish per harvest were recorded. An underwater camera was placed filming the entrance of the middle chamber to record whether the SED would keep the seals from accessing the middle chamber. Statistical analyses were calculated separately for salmon and brown trout. The data was analysed applying the Kruskal-Wallis test. To obtain a valid measure for comparing the number of visiting seals per trap, the frequency of visits per filmed hour was calculated.

3.2 Paper II

Early in the 2000's coastal fishers expressed concerns when fishing whitefish with pontoon traps. Many of the non-commercial whitefish (< 30 cm) were killed or damaged during harvests. The fishers had to manually sort the non-commercial fish from the catch (Fjälling, 2007). It was a time consuming procedure coupled with a high mortality rate. A need for selection panel(s) was recognized and several experiments were carried out. They discovered that the preferred shape for whitefish was square, with 50 mm bar length (Lundin, 2007), that the panels should be placed near the funnel or the cone of the fish chamber (Fjälling, 2007; Lundin et al., 2011) and that selection of non-commercial whitefish was possible (Fjälling, 2007; Lundin et al., 2015).

The study used a selection panel to reduce the proportion of non-commercial whitefish in the catch. Data were collected in 2013 and 2014 during field experiments at Ljusne. Three pontoon traps for salmon and whitefish were used. One control and two experimental traps. The fish chamber of a pontoon trap has a double netting. The standard mesh size for the inner netting is 35 mm bar length. The control trap had the standard inner netting fully and no selection panels. The two experimental traps had 30 % and 100 % respectively of the inner wall area substituted with 50 mm bar netting, areas serving as selection panels. The hypothesis tested was that an increase of selection panel area would result in a reduction of non-commercial whitefish in the catch.

The caught whitefish were measured in half cm increments, from the tip of the nose to the end of the tail, when brought together. The proportion of non-commercial whitefish was calculated and differences between mean length between traps and between years were tested with a two-way ANOVA.

3.3 Paper III

Studies of aquatic interactions between grey seals visiting fishing gear has to a great extent been uncharted waters. Describing the behaviour of the rogue seals which exploits fishing gear, will bridge a knowledge gap of their interactions with conspecifics and can be of use in the future management of their population.

The data was collected in 2009. A pontoon trap for herring was placed off the coast of Mellanfjärden, Sweden. A camera was placed inside the middle chamber and was aimed at the entrance, filming seals and fish on their way in. In a previous study in a salmon/whitefish trap, recordings of visiting seals yielded more than 500 visits in one season (Königson et al., 2013).

The collected data were recordings of seals when they visited the middle chamber. Each visit by a seal was logged with time for enter and exit. A photo identification journal of the individual seals was created. The individual identification was based on the seals' pelage pattern and/or scars. This method for identification has previously been used by e.g. Gerondeau et al. (2007), Hiby et al. (2009) and Königson et al. (2013).

The time data for pairs of seals that participated in overlapping visits were analysed with respect to whether the probability of this certain pair to coincide in an overlapping visit differed from random. The probability of how many overlapping visits there should mathematically have been was calculated by multiplying the proportion of visits seal A was in the middle chamber on a given day, with the proportion of visits seal B was in the middle chamber on the same day. A Half Weight Index (HWI) was also calculated (Cairns & Schwager, 1987). HWI is an association index and values range from 0 (pairs of animals which are never seen together) to 1 (pairs of animals which are always seen together (Carter et al., 2009). The lowest HWI in the current study was 0 and the highest was 0.11, with an average of 0.03. Most of the possible pairs of seals that could have participated in an overlapping visit did not occur. Of the 28 possible combinations of pairs of seals, 16 pairs did not participate in overlapping visits.

Forty simulations of overlapping visits were executed to determine whether the overlapping visits were random or non-random. The simulations used the same number of seal visits, the same 'working hours' and the same length of visits as in the actual visits. If the visits were random, the proportion of simulated visits vs. realised visits were expected to be approximate to each other. If the visits were non-random, the proportion of simulated visits vs. realised visits would be either less or more than what occurred.

4 Results and discussion

4.1 Paper I

A SED placed in the entrance of the middle chamber prevents most, but not all, seals from entering. The expectations were that using a SED would prevent seals from entering the middle chamber, increase the catch of salmon and brown trout, and deter larger salmon and brown trout from entering the middle chamber. The number of seal visits by the SEDs or in the control traps was unexpectedly low. There was only one observed seal visit. It was at the trap with the square mesh SED. During this single visit, which lasted a little over five minutes, the seal destroyed the SED.

Using a SED did not have any significant effect on the total catch of either salmon or brown trout. The SED did have a significant effect on the individual size of salmon but not on brown trout. Heavier salmons were caught in the trap equipped with the square mesh SED. There was a trend of larger trout being caught in the traps with a SED, then in the control trap. Contrary to our expectations, the SED did not deter large salmons from swimming into the middle chamber.

With a diamond mesh SED, there are many half- and quarter mesh, making a possible visual impression, with only a little over half of its area (56 %) being unabridged mesh. This might be perceived as an obstacle by hesitant fish. It is imperative to make full use of the total area of the opening, which is achieved by using a square mesh SED, with the frame rotated 45°.

4.2 Paper II

The proportion of non-commercial whitefish was larger in the control trap than in the experimental traps. The result was significant both years. From a selection efficiency point of view, there was no significant difference in selection efficiency between the trap with the partial selection panel and the trap with the full selection panel. A plausible reason for this is that whitefish actively seeks for an escape while trapped inside a fish chamber (Fjälling, 2007). From a fishers and manufacturers point of view, the full inner netting is preferable. There is less material for algal growth to adhere to and the material cost is less than when using the standard mesh (35 mm bar length). The difference in the weight between the two different nettings is negligible (approximately 0.7 kg).

The experiment was disrupted earlier than planned in 2014, due to increased water temperatures. The increased water temperatures had two negative effects on the fishing. It decreased the catch of whitefish and the algal growth on the netting of the trap became heavy and dense. Whitefish is a species which generally prefers cold waters (Ask & Westerberg, 2006). Profuse algal growth on the trap also reduces the light inside the trap. Fishers report that whitefish are not caught in 'dirty' traps (P.G. Persson, 2018[5]). The earlier onset of algal growth might have affected the catches negatively. In addition, the fouling algae increases the total weight of the traps, making it more difficult to lift to the surface. Smaller mesh will mean more material for algae to adhere to and the difference in total weight (netting with algae) can become substantial.

Allowing non-commercial whitefish to escape through the selection panels, contributes to a sustainable fishery. It also contributes to less sorting of fish for the fishers and improves their working conditions.

4.3 Paper III

The seals made 1 390 visits in the middle chamber with a total time inside the middle chamber of just over 20 hours. Twelve different seals were identified. There were 138 occasions where it was not possible to identify the visiting seal. Too many fish were obstructing the view or it was too dark to discern identifiable features. One young female was unfortunately small enough to swim through the entrance into the fish chamber where she subsequently perished. The seals visits to the middle chamber were logged with time when they swam in and out. There were 48 overlapping visits, i.e. two seals inside the middle chamber at the same time, or in 3.5% of all visits. To explore whether the actual overlapping visits were less or more than could be expected, 40 simulations of visits were performed. The time of day and the length of the visits were randomly chosen.

In the simulations, the lowest incidence of overlapping visits was 6.0 % and the highest was 8.6 %, with a mean of 7.1 %. The difference in the realised

[5]. Personal communication. P.G. Persson is a commercial fisher.

overlapping visits vs. the simulations indicates that the seals were informed of the presence of other seals and that they chose to not enter the middle chamber while another seal was present. There is a possible risk of injuries when encountering a conspecific in a limited space.

The probability of overlapping visits between a certain pair of seals was calculated. The pair of seals with the highest probability of an overlapping visit (18 %) on a certain day, did not participate in any overlapping visits that day.

There was a significant difference in the simulated vs. the actual overlapping visits in both number of visits and the total length of overlapping visits. This is indicative of that the seals visits were non-random and that they were aware of the presence of a conspecific and choose to not swim into the middle chamber when another seal was present. Association patterns between individuals are generally non-random (Pinter-Wollman et al., 2014).

The knowledge gained from this study, will possibly contribute to the future management of the grey seal population and in finding new methods of mitigating the interactions between fishers and seals.

5 Concluding discussion

In short the use of the SED (Paper I)

1. appeared to have a retaining effect on larger salmons, possibly by functioning as a non-return device,
2. had no visible effect on the size of caught brown trout,
3. had no visible effect on the total catch of salmon or brown trout.

In the fishery participating in the study, 93 % of the total catch (kg) consisted of salmon. Considering that the major part of the catch consists of salmon, the information given to coastal fishers is that using a SED matters on the size of the salmon. It is possible that in areas where the catches are more bountiful it would also have an effect on the total catch. As the seals have learned to find their way in to the middle chamber, it has become essential to prevent them from entering the middle chamber, where they damage and stress the fish.

Selection of non-commercial whitefish from a pontoon trap for salmon and whitefish was efficient (Paper II). There were no differences in selection efficiency between the two experimental traps (partial and full selection). Allowing non-commercial whitefish to escape will reduce bycatch and contribute to a sustainable fishery. The advantages with using pontoon traps with partial or full selection panels are of a more practical nature. When more of the inner netting consists of larger mesh (50 mm vs. 35 mm bar length), the amount of material which algae can adhere to is reduced and the material cost will be less.

The seals' interactions with other seals while foraging inside a fish trap, is an area previously scarcely studied (Paper III). The results have yielded new insights into their aquatic behaviour and indicate that they waited before swimming into the trap, when another seal was present. The new findings from this study can be used in the future management of the grey seals.

The results from these studies have been shared with coastal fishers. The square mesh SED and the full selection panel have been implemented in existing fisheries.

6 Future research

With the middle chamber nowadays often inaccessible for seals, due to the more prevalent use of SEDs, it can lead to three potential outcomes in future: (1) The seals turn away from the SED as visiting the middle chamber becomes impossible. (2) The seals motivation to forage in other parts of the trap will increase. (3) The seal might direct its attention of getting to the catch inside the fish chamber by destroying or damaging the SED or other parts of the trap.

In a pilot project in 2010, a diamond mesh SED was placed in a pontoon trap for herring. The number of seal visits by the SED was 612 (unpublished data). At no time were seals observed to bite or destroy the Dyneema® yarn used in the mesh. In Paper I, seals destroyed three of four SEDs during the experiment. A new SED using the square mesh design, but with metal rods instead of Dyneema® yarn has recently been tried by three fishers. So far, they have attested to a good functionality. If it will withstand the seals perseverance, remains to be seen.

What seals do while near or in fishing gear, how and if they interact with conspecifics, needs to be further investigated. Learning more about their aquatic behaviour should result in new means of keeping the seals at bay.

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Popular science summary

It is a great success for the management of the Baltic Sea Area that the populations of the three seal species have recovered from the historically low levels of the 1970's. The three species are the grey seal, the ringed seal and the harbour seal. One example of recovery is the population of the grey seal, which grows with around 8 % per year. In the 1970's it was estimated that there remained 3 000 grey seals. The reason behind the low number of seals was an earlier excessive hunt and pollutants. Today the population is estimated to be between 38 000 to 50 000.

The growing seal populations are however a cause of concern for the coastal fisheries. Predominantly the grey seal causes most of the problems. They take fish and damage fishing gear. The coastal fisheries are an important part of a viable rural coastal area. They contribute with locally produced food of high quality, are an important part of a cultural heritage and are a popular feature of the tourism industry.

Due to the increasing populations of seals, it became difficult, if not impossible, to fish with nets in many places. The seal removed the fish from the nets. In the beginning of the 2000's an innovator and fishing gear developer invented a new type of trap. The pontoon trap. The trap is similar to earlier fishing traps, with the difference that its final part is lifted out of the water by inflating pontoons. Hence the name 'pontoon trap'. The trap works by leading the fish into a series of chambers, which progressively becomes smaller. The last chamber is the fish chamber, from where the fish is harvested. The pontoons are placed under the fish chamber. By inflating them with air from a compressor, the trap is lifted out of the water and floats on the surface. During the lifting process, the fish is gathered at one end of the fish chamber and ends up in the fish box, situated at the bottom of the fish chamber. The fisher 'parks' the boat below the fish box, opens a hatch and the catch falls into the boat. Compared to previous traps, the pontoon trap can take just a few minutes to harvest.

The pontoon trap can be adapted to different fish species. From vendace with a maximum weight of 80 grams, to salmon and trout which can weigh towards 20 kg. There are bigger salmons, but they are usually not caught in pontoon traps. The trap can be used for different species of fish. The shape and size of the chambers are then altered and the size of the mesh in the netting. One of the most commonly used pontoon traps along the coast of Northern Sweden is for salmon and whitefish. Its fish chamber is equipped with an inner- and an outer netting. It distances seals from the catch. Had there been only one layer of netting, the seal might reach the fish through the large mesh in the outer netting. There is a steel rod in the middle of the entrance to the fish chamber. This prevents seals from swimming in to this part of the trap. Seals have had access to all other parts of the trap, including the middle chamber. Besides taking fish, they also stress caught fish. One fisher realised early that there was a problem with the open entrance into the middle chamber. He manufactured a Seal Exclusion Device (SED) using diamond mesh. A diamond mesh is shaped like the diamond in a deck of cards. SEDs prevents seals from entering the middle chamber. It took a couple of years before a scientific experiment investigated the possible effects of a SED. This is what the first study of this thesis addresses.

The first study compared a control with two different SEDs. The study was carried out in Ljusne in collaboration with a commercial fisher. The expected result was that seals would be prevented from swimming into the middle chamber and that the catch would increase. It was also expected that it would deter larger fish from swimming in. The control was an open entrance (Fig. 2). One of the SEDs had diamond mesh. The other had square mesh, with the frame rotated 45°. Every salmon and trout were individually weighed and a camera system was used to film visiting seals.

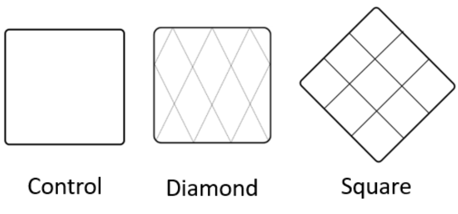


Figure 2. The control and the two SEDs, diamond mesh SED and square mesh SED. The diamond mesh here has the shape of a rhomb.

The only significant difference was that larger salmons were caught in the trap with SEDs. There were no significant differences for trout. The total catch in kg or in numbers were not affected. There were too few visits of seals to be able to draw any conclusions. By using a SED, larger salmons are caught. The SED probably functions as a non-return device, making it difficult for larger fish to swim out.

The second study concerned reducing bycatch of non-commercial whitefish, i.e. those under 30 cm. Bycatch is all non-wanted catch. It is fish of other species than the target fish, fish of the same species as the target fish but too small and also marine mammals and birds. Fishers using the pontoon trap observed that there was an unnecessarily large proportion of bycatch of whitefish.

A standard salmon and whitefish trap has an inner netting with diamond mesh with 35 mm bar length. The bar length is the length of one side of the diamond. The mesh is actually a square mesh, but oriented so that the diagonal of the square is vertical (Fig. 3). Selection panels reduce the bycatch of non-commercial whitefish. They can be a net where the mesh are of a certain shape and size, or a grid with steel rods with a certain width between them. Different species prefer different shapes and sizes of the openings to swim out through. Whitefish prefers square mesh (Fig. 3).

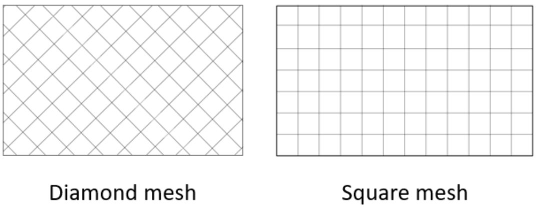


Figure 3. Diamond and square mesh. The diamond mesh here above are all square. In figure 2, the diamond mesh are rhombuses.

The experiment was carried out at Ljusne, in collaboration with two commercial fishers. Three pontoon traps were used. One control, which was a standard trap and two experimental. It was deemed suitable to use square mesh with 50 mm bar length for the selection panel. In one of the experimental traps the selection panel covered 30 % of the inner netting. In the other, the entire inner netting consisted of selection panel, i.e. 100 %. The length of the whitefish was measured and calculations of the selection efficiency were made.

Using selection panels allowed basically all non-commercial whitefish to escape. There was no difference in efficiency between the trap with 30 % selection panel and the trap with 100 % selection panel. From a selection point of view, it did not matter whether the selection panel covered 30 % or 100 % of the inner netting. The small whitefish found their way out anyway. For practical reasons the full selection panel is preferable. There is less material for algae to grow on, it is less affected by currents and it is easier to manufacture. Using selection panels in a pontoon trap for salmon and whitefish contributes to a sustainable fishery by decreasing bycatch of non-commercial whitefish. It also becomes less labour intensive for the fishers, as less fish needs to be manually sorted.

The third study analysed whether there was a pattern to the seals visits when they visited a pontoon trap for herring. The trap was placed off the coast of Mellanfjärden, Sweden. A camera was mounted in the roof of the middle chamber and aimed at the entrance to film seals entering and exiting. The film was provided with a time stamp. The visiting seals were identified by the pattern in their fur and eventual scars.

There was a total of 1 390 visits over 40 days. A total of 735 hrs of film were recorded. The total amount of time that seals spent inside the middle chamber was just over 20 hrs. There were 48 overlapping visits, i.e. two seals inside the middle chamber at the same time. This corresponds to 3.5 % of all visits. The total time with overlapping visits, was 18 min 43 s. This corresponds to 1.6 % of the total time for all seal visits.

A simulation of the seal visits was carried out using their ‘working hours’ and the length of their visits. The seals visited the trap during all hours of the day, except between 7 to 9 in the morning. This period coincided with when the trap was most often harvested. The actual length of their visits ranged from 1 to 242 s. Forty simulations were performed.

The lowest simulated number of overlapping visits was 83, the highest was 120 and the average was 99. This was slightly twice as much as the actual overlapping visits were. The shortest simulated total time of overlapping visits was 1 h 7 min, the longest was 1 h 40 min, with an average of 1 h 23 min. The average simulated time of overlapping visits was almost 4.6 times as long as the actual overlapping visits.

To summarize the results of the simulation: If the seal visits had been random, there would have been almost 100 overlapping visits (instead of 48). There would have been two seals inside the middle chamber for a total of almost 1.5 hr (instead of just under 19 min). These results indicates that the seals avoid to be inside the middle chamber at the same time and are probably informed of the presence of another seal. Gaining more insight into the pattern of seal visits into a fish trap can be used in the future management of the seal populations.

Populärvetenskaplig sammanfattning

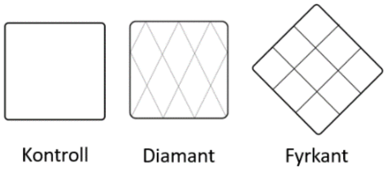
Det är en stor framgång för förvaltningen av Östersjöområdets tre sälarter att deras bestånd har återhämtat sig från de historiskt låga nivåer som det var på 1970-talet. De tre arterna är gråsäl, vikarsäl och knubbsäl. Ett exempel på återhämtning är gråsälen, vars bestånd växer med runt 8 % per år. På 1970-talet beräknades det återstå ca 3 000 gråsälar i Östersjöområdet. Anledningen till den låga nivån var en tidigare omfattande jakt samt miljögifter. Idag beräknas deras bestånd uppgå till mellan 38 000 till 50 000 sälar.

De växande bestånden ställer dock till med problem i det kustnära yrkesfisket. Det är framförallt gråsälen som orsakar problem i stora delar av Östersjöområdet. Gråsälarna tar fisk och skadar redskap. Det kustnära yrkesfisket är en viktig förutsättning för en levande landsbygd efter Sveriges kuster. De kustnära yrkesfiskarna bidrar med lokalt producerad mat av hög kvalitet, de är ett viktigt kulturarv samt ett populärt inslag i turistnäringen.

På grund av de ökande sälbestånden blev det på många håll besvärligt, om inte omöjligt, att fiska med nät. Sälen tog fisken från näten. I början av 2000-talet uppfanns en ny typ av fiskfälla, push-up fällan. Den uppfanns av en innovatör och redskapsutvecklare. Fällan påminner om tidigare fällor med den skillnaden att den sista delen lyfts upp ur vattnet när fällan vittjas. Därav namnet ’push-up’, från engelskans ‘tryck upp’. Fällan fungerar genom att fisken leds in i en serie kammare som gradvis blir mindre och mindre och gör det svårt för fisken att hitta ut. Den sista kammaren är fiskhuset, varifrån fisken vittjas. Under den sitter det pontoner. Då de fylls med luft från en kompressor, lyfts fällan ur vattnet och flyter sedan på vattenytan. Vid lyftet hamnar fisken i fisklådan som sitter i botten av fiskhuset. Yrkesfiskaren parkerar sedan båten så att det bara är att öppna luckan i fisklådan och fångsten töms rakt ner i båten. Med fällor utan pontoner, innebar vittjning en stor arbetsansträngning. Idag kan det ta några minuter att vittja en fälla.

Push-up fällan tillverkas och anpassas för att användas till olika fiskarter. Från siklöja som kan väga uppåt 80 gram, till lax och öring som kan väga uppemot 20 kg. Det finns även större laxar än så, men de brukar inte fångas i push-up fällor. Anpassning till de olika arterna görs genom att använda olika storlekar på de olika kamrarna, samt ändra storleken på maskorna. En av de vanligast före-kommande typerna av push-up fälla efter Norrlandskusten är lax- och sikfälla. Dess fiskhus är utrustat med både inner- och yttergarn (garn = nät). De två väggarna av nät behövs för att hålla sälarna från fångsten. Hade det bara varit en nätvägg i fiskhuset kan sälarna nå fisken genom de stora maskorna. I ingången till fiskhuset sitter det en metallstav som förhindrar sälar från att simma in. Till de föregående delarna av fällan har sälarna haft fritt tillträde. Förutom att ta fisk, stressar de den fisk som finns i fällan. En yrkesfiskare insåg tidigt problemet med den öppna ingången till vatthuset och tillverkade en sälgrind med diamantmaskor. En diamantmaska är formad som ruter i en kortlek. Sälgrindar förhindrar säl från att simma in i vatthuset. Det dröjde några år innan ett vetenskapligt experiment gjordes. Det är här den första studien i avhandlingen kommer in.

Den första studien jämförde en kontroll med två olika typer av sälgrindar. Försöket bedrevs i Ljusne i samarbete med en yrkesfiskare. Det förväntade resultatet var att fångsten skulle öka, att sälar skulle hindras från att simma in och att sälgrinden även skulle innebära att större fiskar inte simmade in. Kontrollen hade en öppen ingång in till vatthuset (Fig. 4). I en av sälgrindarna användes diamantmaskor. I den andra användes fyrkantsmaskor och hela ramen roterades 45°. Varje lax och öring som fångades vägdes för sig och ett kamerasystem monterades i fällan för att filma besökande sälar.

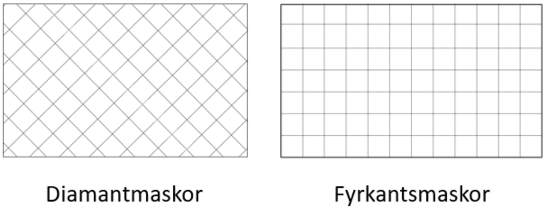


Figur 4. Kontrollen samt sälgrind med diamantmaska eller fyrkantsmaska.

Den enda betydande skillnaden som erhölls var att större laxar fångades i fällor med sälgrind. För öring var det ingen betydande skillnad alls. Den totala fångsten i kg eller i antal påverkades inte. Det var för få besök av säl vid de olika fällorna för att kunna säga något om sälgrindens effektivitet i att hålla säl från fångsten. Att använda en sälgrind innebär att större laxar blir fångade. Den fungerar troligen som en 'backventil' som gör det svårare för större fisk att simma ut.

Den andra studien handlade om att minska bifångsten av icke-kommersiell sik, d v s de sikar som är under 30 cm i längd. Bifångst är all icke önskvärd fångst. Det är fisk av andra arter än den avsedda, fisk av samma art som den avsedda men som är för små, samt även marina däggdjur och fåglar. Redan tidigt efter att fällorna började användas såg yrkesfiskarna att det blev en onödigt stor andel små sikar kvar i fällan.

En standard lax- och sik fälla har ett innergarn med diamantmaska med 35 mm stolpe. Stolpe är längden på sidan av maskan. Maskan är egentligen en fyrkantsmaska, men garnet är orienterat så att maskan står med diagonalen lodrätt (Fig. 5). Selektionspaneler sattes in för att minska bifångsten av små sikar. En selektionspanel kan vara ett nät med maskor med en viss form och storlek eller ett galler av ståltråd, med en viss bredd mellan trådarna. Olika fiskar föredrar olika storlekar och former på öppningarna för att simma ut. Sik t ex föredrar fyrkantsmaska (Fig. 5).



Figur 5. Diamantmaskor och fyrkantsmaskor. I diamantmaskorna ovan, är maskorna kvadrater, till skillnad från diamantmaskorna i figur 1, där de är romber.

Försöket bedrevs i Ljusne, i samarbete med två yrkesfiskare. Tre push-up fällor användes. En standardfälla användes som kontroll. De två andra var experimentfällor. Det bedömdes som lämpligt att till selektionspanelen använda fyrkantsmaska med 50 mm stolpe. I en av experimentfällorna var det 30 % av innergarnet som var selektionspanel. I den andra bestod hela innergarnet av selektionspanel, d v s 100 %. De fångade sikarnas längd mättes och beräkningar av selektionseffektiviteten gjordes.

Användandet av selektionspanel innebar att i stort sett all sik som var icke-kommersiell hittade ut. Det var ingen skillnad i selektionseffektivitet mellan fällan med 30 % och den med 100 % selektionspanel. Ur en selektionssynvinkel spelar det ingen roll om selektionspanelen täcker 30 % eller 100 % av innergarnet. De små sikarna hittar ut ändå. Av praktiska anledningar är en fälla med hela innergarnet av selektionspanel att föredra. Det blir mindre mängd material som det kan växa alger på, den blir mindre känslig för strömmande vatten och är lättare att tillverka. Genom att använda selektionspaneler i en push-up fälla för lax och sik, blir bifångsten av icke-kommersiell sik mindre än om man använder en standardfälla. Det blir även mindre arbetskrävande för fiskaren, med mindre mängd fisk att sortera.

Den tredje studien är en analys av om det fanns ett mönster i sälarnas besök i en push-up fälla för strömming. Fällan placerades utanför Mellanfjärden. En kamera monterades i taket i vatthuset och riktades mot ingången för att filma sälar som simmade in och ut. Inspelningen var kopplad till en klocka, som samtidigt satte en tidsstämpel på filmen. De besökande sälarna identifierades m h a deras teckningar i pälsen och eventuella ärr.

Det var totalt 1 390 besök av sälar under en period av 40 dagar. Under den tiden erhölls 735 timmar film. Den totala tid som de tillbringade i fällan var strax över 20 timmar. Av alla besök var det 48 st som var överlappande, d v s två sälar var inne i fällan samtidigt. I antal besök motsvarade det 3.5 % av totalen. Den totala tiden med överlappande besök var 18 min 43 s. Det motsvarar 1.6 % av det totala antalet timmar det var säl i fällan.

En simulering av besökande sälar gjordes, där deras ‘arbetstider’ och längd på besöken användes i simuleringen. Sälarna besökte fällan under dygnets alla timmar, utom mellan ca kl 7 till 9 på morgonen. Den perioden sammanföll med när fällan oftast vittjades. Längden på besöken varierade från 1 till 242 s. Fyrtio simuleringar gjordes. I simuleringen var det lägsta antalet överlappande besök 83 st och det högsta 120 st. Medel var 99 st, d v s något mer än 2 gånger det verkliga antalet. Den kortaste totala överlappande tiden i simuleringarna var 1 timme 7 min, den längsta tiden var 1 timme och 40 min och medel var 1 timme 23 min. I simuleringarna var det i snitt således nästan 4.6 gånger längre tid det var två sälar inne i vatthuset än i verkligheten.

För att sammanfatta resultatet av simuleringen: Om sälarnas besök hade varit slumpmässiga, hade det varit nästan 100 överlappande besök (istället för 48) och de hade samtidigt varit inne i vatthuset i totalt nästan 1.5 timme (istället för strax under 19 min). Det här resultatet indikerar att sälarna undviker att vara inne i fällan samtidigt, vilket tyder på att de är informerade om varandras närvaro. Att få mera insikt om sälarnas beteende när de besöker en fiskfälla kan vara av betydelse för framtida förvaltning av sälbestånden.

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Appendix 1.

Global mitigation methods divided into the two sub-groups, lethal and non-lethal.

Non-lethal	Acoustic deterrent	Cracker shells	Gearin et al, 1988; Jefferson & Curry, 1996; National Seal Strategy Group & Stewardson, 2005
		Acoustic Harassment Devices (AHD)	Fjälling et al., 2006; Jacobs & Terhune, 2002; Mate & Harvey, 1986; Nelson et al., 2006
		Acoustic Deterrent Devices (ADD)	Götz & Janik, 2013; Graham et al., 2009; Harris et al, 2014; Quick et al, , 2004
		Scaring with killer whale sounds	Jamieson & Olesiuk, 2001; Mate & Harvey, 1986; Stewardson & Cawthorn, 2003
	Aversive stimuli	Taste aversion - emetics	Gearin et al., 1988; Jenkinson, 2011; Würsig & Gailey, 2002
		Electrical deterrents	Forrest et al., 2009; Marine and Marine Industries Council, 2002; Schakner & Blumstein, 2013
	Capture	… and relocation	Hume et al., 2002; Würsig & Gailey, 2002
	Exclusion	Physical barrier (e.g. predator netting, bag enclosure)	Hooper et al., 2005; Königson et al., 2015; National Seal Strategy Group & Stewardson, 2005; Nelson et al., 2006; Yurk & Trites, 2000
		Physical barrier - pontoon trap	Hemmingsson et al., 2008; Lehtonen & Suuronen, 2004; Lunneryd et al., 2003; Varjopuro, 2011
		SED – to prevent from entering	Calamnius et al., 2018; Königson et al., 2015
		SED – as an escape means	Chilvers, 2008; Hamer & Goldsworthy, 2006; National Seal Strategy Group & Stewardson, 2005; Tilzey et al., 2006

Non-lethal	Management	Co-existence/adaptation	Varjopuro, 2011
		Economic subsidies/compensation schemes	Varjopuro, 2011
		Adaptation to high abundance of seals by using appropriate gear	Holma et al., 2014
		Marine Mammal Sanctuaries/avoidance of certain areas	Chilvers, 2008; National Seal Strategy Group & Stewardson, 2005
		Adaptive co-management	Bruckmeier & Höj Larsen, 2008; Butler et al., 2015; Smith et al, 1998
	Tactile harassment	Rubber bullets	Gearin et al., 1988; Jamieson & Olesiuk, 2001; Jenkinson, 2011; Stewardson & Cawthorn, 2003
		Cattle prods	Marine and Marine Industries Council, 2002
	Vessel handling	Vessel chase (hazing)	Marine and Marine Industries Council, 2002; National Seal Strategy Group & Stewardson, 2005
		Trawlers avoiding seals, driving away at high speed	National Seal Strategy Group & Stewardson, 2005; Tilzey et al., 2006
		More frequent lifts/harvests	Fjälling 2006
	Visual deterrent	Killer whale decoy	Mate & Harvey, 1986; Stewardson & Cawthorn, 2003
Lethal	Shooting	Killing – removal of non-discrete individual(s)	Bruckmeier et al, 2013; Jounela et al., 2006
		Culling – removal of specific problem individual(s)	Bruckmeier & Höj Larsen, 2008; Jamieson & Olesiuk, 2001; Marine and Marine Industries Council, 2002; Sand & Westerberg, 1997