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Feasibility and effectiveness of seal deterrent in coastal trap-net fishing – development of a novel mobile deterrent

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Abstract

With the rapid growth of grey seal (*Halichoerus grypus*) population in the Baltic Sea, seal-induced catch losses have increased dramatically in coastal fisheries. There have been various attempts to mitigate these damages, such as modification of fishing gear, but solutions have proven inadequate. Promising research results have recently been obtained by using acoustic deterrent devices (ADDs) to keep seals away from the immediate vicinity of the gear. We tested the feasibility and effectiveness of a raft-mounted and a novel mobile ADD in Baltic salmon (*Salmo salar*) trap-net fisheries along the Finnish coast in collaboration with 13 commercial fishers. Fishers operated trap-nets (pontoon traps) that were equipped with and without an ADD. Our results indicate that a fisher with a trap-net equipped with an ADD can expect to catch on average 3.4 salmon per day whereas in trap-net without an ADD a fisher can expect on average 2.1 salmon per day. The deployment of ADDs over the two years testing period indicated an average increase of 64 % in salmon catches. Our study suggests that in salmon trap-net fisheries an ADD is a useful and economically viable (given that the investment is subsided) mitigation tool for reducing seal-induced catch losses. Furthermore, the mobile ADD developed in this study provides unique practical opportunities and notable potential for a wider use of an ADD.

Keywords: *seal-fishery conflict, ADD, grey seal, Halichoerus grypus, Baltic salmon*

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1. Introduction

The annual growth of grey seal (*Halichoerus grypus*) population in the northern Baltic Sea has been 5-9 % since 1990 (Harding and Härkönen, 1999; Harding et al., 2007; Hansson et al., 2018; SwAM, 2019). In concert with growing grey seal population, seal-induced catch damages have increased dramatically in coastal fisheries (Kauppinen et al., 2005; Fjälling, 2005; Svels et al., 2019; Vetemaa et al., 2021). In many Baltic Sea regions, seals are considered by fishers the biggest threat for the viability and continuation of their livelihoods (Svels et al. 2019; Vetemaa et al., 2021). There is no doubt that the total societal costs of grey seal in the Baltic Sea fisheries have been extensive and likely much larger than the observed costs (Svels et al., 2019; Waldo et al., 2020a; Blomquist and Waldo, 2021; Johansson and Waldo, 2021).

At the same time, as a top predator in the Baltic Sea, grey seal is considered an important and valuable component of the Baltic Sea ecosystem, and its continued survival and wellbeing is paramount (HELCOM, 2006). All seal species in EU enjoys strong protection through various international recommendations and directives, and grey seal is listed as "of community importance" in the EU's Habitats Directive (EU 1992).

There have been intensive research activities, focusing largely on gear modifications, to mitigate seal-induced damage in the Baltic coastal fisheries (Lunneryd et al., 2003; Lehtonen and Suuronen, 2004; Suuronen et al., 2006; Hemmingsson et al., 2008; Lehtonen and Suuronen, 2010; Königson et al., 2015). Even though a wide range of potential gear-based solutions have been invented, the problem has not been adequately resolved. While the fish chamber of a trap-net can be made seal-safe (Suuronen et al. 2006; Hemmingson et al., 2008), seals are still able to catch fish and disturb the capture process in the other parts of the trap-net and in the vicinity of the gear (Lunneryd et al. 2003; Fjälling et al., 2006).

The fishing sector considers a drastic reduction of the size of seal population the most effective measure to mitigate the seal-fishery conflict (Svels et al., 2019; Waldo et al. 2020b). Hunting of grey seal, however, is difficult and time-consuming. Furthermore, population management limited solely to hunting is not feasible although could complement other measures. Clearly, the seal-fishery conflict in the Baltic Sea has become increasingly difficult to solve (Bruckmeir and Larsen, 2008; Waldo et al., 2020b; Blomquist and Waldo, 2021). There is a need for an effective mitigation measure that is acceptable for both the societies and the fishing sector.

Promising results in reducing the damage caused by grey seal in the Baltic Sea have been obtained by using acoustic deterrent devices (ADDs, Fjälling et al., 2006; Vetemaa et al., 2021). ADD produces sounds of high enough intensity to cause discomfort in the seals that enter the vicinity of the gear where an ADD is mounted (e.g. Götz and Janik, 2010). Hence, ADD offers a potential way to discourage seals from entering the vicinity of the gear. Despite promising results, ADDs have not yet been adopted by the fishers in the Baltic Sea. There is a common perception among fishers that ADDs act more like dinner bells than deterrents, and that the sound produced by ADDs elicit curiosity rather than fear in the seals (see also Mikkelsen et al., 2017). Interestingly, ADDs are widely used by aquaculture sector in the northern Baltic Sea to protect fish-cages from grey seal attacks; up to 50% of the farmers are using ADDs (Markus Kankainen, personal communication). In fact, fish farmers were the one that started to use ADDs in the northern Atlantic region (e.g. Götz and Janik, 2013), including the Baltic Sea.

In this study, ADDs were deployed over two fishing seasons in Baltic salmon (*Salmo salar* L.) trap-net fishery along the Finnish coast in collaboration with commercial fishers. The primary objective was to systematically measure the effectiveness of ADD and assess its feasibility in coastal salmon trap-net fishery. An additional objective was to develop a mobile seal-deterrent device that would be handy and effortless. The overall goal was to find a technical solution which is acceptable to key stakeholders, such as fishers and environmental organizations, that are involved in the seal-fishery conflict in the Baltic Sea.

2. Material and methods

2.1. Fishing experiments

To test the effectiveness of ADDs, altogether 13 commercial trap-net fishers from the southern and southwestern coast of Finland (Fig. 1) were engaged in a series of fishing trials during the salmon fishing season in May-August in 2020 and 2021.

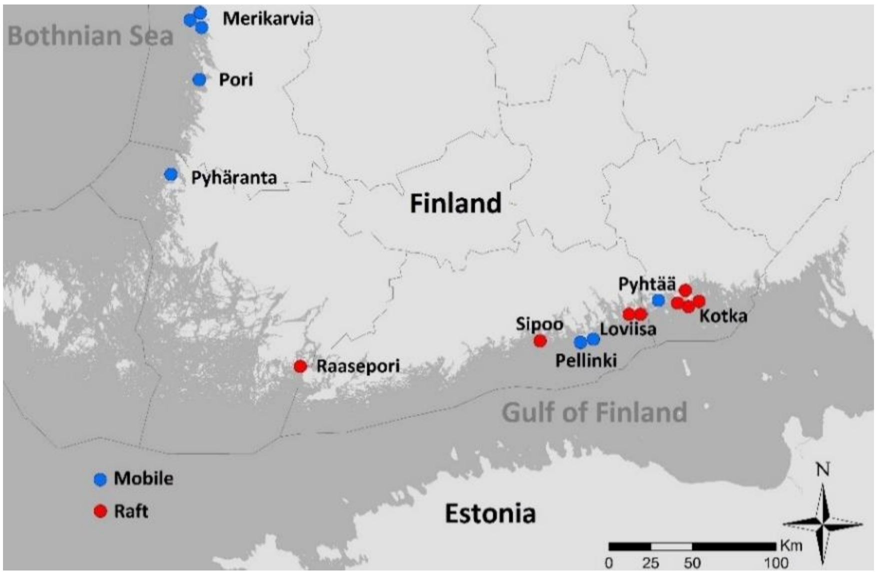

Figure 1. Locations of the seal deterrents (ADDs) used along the Finnish southern and southwestern coast in 2020-2021. The type of ADD is indicated with a color code. Blue = mobile ADD, Red = raft-mounted ADD.

All fishers used pontoon traps which are currently the standard trap-net design for capturing salmon and some other species such as European whitefish (*Coregonus lavaretus* L.) in the coastal regions of the northern Baltic Sea. The gear has a leader net of several hundred meters and wings ending with funnels that lead into the fish chamber equipped with hoops (2.9 m diameter) and double wall of firmly stretched netting made of extra-strong seal-safe polyethylene (Dyneema) material (Fig. 2). All pontoon traps in this study had a wire-grid in the funnel to prevent seals entering the chamber.

Figure 2. Aerial view of a pontoon trap with the chamber, intermediate funnels and wings. Only a part of the leader net is shown. The seal deterrent is marked with a star symbol. Photo: Esa Lehtonen

Each fisher operated two similar trap-nets located in the same region in as similar conditions as possible. The trap-nets of each fisher were separated by a distance of about 1-2 kilometers which is a common practice by fishers. In the experimental set-up, one trap-net was equipped with an ADD and the other was without an ADD. In total, 1627 fishing days were done over the two years (Table 1). The number of days when the trap-nets had an ADD was 869 which is 53.4 % of total number of fishing days.

Table 1. Number of fishers, trap-nets, number of fishing days with the ADD on and off, total number of salmon caught, and the average number of salmon caught per day.

Year	Number of fishers	Number of trap-nets	ADD off / on	Fishing days	Catch in numbers	Catch / fishing days
2020	5	10	Off	219	423	1.93
			On	235	814	3.46
2021	12	31	Off	539	640	1.19
			On	634	1134	1.79

2.2. Technical specifications and mounting of seal deterrents

Otaq Sealfence (offshore.otaq.com) seal-deterrents used in this study are acoustic systems designed to deter seals. The system uses an underwater transducer to emit an omnidirectional sound which seals find uncomfortable inside the system's 40-45 m effective range. The device works at a frequency range of 9-11 kHz. It transmits a "pulse wall" consisting of several different frequencies that are transmitted in variable cycles so that seals would not become accustomed to the sound. The source level (Otaq laboratory measurements) at 10 kHz is about 189 dB re1 µPam RMS at 1 m.

The deterrents were anchored beside the fish chamber of the trap, near the trap-net funnels (see Fig. 2). Two different ADD mountings were used: a self-contained raft-mounted ADD with power sources (Fig. 3), and a mobile ADD where batteries were placed inside a compact polyethylene housing (Fig. 4).

Figure 3. Raft carrying an ADD unit and outfitted with solar panels and a wind generator for charging the batteries. Photo: Esa Lehtonen

In the raft-mounted ADD, the control unit with the batteries (2 x 240 Ah AGM) was set in a waterproof case held on the raft. The electricity for the system was produced by solar panels (2 x 300 W) and a wind generator fitted to the raft. Rafts were anchored in the close vicinity (about 20 m) of the trap-nets. The transducer (underwater sound projector) was lowered to a depth of about 3-8 m; the depth varied depending on depth of water at site. The advantage of a raft-mounted ADD is the constant battery voltage. No attention is required from the fisher, and the device functions autonomously.

In the mobile ADD the deterrent with two battery back units and control unit were packed inside a 2.5 meters waterproof housing (Fig. 4). The 30 kg battery back unit contains 2 x 45 Ah batteries (24 V). In operation, the housing is in a vertical position with the top of the housing ca 50 cm above water surface. The transducer at the bottom of housing is at a depth of ca 2 m. Mobile ADD has several operational benefits compared to raft-mounted ADD. Because of smaller water resistance, fewer anchors are required with mobile ADD. Moreover, it could be anchored closer to fishing gear, at a distance of about 10 m. The device is also less sensitive to rough sea than a raft and is easier to transport. The disadvantage that the batteries must be changed on average every 4 days.

Figure 4. On the left the mobile ADD along the side of a fishing boat. Photo: Esa Lehtonen**.** On the right a schematic drawing of a mobile ADD housing. The deterrent is placed at the bottom of the housing. Source: Modul Plastic Oy.

The change of batteries of a mobile ADD is done at sea. The device (90 kg) is lifted along the side of the boat and the batteries are changed. For transport, the device is lifted onboard. Without batteries, the device weighs 30 kg. Hence, lifting and transfer is handy. Mobile ADD is equipped with a GPS tracker for an eventual loss of device. In addition, fishers can follow the battery voltage of the ADD by their phones and change the batteries before the power drops too low. Low battery voltage would remarkably reduce the sound producing capacity of an ADD.

In the 2020 experiments we had only one mobile ADD available whereas in 2021 we had seven mobile devices in use. In 2020, there were five raft-mounted ADDs and in 2021 eight units.

2.3. Data collection by fishers

Fishers who used raft-mounted ADD had two trap-nets one of which was equipped with ADD over the season whereas the other trap-net served as a control. Nonetheless, one fisher had similar rafts in the vicinity of both of his trap-nets and the operational ADD was alternated weekly. Fishers, who used mobile ADD, moved the equipment weekly between their trap-nets. By alternating the trap-net where the ADD was operational, we could assess the potential effect of trap-net location in the overall results.

In general, trap-nets were hauled once a day. On each hauling of the trap-net, fishers kept detailed records of the number of salmon caught. In Finland, each salmon must have an individual non-removable tag before it is landed, and the catch must be electronically reported to the local fisheries authority. Hence, we can consider our salmon catch data as very accurate. The bycatch was small and consisted mainly of the European whitefish. Bycatches are not accounted in this study. Fishers also tried to keep records of seal caused damage to catch and gear. Because most fishers were not able to accurately record these damages, we did not consider the data reliable enough to be presented in this paper.

2.4. Statistical analysis

The statistical analysis is based on a Bayesian approach (Gelman et al., 2013) and is performed under the implicit assumption that "control trap-nets" were not affected by the trap-nets with ADDs. The size of the catch, as measured by the number of fish caught, is an integer and assumed to be proportional to the time interval between trap-net check-ups. Variation between fishing locations was modelled with a random effect. Informally, the model can be written as:

Catch = Time interval × (catch without ADD (F)+effect of ADD (F) + location(R)),

where the fixed effects are denoted with an F and the random effect with an R. The location in the model is a combination of a physical location and year, i.e., the catches from the same location during the same year more similar than catches from the same location during different years. The formal model is analogous to this informal expression; however, it also takes carefully into account the observed variation in catches. The latent exponential distribution reproduces the long right tail of the distribution, while the Poisson-distributed nature of the realized catch number allows for larger variation for large catches. This also mitigates the effect that any outliers would have on the results. The location specific effect is crucial, since the sample is not balanced with respect to the location. Since we do not have information on the location specific variation, we make the usual mixed-model assumption that this effect is normally distributed.

Based on graphical investigations, the catch is assumed exponentially distributed. The model can be expressed formally as

$$Catch \sim \text{Poisson}(\lambda)$$
$$\lambda|\gamma, t \sim \text{Exp}((t\gamma)^{-1})$$
$$\gamma = \exp(\mu + \kappa \cdot Device + u_{location})$$
$$u_{location} \sim N(0, \sigma^2),$$

where $Catch$ is the number of fish caught, t is the time in days between adjacent check-ups (controls), $u_{location}$ is the random effect related to the fishing location (municipality, based on graphical investigations there was no need for an additional specific location random effect), κ is a parameter which describes the effectiveness of the device, $Device$ has the value 1 when the device has been on and 0 when it has been off. Weekly informative prior distributions were chosen to ensure the convergence of the Markov chains. The priors do not take a stance on whether the device provides a benefit or not. The overwhelming number of catches per day were between 0 and 10, with a small number of individual observations (mostly with an ADD on) exceeding this, which is why the prior distributions have been chosen to be

$$\sigma \sim \text{Unif}(0,10)$$
$$\mu \sim N(0,10)$$
$$\kappa \sim N(0,100).$$

The fitting was done using Markov Chain Monte Carlo (MCMC) with five chains, 75,000 iterations, and a warm-up period of 25,000. The convergence of the chains and the posterior predictive distributions were graphically examined. The fits were done using the software JAGS (*Just Another Gibbs Sampler*) (Plummer, 2003) and the statistical software R (R Core Team, 2021).

3. Results

3.1. Statistical assessment of expected catch with and without ADD

Figure 5 shows the aggregated daily salmon catches throughout the summers of 2020 and 2021 for trap-nets with an ADD and without one. Given that the fishing efforts were comparable, the ADD is associated with an increase in catch. This benefit is seen throughout the summer.

Based on the Bayesian model, a fisher can expect to catch on an average year in a typical (median) location 2.89 salmon per day with a trap-net equipped with an ADD and 1.76 salmon per day without an ADD. This constitutes a 64 % benefit (95 % probability interval 28 - 106%) obtainable by the use of an ADD. Based on the model and data, the probability that the utilization of ADD has a positive effect on the catch is 99.99% (Fig. 6). These expected numbers describe a typical trap-net site in terms of salmon catch. Aggregating over all possible locations, the mean catches are slightly higher, 3.4 and 2.1 salmon per day for ADD use and no ADD, respectively, which reflects the skewed nature of the distribution: a relatively small number of locations account for a disproportionate share of the catch.

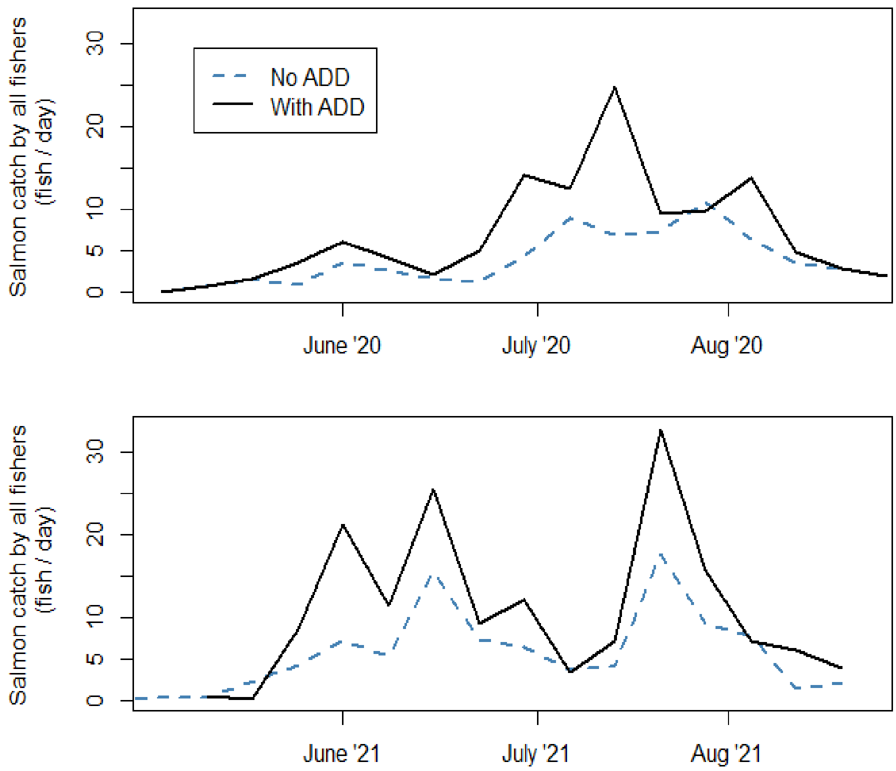

Figure 5. Total catch per day over time by all active fishers in 2020 (upper) and 2021 (lower) while using or not using an ADD in a trap-net. The catch has been aggregated by week.

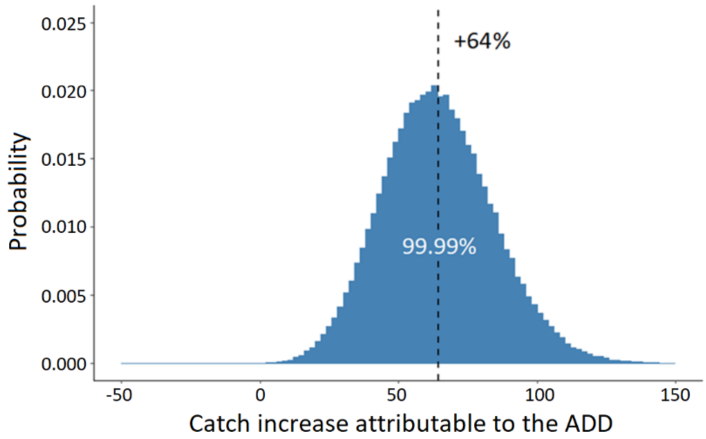

Figure 6. The probability distribution of the increase in catch attributable to ADD based on the collected data and the applied Bayesian model.

It is noteworthy that the predicted number of fish caught is somewhat higher than the numbers presented in Table 1. This is because the data is not balanced with respect to the location, i.e., there was more fishing effort in some locations. Furthermore, in the locations with less fish it will take longer to catch the fishing quotas which is why the number of fish per day will appear smaller in the raw data.

3.2. Fishers' experiences of using ADDs

Fishers' experiences of the effects of ADD were generally positive. They all noted that in the trap-net equipped with an ADD the catch was higher and the number of seal-damaged salmon was smaller compared to trap-net without an ADD. In addition, fishers pointed out that in trap-nets with ADD the catches had less fish with external seal-caused damages. With ADD there were also less fish that were meshed in the netting of the gear which fishers considered a sign of the absence of seals. One fisher noted that an ADD may even act as a fish attracting device (safe place for a fish because there are no seals near).

Some fishers noted that in the open and windy conditions, a raft mounted ADD is not an optimal solution. Most fishers preferred the use of mobile ADD because it is more practical, easier to transport, and cheaper to purchase. Fishers who used the mobile ADD pointed out that replacing the batteries was a quick process and could be done alone at sea. However, they hoped that the battery replacement intervals would be longer, and batteries would be lighter. They pointed out that if there are several devices in use by one fisher, replacing batteries will quickly accumulate excess weight onboard and lifting them may cause additional physical load to a fisher. GPS data and battery charge information in real time was considered useful.

4. Discussion

Promising new results were obtained by using acoustic seal deterrent devices (ADDs) in trap-net fishing of salmon. Compared to the studies of Fjälling et al. (2006) and Vetemaa et al. (2021), our experimental set-up, using several pairs of trap-nets along the coast, allowed a comparison of the catches of trap-nets with and without an ADD under wide-range of commercial fishing conditions. The deployment of ADDs over the two-year testing period indicated an average increase of 64 % in salmon catches. Our results suggest that in salmon trap-net fisheries an ADD is a useful mitigation tool for reducing seal-induced catch losses, at least when fishing is conducted with a pontoon trap. Furthermore, the novel mobile ADD developed in this study provides unique practical opportunities and notable potential for a wider use of ADDs.

The economic benefit of the use of ADDs can be roughly assessed by comparing the increase of catch value to the costs of an ADD. The total initial investment of a fully equipped raft-mounted ADD is € 16 500 whereas the cost of a fully operational mobile ADD is € 12 700 (with Otaq ADD in both). When the value of the catch is calculated from the average first-hand sale value for salmon (7 €/kg) and with an average weight of salmon as 6 kg, the gross return for a trap-net equipped with an ADD with would be € 10 920 for a fishing season with 260 salmon caught, corresponding to the expected catch in a median location. For a trap-net without an ADD the gross return would be € 6 636 with 158 salmon caught. It is noteworthy, however, that these numbers do not take into consideration the costs of ADD maintenance or the extra time needed for operating the device (which are likely not very significant costs). In Finland, commercial fishers get a 50% investment support for purchasing a seal deterrent. Therefore, the mobile ADD pays for itself in one and half season. To our knowledge, at least fishers in Sweden and Estonia have access to similar types of subsidies through the European Maritime and Fisheries Fund (EMFF).

There may be additional benefits in using an ADD. For instance, a fisher would be able to visit the gear less frequently during the periods when catches are small, thereby saving time and fuel. Furthermore, if seal-induced gear damages are reduced with the help of an ADD, a fisher needs less time to repair the gear and has more time for fishing-related work. Besides, as grey seals tend to wait in the entrance of the trap-net and disturb the capture process (Fjälling et al., 2006), an ADD would limit this behavior. Furthermore, an ADD may reduce seals' interest in finding food in the fishing gear with the additional advantage of preventing seals from becoming entangled and drowned in the gear. Nonetheless, seal deterrents do not completely prevent seal-induces damage. Individual seals, especially older ones, may not respond to the sound of an ADD. This could be because they are used to the sound or because of age-related hearing impairment (Madsen, 2005; Götz and Janik, 2010, 2013).

There are potential adverse effects of underwater noise on marine animals. For instance, there may be a risk of inducing hearing-damage to seals by prolonged exposure to the sound of an ADD. More studies are needed to evaluate these risks, taking also seals' motivation into consideration. One important question is whether a hungry seal can tolerate excessive pain that may potentially risk its hearing sense. It is also possible that continuous sound exposure may impair the seal's hearing and thereby improve the seal's ability to tolerate the repellent (Götz and Janik, 2010). Several authors have raised concerns on how ADDs may affect the behavior of co-existing cetaceans, such as harbour porpoises. As cetaceans only rarely appear along the northern Baltic coast, this problem is of a smaller scale in this region (see also Fjälling et al., 2006). Clearly, ADDs should be used with extreme care until more is known of their potential impacts on wildlife.

Obviously, an ADD would be most useful to those fishers who suffer from serious catch damage. The issue then comes whether all fishers in a certain region are forced to have seal deterrents when a few fishers have. Seals may attack more eagerly those trap-nets where there are no ADD. Although the distance between the treatment trap-nets and control trap-nets in our study were on average more than one kilometer, it is possible that our control trap-nets were affected by the ADDs in the trap-nets that were equipped by the ADDs. Unfortunately, our set-up does not allow the verification of this potential phenomenon. This issue would require a separate study.

In conclusion, our study shows that ADD can be a useful and economically viable mitigation tool in the seal-fishery conflict in trap-net fisheries. Nonetheless, there are still technical details that can improve the mobile ADD. For instance, the operating time of the batteries could be extended by installing solar panels at the top of the housing of the ADD and reduce the size of the device.

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