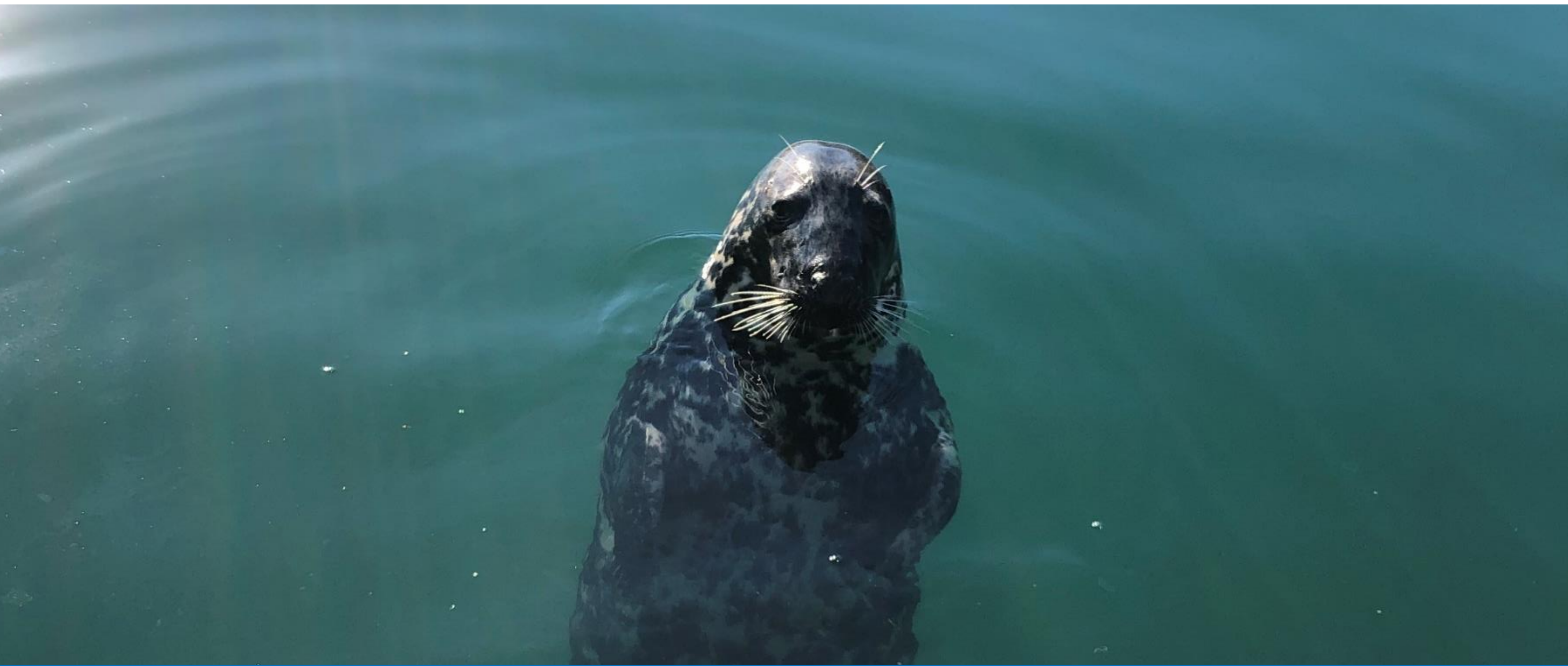
Marine Management Organisation

Assessing Non-Lethal Seal Deterrent Options: Summary Report (MMO1131)



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MMO1131: Assessing Non-Lethal Seal Deterrent Options: Summary Report

February 2020

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1 Executive Summary

Interactions between seals and fisheries include depredation of fish catches by seals and bycatch of seals in fishing gear. Depredation is a particular issue for static net fisheries throughout England, which can lead to significant economic costs from loss of commercial catch, increased gear handling times and gear damage. Interactions can also lead to seal mortality through either legal shooting ('Netsmen's Defence') or as a result of accidental bycatch.

The project aimed to:

- review available literature and data to understand the nature of interactions between seals and fisheries, the factors which influence these interactions, and potential non-lethal deterrent methods and their effectiveness
- undertake a programme of stakeholder engagement through a fishermen's survey and a workshop to gain a detailed understanding of the issue of seal depredation and by-catch in fisheries throughout England, and inform on the potential for at-sea trials of a deterrent
- conduct at-sea trials of a seal deterrent in a capture fishery, to determine its effectiveness and identify any issues for at-sea deployment.

The detailed results of the project are available in three separate reports (Literature and Data Review; Stakeholder Engagement Report; Fishing Trials Technical Report). This Summary Report draws together an overview of the individual reports of the project and the key findings.

Literature and data review

Grey seal (*Halichoerus grypus*) population numbers have generally increased in the UK since the 1980s, and there are important breeding colonies in Scotland and on the north, east and south-west coasts of England. Harbour seal (*Phoca vitulina*) populations have increased since the late 2000s and with significant increases in England. The main colonies in England are in the Thames estuary and The Wash.

A number of factors have a potential influence on rates of seal depredation on net fisheries, including: soak time; depth; net hauling sequence and haul speed; noise from fishing activities; location; seasonality; time of deployment; and gear type.

Acoustic Deterrent Devices (ADDs) are the most documented method of deterring seals from fisheries and aquaculture installations to prevent depredation. They work by emitting a noise that either causes pain or is distracting enough to create an aversion. There are many examples where ADDs have been shown to be at least partially effective, but they can also cause impacts on other species and the surrounding marine environment. A type of ADD that uses a specific type of noise that causes a startle response in seals (low frequency and sharp rise time) has been shown to be particularly effective at deterring seals, may avoid habituation, and limits noise impacts on the marine environment. Other deterrent options that are currently available are generally considered ineffective at reducing seal depredation, and the potential for modifications or alternatives to fishing gears and tactics to reduce depredation is limited.

Stakeholder engagement

An online survey was run to better understand fishermen's experiences and opinions on interactions between seals and fisheries. Static nets are the predominant gear type to experience interactions with seals, with drift nets and lines also reported to suffer frequent interactions, and pots/traps and trawls to have occasional interactions with seals. Interactions were reported to occur throughout the year. Around 30% of catches overall were reported to be affected by damage from seals and fishermen reported that in many cases, seals can make fishing (particularly with nets) uneconomical. Increasing seal populations were believed by fishermen to be the main cause of the increase in interactions, and interventions to control seal population sizes were favoured by fishermen to address the issue.

The stakeholder workshop reviewed the latest research, the problems, possible solutions and possible deterrent options to trial at sea. The workshop concluded that there is a need to engage, build trust and create dialogue between different parties to ensure different perspectives on the issue are integrated in any potential management solution or policy. All attendees had a preference for using the at-sea trials to test ADDs, with a preference for ADD technologies that are specific to seal hearing sensitivities and that use a startle response. Fishing tactics and avoidance measures tried by fishermen were not successful and therefore were not considered further.

At-sea trials

The Genuswave Acoustic Startle Device (ASD) was selected for the at-sea trials, which were conducted in a mackerel net fishery in Torbay by two inshore fishing vessels. Nets were approximately 200m long and set overnight in inshore waters of approximately 10m depth. On each fishing trip, each vessel deployed a 'control' net that was fished normally, and a 'test' net with one or more ASDs deployed next to it.

The use of the ASD increased the total catch in the test net by an estimated 74% compared to the control net. However, there was high variability in catch weights during the trial, and a number of technical errors with the ASDs affected the results. As such, there was a large uncertainty around this estimate, with the actual increase likely to lie between 5% and 189%. The data also indicate that an appropriate adjustment of the duty cycle (percentage of time that the device emits a sound) and the number of devices deployed could allow catches to be increased further.

Project Conclusions

Fishermen report experiencing interactions with seals leading to depredations losses. Changes to fishing practices have not been shown effective although ADDs can be at least partially effective. Of the ADDs, the ASD inducing a startle reflex in seals shows promise for increasing catches by reducing seal depredation as shown in the static net fishery in Torbay. However, further development is required. The technical issues encountered, and the characteristics of the Torbay fishery (shallow depth, overnight soak times) mean that the results may not be generalisable to different locations or fisheries. Further testing and improvements are required - to increase robustness, ease of handling, and applicability to other fisheries - for the ASD to be considered a viable non-lethal deterrent. Interactions between seals and fisheries are likely to continue as seal populations increase, and a viable solution is needed for the benefit of both the fishermen and the seals.

2 Project Background

Interactions between seals and fisheries include depredation of fish catches by seals and bycatch of seals in fishing gear. Throughout England, particularly in the south-west, north-east and east, depredation is an issue for static net fisheries in particular, that can lead to significant economic costs to fishermen from loss of commercial catch, increased gear handling times and gear damage. Interactions can also lead to seal mortality through either legal shooting ('Netsmen's Defence') or as a result of accidental bycatch.

The Marine Management Organisation (MMO) Marine Conservation Team is required to provide advice on the implementation of and compliance with the Conservation of Seals Act (1970) in regard to seal and fishing gear interactions. Defra policy is that prior to shooting under the Conservation of Seals Act (1970), non-lethal methods of deterrent should be tried and shown to be ineffective at resolving the problem. However, effective non-lethal seal deterrent alternatives to shooting are currently limited for application from fishing vessels in sea fisheries.

In order to improve the specificity of advice, the MMO commissioned this project to understand the interactions between seals and fishing gear and to examine non-lethal deterrent options such that the MMO is better able to offer advice that can reduce the need for shooting. This may have secondary positive effects for conservation and fisheries by reducing seal by-catch and net-based feeding.

The project therefore aimed to explore the following seven objectives:

1. understand how seals take fish from nets and what factors assist them (for example location, visual cues etc.);
2. identify what factors influence depredation behaviour (for example opportunistic, or specialist);
3. identify the breeding populations of individuals undertaking depredation;
4. review non-lethal deterrent measures currently available that may be appropriate for reducing the seal–gear interactions at sea;
5. review what modifications to fishing gear or fishing tactics may mitigate seal depredation and bycatch;
6. clarify potential impacts and benefits and risks to the fishing industry, managers and seals of implementing non-lethal measures, gear modifications or tactics identified through 5) and 6) and prioritise a sub-set of mitigation measures for testing;
7. design and undertake testing in collaboration with the fishing industry of the most promising depredation deterrent measures.

2.1 Project approach and implementation

The project met these objectives through four main tasks. These are reported on in detail through three individual reports (Table 1). This report draws together an overview of the individual parts of the project to provide a summary of the project, its implementation and the key findings.

Table 1: Overview of project tasks and reports

No	Task	Objective	Report
1	Desk-based literature and data review	Inform understanding of the nature of fishing gear/seal interactions, the factors which influence these interactions and potential non-lethal deterrent methods and their effectiveness	Literature and Data Review (MMO, 2018)
2	A programme of stakeholder engagement through survey and interview	Gain a detailed understanding of the issue of seal depredation and by-catch in fisheries throughout England	Stakeholder Engagement Report (MMO, 2019)
3	Expert/steering group workshop	Review the above outputs and inform on the preferred deterrent to be trialled, the geographic area for the trials and the trial design	
4	At-sea trials of the chosen deterrent method	Determine the effectiveness of the deterrent and identify issues for at-sea deployment	Fishing Trials Technical Report (MMO, 2020)

Figure 1: Overview of project approach

3 Literature and Data Review

A review of existing literature and data was carried out in order to assess:

- the nature of seal-fishery interactions and the factors that influence them (objectives 1 and 2)
- the distribution of seal colonies and of at-sea usage around England (objective 3)
- the distribution of inshore fisheries and of static net fisheries around England, and in particular in the vicinity of the main areas of at-sea seal usage (objectives 3 and 7)
- current literature on available deterrent options and their effectiveness (objectives 4, 5 and 7)
- pros and cons of implementing non-lethal measures, gear modification and tactics to minimise depredation (objective 6).

3.1 Seal Populations

There are two species of seal that occur in UK waters: grey seal *Halichoerus grypus* and harbour seals (also known as common seal) *Phoca vitulina.* Other Arctic species occasionally occur in the UK, such as ringed seals, harp seals, bearded seals and hooded seals (SCOS, 2017).

Seals in the UK are generally considered to be common. Both grey seals and harbour seals are recorded as 'Least Concern' under the ICUN Red List though populations of harbour seal have declined in Scotland (see Section 2.2.2). Both species are also listed under Annex II and V of the Habitats Directive (92/43/EEC) and therefore Member States are legally obliged to monitor and maintain their populations at a favourable conservation status (Cosgrove et al., 2013; Cosgrove et al., 2016).

Grey seal numbers have generally increased in the UK since 1984 and are still increasing in the North Sea (Thomas, 2013). In 2010 the total UK population was estimated to have been 111,300 (SCOS, 2011). In 2017 this estimate had risen to 150,000 (SCOS, 2018). Eighty-eight percent of British grey seals breed in Scotland, but there are also important breeding colonies on the north and east coasts of England, particularly around the Farne Islands, the Humber Estuary (Donna Nook), and on the Norfolk coast including The Wash, and south west England (primarily around the Isles of Scilly and Lundy) (Figure 2).

The estimated UK population of harbour seals was 45,100 in 2017 and has increased since the late 2000s, with significant increases in England (SCOS, 2018). England holds approximately 16% of the UK harbour seal population, with the main colonies in the Thames and The Wash (Figure 3).

3.2 Interactions between seals and fisheries

Comparison of the distribution of grey and harbour seals (haul outs and at-sea usage) and of areas of netting activity, indicate that there are potentially significant overlaps between seals and netting activity in the following areas in England:

- Grey seals
  - the north-east – specifically around Alnmouth
  - the east coast – around Great Yarmouth/Lowestoft and Southwold
  - the south west – particularly the Isles of Scilly, Lands End and north Cornwall coast.

- Harbour seals
  - the north-east – specifically off Tynemouth
  - the east coast – around Great Yarmouth/Lowestoft
  - the south-east – around Felixstowe and Sheerness, the Greater Thames Estuary, to Dover.

3.3 Factors influencing depredation behaviour

Seals detect and hunt for prey in a variety of ways, including using sound, visual cues, and their whiskers to detect food and movement.

At an operational fishing level, an understanding of the factors that affect seal depredation in static-net fisheries could theoretically be used to reduce seal depredation. However, most factors co-exist and it is difficult to separate these and identify which may be having an effect on seal depredation.

Figure 2: Haul-out count data for grey seals between 1996 and 2015. Source: Russell et al. (2017).

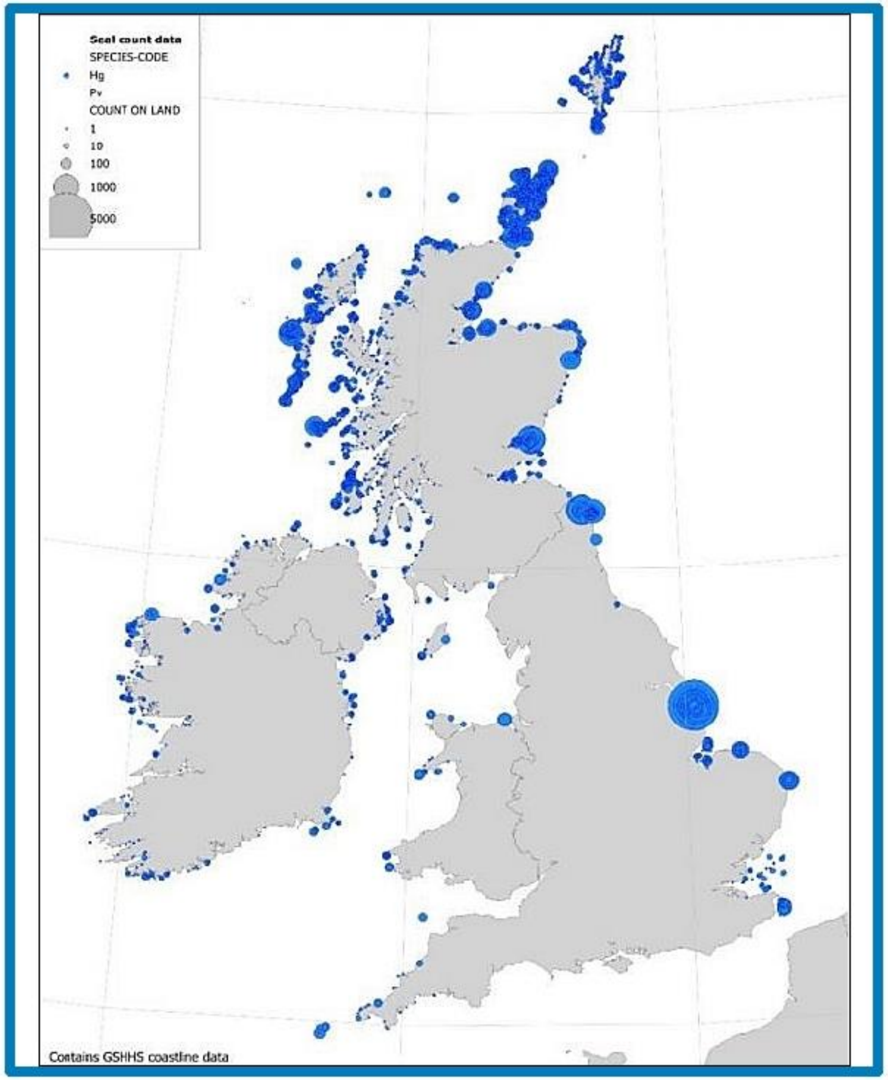
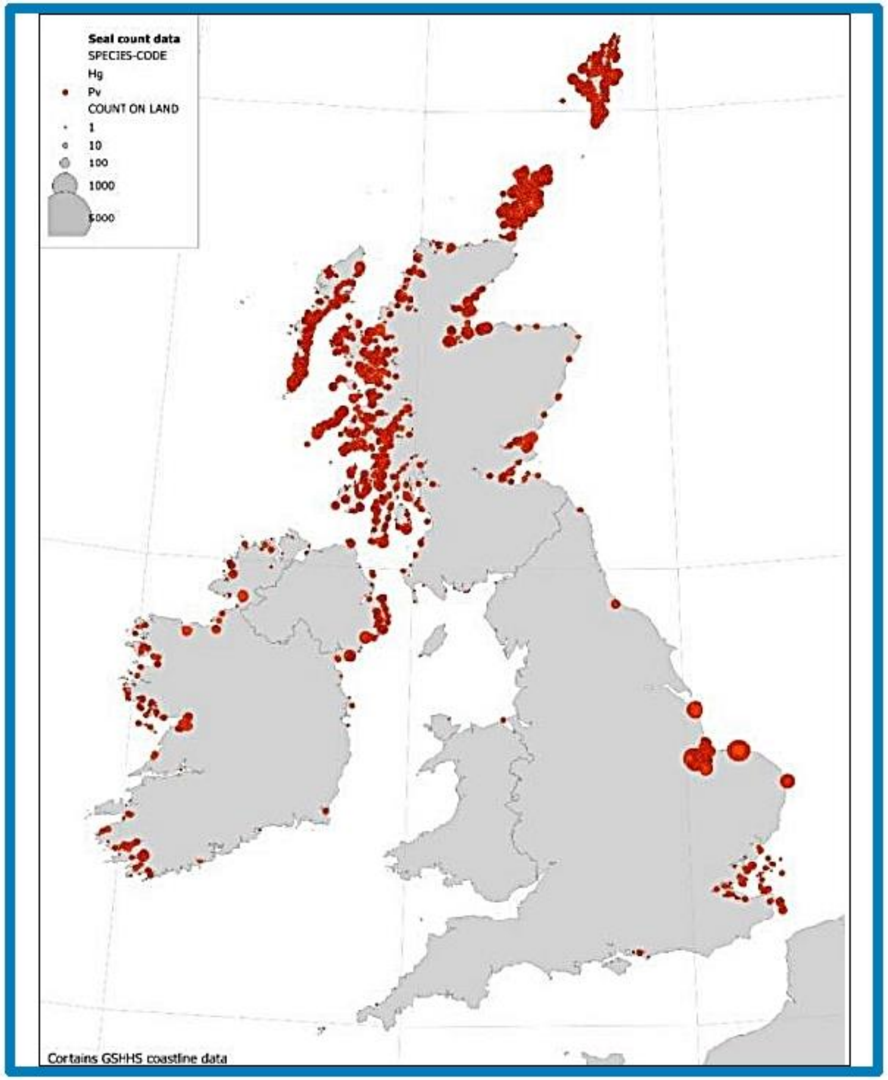


Figure 3: Haul-out count data for harbour seals between 1996 and 2015. Source: Russell et al. (2017).



Nevertheless, the following factors were identified as having a potential influence on rates of seal depredation (see Literature and Data Review for full details):

- **Soak time** – may increase depredation by approximately 5% per hour when nets are within seals' diving range.
- **Depth** – seals may preferentially depredate on shallower nets due to easier accessibility.
- **Hauling and haul speeds** – hauling nets provides an opportunity for seals to feed on the catch, which may be easier than diving on deeper set nets, especially if hauling is slowed or stopped to clear catch from the net.
- **Fishing activity** – seals may be gradually attracted to areas of fishing operation by the noise of a vessel, or fishing activity in general, resulting in a 'dinner bell' effect. The haul sequence of nets, amount of gear deployed, and noise can affect this.
- **Location** – higher depredation is generally observed in areas of high seal usage likely due to seals and fishermen targeting the same resources and areas (though fishermen also report seals will follow a vessel).
- **Season** – seasonality may also influence depredation as grey seals tend to spend most time at sea during summer, and ashore during breeding and moulting periods (between September and April).
- **Day/night deployment** – evidence of seal preference for both day and night feeding is recorded in different studies, attributed to differences in prey behaviour.
- **Gear type** – the type of netting or mesh size does not appear to affect depredation rates but may impact seal by-catch and some gears such as towed gear or mid-water cod traps can be less vulnerable to depredation.

However, any modifications to fishing operations need to be balanced with the implications they may have on overall landings.

3.4 Deterrent options

Deterrents are management techniques that use an unpleasant stimulus to prevent animals using resources of interest to humans (Ramp et al. 2011). They need to be aversive, harmful, fearful or noxious, resulting in a defensive response in the animals concerned (Götz and Janik, 2010). Available deterrent measures consist of:

- Acoustic Deterrent Devices (ADDs)
- electrified netting
- visual and olfactory deterrents.

In addition, the following were explored for their potential to avoid or minimise interactions negative seal-fishery interactions:

- gear modifications and alternative gear types
- fishing tactics (location, time, depth and methods of setting and hauling gears).

ADDs are the most documented method of deterring seals to prevent depredation, and much of the existing evidence is from aquaculture. As such, the majority of devices have been developed for static deployments (e.g. on fixed cages) and are untested in at-sea fisheries. They work by emitting a noise that either causes pain or is distracting enough to create an aversion.

The effectiveness of an ADD varies with location and species, and can depend on ambient noise, water depth, seabed profile, geology, and hearing thresholds of seals. Whilst there is evidence to suggest ADDs are somewhat effective at deterring seals (e.g. Yurk and Trites, 2000; Fjälling et al., 2006; Graham et al., 2009), there is also evidence of ADDs being ineffective (e.g. Mate and Harvey, 1987; Jacobs and Terhune, 2002; Götz and Janik, 2010). Seals may become habituated (used to) a deterrent, resulting in it becoming less effective over time, and in a few cases ADDs have attracted seals.

The sound from an ADD is often designed to exceed a discomfort threshold or inflict pain in order to work as a deterrent (Kastelein et al., 2007; Götz and Janik, 2013). Excessive noise may cause hearing loss to seals and other marine animals and is a concern for use of ADDs. ADDs may also prevent animals from entering some areas which may be important for them, e.g. for feeding or breeding.

There is evidence that a new type of ADD that uses a specific type of noise (low frequency and sharp rise time) causes an involuntary startle response in seals and because the startle response is involuntary, it may avoid habituation. This type of ADD produced to lower frequency, lower volume and lower duty cycle[1] noise that targets seals, and limits or eliminates noise impacts other species and the surrounding marine environment. Therefore, the literature review concluded that startle-eliciting ADDs appeared to be the most promising deterrent and should be prioritised for trials.

Other deterrent options that are currently available are generally considered ineffective at reducing seal depredation, and the potential for modifications or alternatives to fishing gears is limited. Changes in fishing tactics may achieve some reduction in seal depredation, though fishermen have tried feasible options and the problem persists (see Sections 4.1 and 4.2).

[1] The 'duty cycle' is the percentage of time that the device emits a sound. For example, a duty cycle of 1% means the device is making a sound 1% of the time; over one minute, the device would be making a sound for 0.6 seconds in total, made up of multiple short bursts (usually randomly spaced throughout the minute).

4 Stakeholder Engagement

Stakeholder engagement was a key part of the project, and was implemented through:

- fishermen survey – to gain a detailed understanding of the issue of seal depredation and by-catch in fisheries throughout England, through an online survey to capture fishermen's knowledge and experience regarding where, how and why seals interact with fisheries and potential options for deterring this behaviour
- stakeholder workshop – to review the project outputs and discuss options for the deterrent to be trialled, the geographic area for the trials and the trial design.

4.1 Fishermen survey

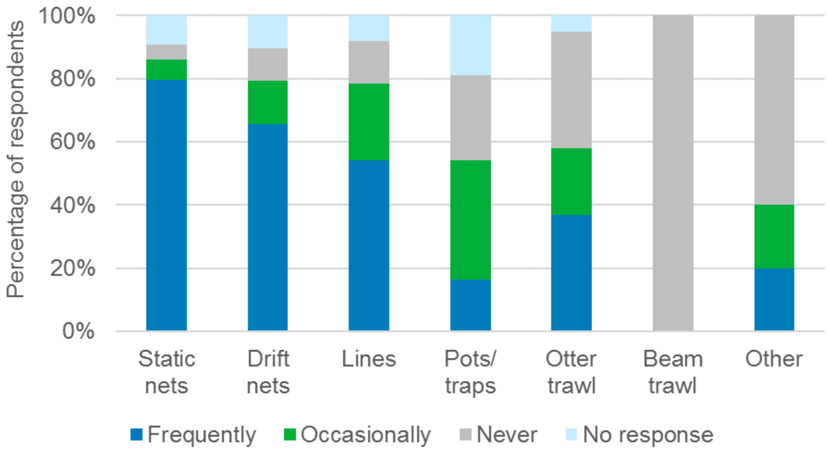
An online survey was run in July and August 2018 to better understand fishermen's experiences and opinions on seal-fishery interactions. The online survey received ninety two responses from fishermen working throughout English waters and explored:

- the nature and magnitude of interactions between seals and different fishing gears
- the geographical areas where these interactions occur
- the non-lethal deterrents or strategies that have been/are being used by fishermen and their effectiveness at preventing interactions.

4.1.1 Key findings

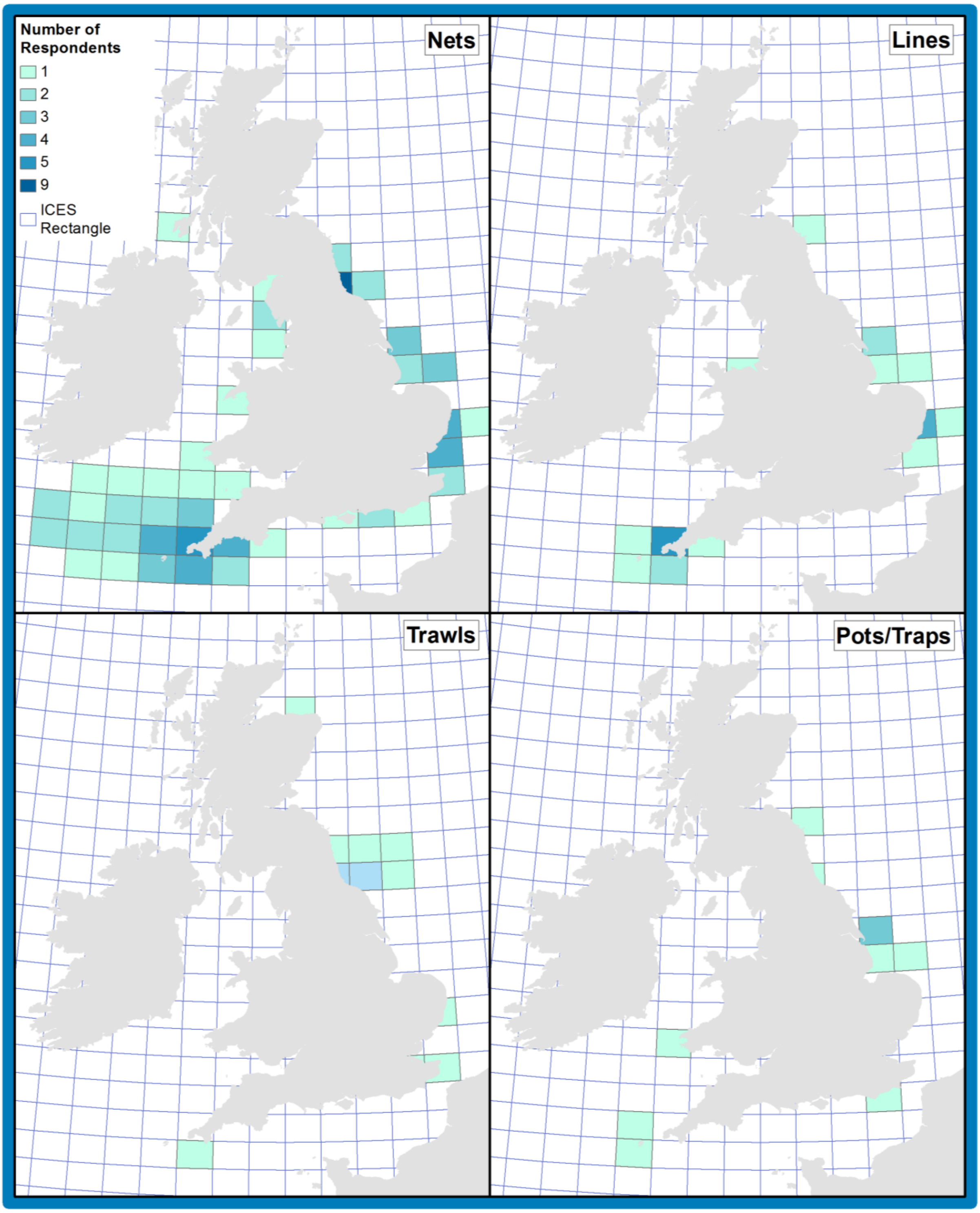
Problematic gear types: Static nets are the predominant gear type to experience frequent interactions with seals (Figure 4), although drift nets and lines were also reported to suffer frequent interactions. Interactions with pots/traps and trawls were reported to be of a more occasional nature.

Figure 4: Frequency of interactions with seals by gear type (all areas combined) (Number of respondents: static nets = 64; .drift nets = 29; lines = 37; pots/traps = 37; otter trawl = 19; beam trawl = 9; other = 10)**.**



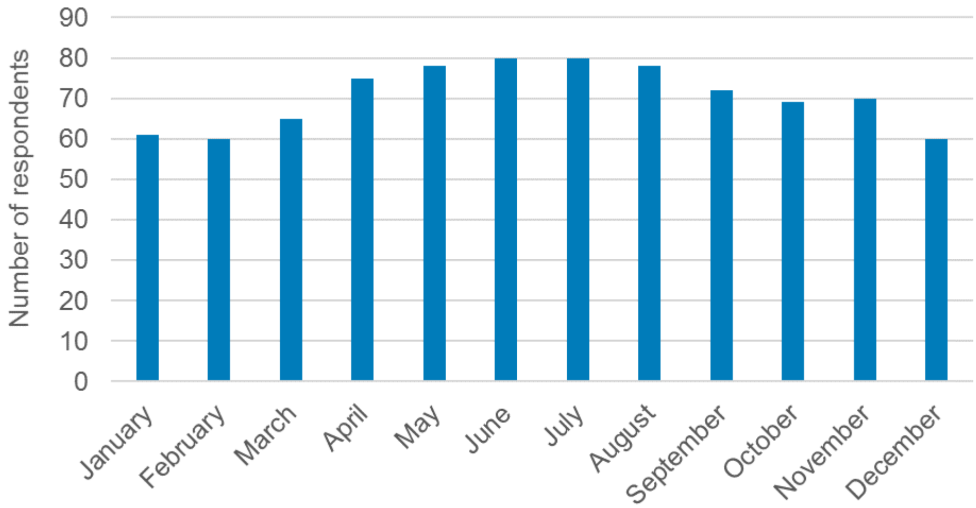
Where interactions occur: Figure 5 shows the areas where interactions with seals were reported to be a problem by fishermen. For nets, interactions were reported around most of the English coast, with the most problematic areas in the south-west, east coast and north-east of England.

Figure 5: ICES rectangles where fishermen reported interactions with seals are reported to be a problem (nets, lines, trawls and pots/traps) (Number of respondents: Nets = 54; Lines = 18; Trawls = 7; Pots/traps = 9)



When interactions occur: Seal-fishery interactions are reported to occur throughout the year, peaking between April and August (Figure 6). Some variation was reported between regions and the peak over the summer months may reflect a higher level of fishing activity in this season.

Figure 6: Months in which interactions occur (all gears, all areas) (Number of respondents =107).



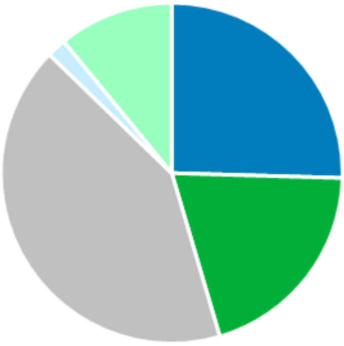
Interaction with set net fisheries: The main problem that fishermen reported for set nets was seals damaging or taking catch from the gear. Seals damaging the gear and seals getting entangled in the gear were also reported. The majority of respondents indicated that over half of tows/hauls were affected by seal damage when interactions occur, and the reported proportion of value lost from seal-damaged catches varied from less than 10% to over 75%. Around 30% of catches overall were reported to be affected.

Impacts on fisheries: fishermen indicated that in many cases, seals can make fishing (particularly with nets) uneconomical. Some claimed to have stopped fishing as a result of the damage caused by seals.

> "Seals have more [or] less killed off the cod net fishery in our area."
>
> "Seals have become a very big problem in some areas and have been seen as far as 130 miles from the nearest point of land. Fish can be hard to find most of the time and when what you catch is damaged beyond sale it's really heart breaking. The seal will tend to only eat the liver of a fish which means it normally destroys the fish beyond sale."
>
> "They put me out of fishing with nets. They would follow my boat and wait for me to shoot my nets."
>
> "We used to tangle net for monk fish as well but not anymore; can't keep a whole one in the nets."

Factors affecting the level of interactions: Most fishermen perceived that there had been a large increase in the level of interactions with seals over the last ten years. Increasing seal populations was felt to be primary factor driving this. Other factors proposed by fishermen to explain increased interaction were catches being an easy food source, and human interaction and release of seal pups (Figure 7).

Figure 7: Fishermen's opinions on the main factor affecting seal interactions with fisheries[2] (Sample size = 55**).**



> "Seal colonies have been allowed to grow and the increased numbers mean that the seals are forced to feed further from their colony. As soon as the seals know that fish are available at a certain location they are there after two tides and will stay in that area until the food source is removed i.e. the nets are taken off."
>
> "…it's mainly to do with the human interaction and subsequent release of seal pups that would have naturally died through natural selection."
>
> "Seals are intelligent creatures, they have followed boats out from the beach in the past, and as soon as the dhan buoy goes over they equate that with an easy meal. Once a line is located they will patrol up and down it for the duration of the soak."

Actions taken to reduce seal interactions: Around half of respondents said that they currently try to reduce the level or frequency of interactions with seals, for example, by:

- reducing soak times
- moving to a different area
- attending gear
- reducing noises that may attract seals
- adjusting rigging (for pots).

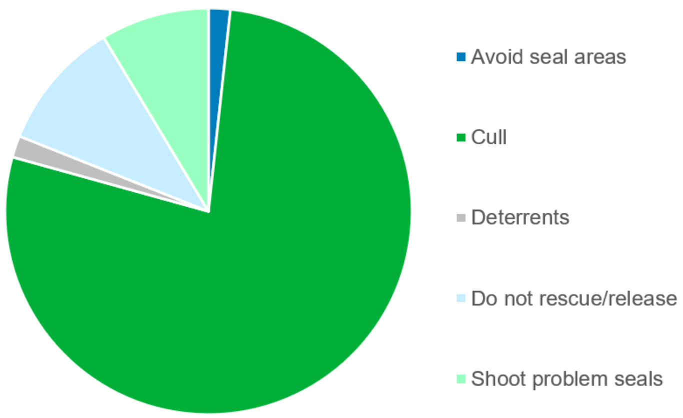
[2] Responses were free text, and were then classified according to theme, with the themes being identified from the responses. Where more than one theme was mentioned in a response, it was attributed to the category that reflected the main theme.

> "We have tried shorter soak times on the gear but seems to make little or no difference and moving the gear around but that also makes no difference the seals seem to be everywhere."

Netsmen's defence: 14% of respondents indicated that they had used the netsmen's defence in the last three years to prevent damage to their nets and/or catch.

Other ways to reduce interactions: The most frequent suggestion for how to reduce the level of interaction with seals was a cull. Other methods suggested indirectly relate to ways of reducing the size of the seal population (by not rescuing and releasing seals into the wild, and by shooting problem seals). Only 2% of respondents suggested moving fishing area or using deterrents as ways of reducing interactions (Figure 8). Culls, stopping rescue/release activities and shooting problem seals are not currently considered as policy options.

Figure 8: Suggestions of ways to reduce interactions with seals (Sample size=58).



4.2 Stakeholder workshop

A workshop was held in November 2018 to review the latest research on seal-fishery interactions (including the survey outputs), the problems, possible solutions and possible deterrent options to trial at sea. Attendees included 19 members from the commercial fishing, regulatory, academia and NGO sectors.

4.2.1 Summary and outputs

The initial presentations highlighted that the increasing population of seals was problematic for fishermen, who are losing part of their catch to damage by seals, and fishermen feel that the rescuing and release of seals by sanctuaries is contributing to the problem, although there is currently no data to support this perception. Seals are also a protected species and a key part of healthy marine ecosystems, but they are being impacted by fisheries, habitat loss, noise, recreational disturbance and pollution. Fisheries impact seals through bycatch in fishing gear, entanglement in lost gear and use of lethal methods. All presenters agreed that the current situation was undesirable.

Going forward, the workshop concluded that:

- there is a need to engage, build trust and create dialogue between different parties to ensure different perspectives on the issue are integrated in any potential management solution or policy
- there is an ongoing need for further research and the at-sea trials may contribute to the evidence on some issues.

Recent developments in ADD technology appeared to be promising (those that are specific to seal hearing sensitivities and that use a startle response) and technological readiness could be improved. All stakeholders had a preference for using the at-sea trials to test ADDs. Fishing tactics and avoidance measures tried by fishermen had not been successful and therefore were not considered feasible.

Key points for the at-sea trials identified by the workshop were:

- trials must be transparent and ensure involvement of the fishing industry
- devices must be tested in high-depredation areas, to ensure an adequate level of baseline depredation to be able to test effectiveness of the device
- the deterrent device could be ‘net-integrated’ on surface buoys or deployed from the vessel
- devices must be robust and must not significantly interfere with normal fishing operations
- photo identification could be used to identify seals and gather evidence on whether specific individuals are responsible
- trials must have a robust experimental design (i.e. carry out test and control hauls on the same days/times).

5 At-Sea Testing of Acoustic Startle Deterrent

At-sea testing was conducted from June to August 2019 to assess the feasibility of deploying ADDs in a static net fishery, and to assess their effectiveness in reducing seal-fishery interactions.

The Genuswave Acoustic Startle Device (ASD) was selected for the trials. The device is not at commercial readiness for deployment at sea and required some development for this trial. The ASD has previously exhibited promise in trials on fish farms in Scotland (Götz and Janik, 2015; Götz and Janik, 2016) and in wild-capture fisheries in Ireland where it was deployed from the vessel (Gosch et al., 2017; Gosch et al., 2018).

The Genuswave ASD is a type of ADD that emits a sound that causes an involuntary startle reflex reaction in seals. Evidence suggests it is effective at deterring seals over time (Götz and Janik, 2011) and seals do not get used to the sound as they do with conventional ADDs (Götz and Janik, 2010). The ASD also uses a frequency to which seals are more sensitive than cetaceans (Götz and Janik, 2013; 2015), and operates at lower duty cycles, signal durations, and lower maximum source levels (volumes) (sound pressure levels at 1m distance) than other ADDs. Therefore, the ASD does not present other risks such as hearing damage to seals and other marine mammals, or habitat exclusion in non-target species (such as harbour porpoise) (Götz and Janik, 2015; 2016).

The trials were conducted in a mackerel net fishery in Torbay by two inshore fishing vessels (Rachael of Torquay PZ736 and Thankful BM488, Figure 9). In this fishery, nets are approximately 200m long and are set overnight in inshore waters of approximately 10m depth.

Figure 9: The vessels involved in the fishing trials

Rachael of Torquay, PZ736

Thankful, BM488

These features of the fishery allowed the project to overcome many of the challenges encountered in other fisheries (e.g. having sufficient battery power to last through longer soak times if nets are left out for several tidal cycles; longer nets would require additional devices to provide coverage to the whole net; deeper water would require the equipment to be deployed at depths beyond which the device had previously been tested). These challenges also mean that the fishery in which the device was trialled is fairly unique and technological and practical challenges will remain if the technology is to be transferred to other fisheries.

5.1 Trial design

On each fishing trip, each vessel deployed a ‘control’ net that was fished normally without an ASD, and a ‘test’ net with one or more ASDs deployed next to the net. Nets were set a minimum of 500m apart where possible. The collective duty cycle across all devices deployed on the test net ranged from 1.2% to 4.2%. Catches of fish, and numbers of seal-damaged fish, were recorded from each net to test the effectiveness of the device at reducing seal depredation.

The ASD consisted of a pod (control unit), a battery inside a pelican case, speaker (transducer array) and associated cables (Figure 10). The device was suspended from a surface buoy, with a flag and pick-up buoy, and moored to the seabed by an anchor. The set-up is shown in Figure 10 and positioning of the devices with the nets in Figure 11.

Figure 10: Device set up, (a) independent of the net; (b) pod and battery box being deployed; and (c) device deployed on a surface buoy during deployment testing

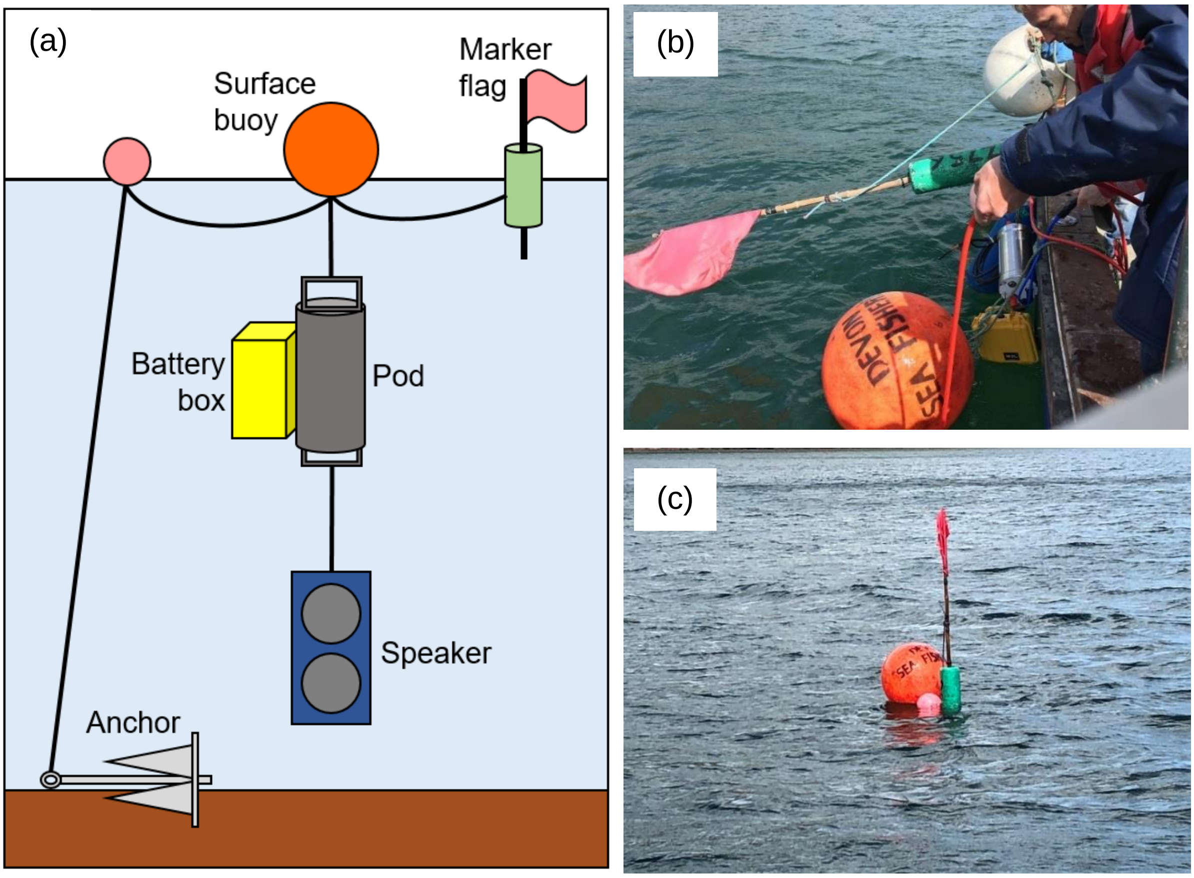
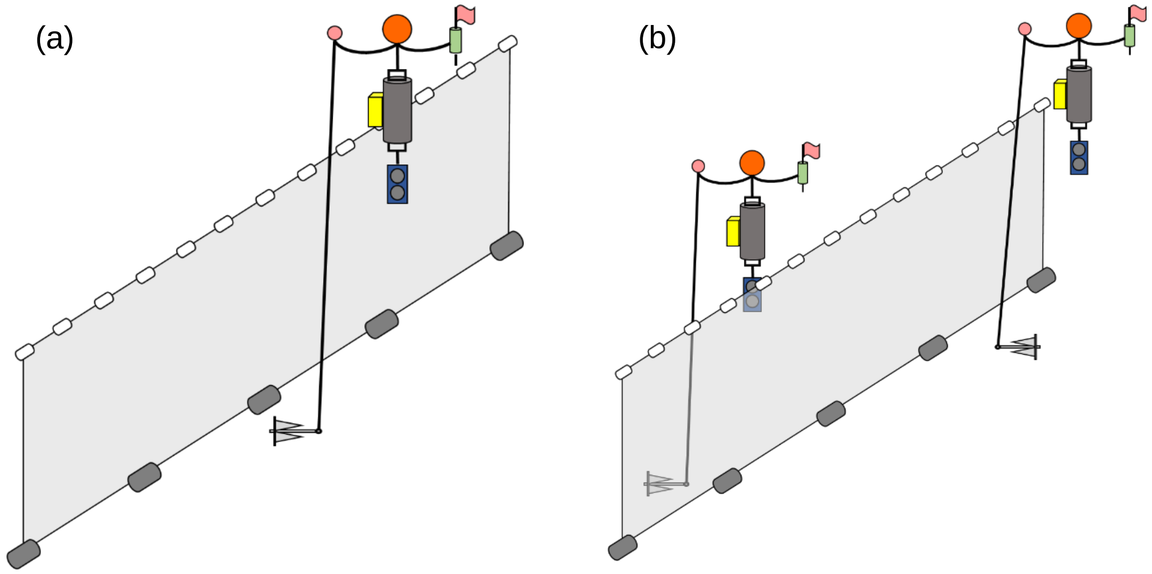


Figure 11: Setup of device with the test net (a) one device deployed mid-point of the net; (b) two devices deployed 1/4 to 1/3 from either net end.



Thirty-six fishing trips were conducted in total by the two vessels. Catches from the test and control nets were recorded – fish were cleared from each net, noting any damaged fish[3], and the undamaged fish were landed and sent to Brixham fish market for auction the following day. Auction data were provided by the fish market detailing the weight of fish per species and per grade where appropriate. Devon and Severn Inshore Fisheries and Conservation Authority also counted, weighed and measured fish from each grade before the fish were sold when possible.

5.2 Data analysis

Data analysis aimed to identify whether the ASD is effective at increasing overall catches and/or reducing the number of fish damaged by seals, what the relevant factors (variables) are that influence this, and how the variables influence the result.

Thirteen trips were excluded from the analysis due to a combination of:

- device malfunction (the device was not working when hauled, meaning it is not clear whether there was any difference in the conditions between the test and control nets)
- auction recording error (meaning the landings from the test and control nets could not be separated)
- zero catch in both test and control nets (meaning there may not have been any fish around to be caught, therefore a comparison of the test and control nets does not provide any insight on how effective the device is at deterring seals).

[3] This included whether damage appeared to have been inflicted by seals, or by other means (e.g. crabs/other scavengers, heat-damaged causing deterioration in quality).

A number of technical problems occurred in the prototype ASDs during the trials. This resulted in the source level (volume) being lower than expected, and a shorter pulse that may have reduced the effectiveness of the devices. For these trips where the devices were still functioning but with errors (reduced volume or shortened pulses), an error variable was included in the analysis to account for these errors where possible.

The following measures were analysed:

- catch weight data, which was assessed using two variables:
  - landed catch – the weight of all species that were landed to the auction, based on data from the auction.
  - total catch – the weight of all species landed to the auction, plus the weight of the catch that had been damaged but not by seals (e.g. by crabs, or damaged from exposure to the sun whilst clearing the nets) and was therefore not landed to the auction. The latter was based on the count of the number of fishes that were damaged, multiplied by the average (median) weight per fish of each species.
- depredation count: the number of fishes that were damaged by seals (and there was some evidence of them still in the net, e.g. whole fish with a bite mark; fish head with body removed; gill cover left in the net).

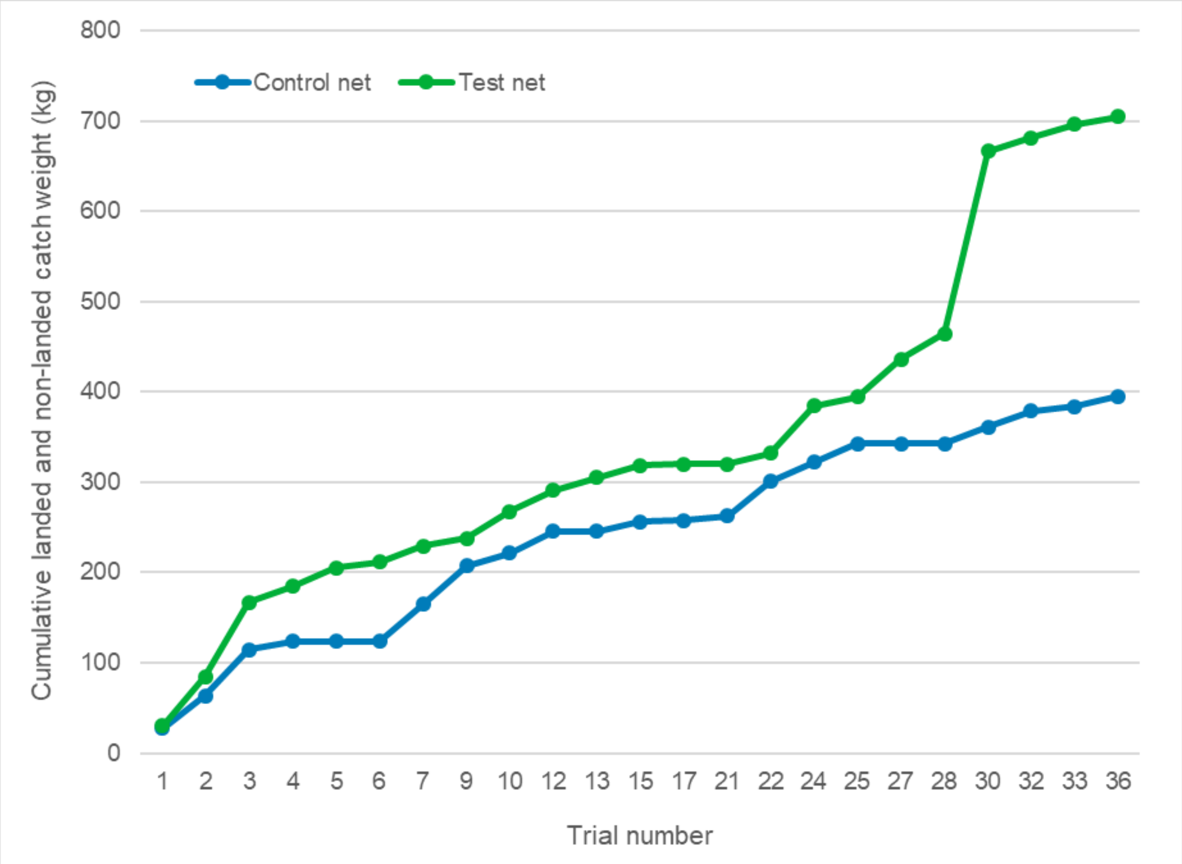
The effect of the following variables was also considered in terms of their influence on the measures above in the test and control nets:

- test vs control net
- duty cycle (percentage of time that a sound is emitted from the device)
- number of devices deployed on the test net
- error variable (to account for when devices were not operating as expected)
- trial number (each fishing trip treated individually)
- trip number for each vessel (each trip linked to the vessel concerned)
- trip number and vessel separately (each fishing trip treated individually, and which vessel undertook the trip, treated separately).

5.3 Results

There was a high variation in catch weights during the trial, reflecting the variability in fishing and the presence or absence of fish in the area. In most fishing trips, there were higher catch weights in the test nets with the ASD(s) compared with the control nets without the ASDs (see Fishing Trials Technical Report (MMO, 2020) for details). Overall, the total catch of fish was 705 kg in test nets and 395 kg in the control nets (Figure 12).

Figure 12: Cumulative total catch weight (landed and non-landed) over trials in control and test nets



5.3.1 Effect on total catch

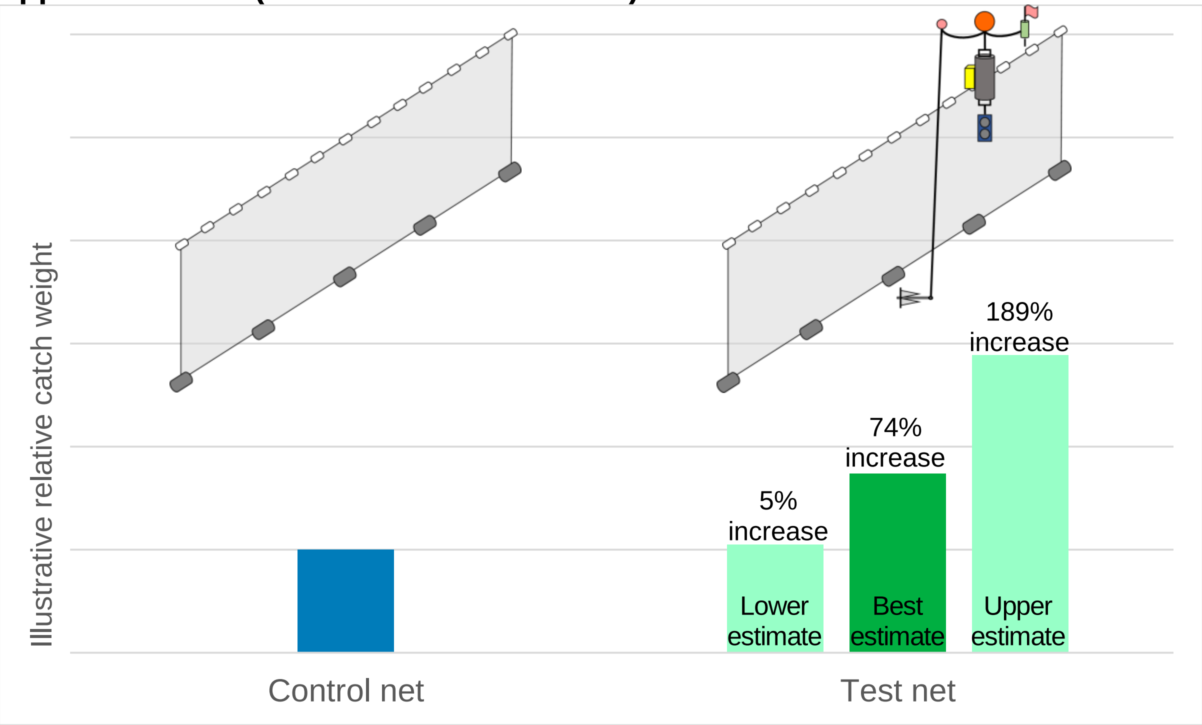
The use of the ASD increased the total catch in the test net by an estimated 74% compared to the control net[4]. However, there was a large uncertainty around this estimate – the actual increase is likely to lie between a 5% increase and a 189% increase[5] (Figure 13).

High variability in ASD effectiveness reflects the fishermen's experience during the trials - at times the test net performed much better than the control, at other times the difference in catch of the two nets was minimal, and sometimes catches were higher in the control than the test net.

The analysis indicated that using more ASDs on a net also increased catches in the test net (through providing better coverage along the length of the net)[6].

[4] This was significant, p=0.03.
[5] 95% confidence interval.
[6] The second-best model fit included the number of devices used, indicating a 135% increase in catch for each additional device added to the net. This approached significance (p=0.054).

Figure 13: Predicted percentage increase in total catch weight (landed and non-landed) in nets with the ASD compared to control nets, with lower and upper estimates (95% confidence interval)



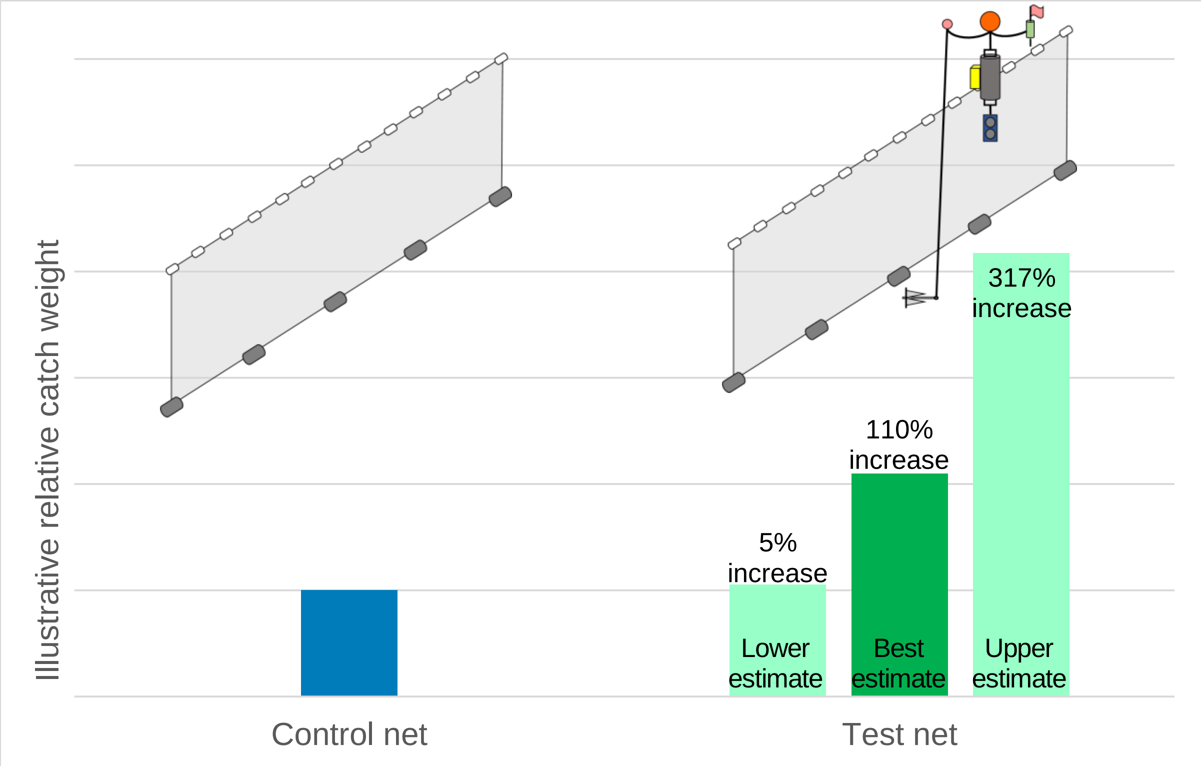
5.3.2 Effect on landed catch

The use of the ASD increased the catch landed to the auction compared to the control net. The duty cycle had an effect on the result, with each 1% increase in the duty cycle of the device(s) leading to a 110% increase in landed catch from the test net (for the range of duty cycles tested)[7].

Similar to the results for total catch, there was a high uncertainty, with the actual increase likely to lie between a 5% increase and a 317% increase for each 1% increase in the duty cycle.

[7] This was significant, p=0.036.

Figure 14: Predicted percentage increase in landed catch weight in nets with the ASD compared to control nets, with lower and upper estimates (95% confidence interval)

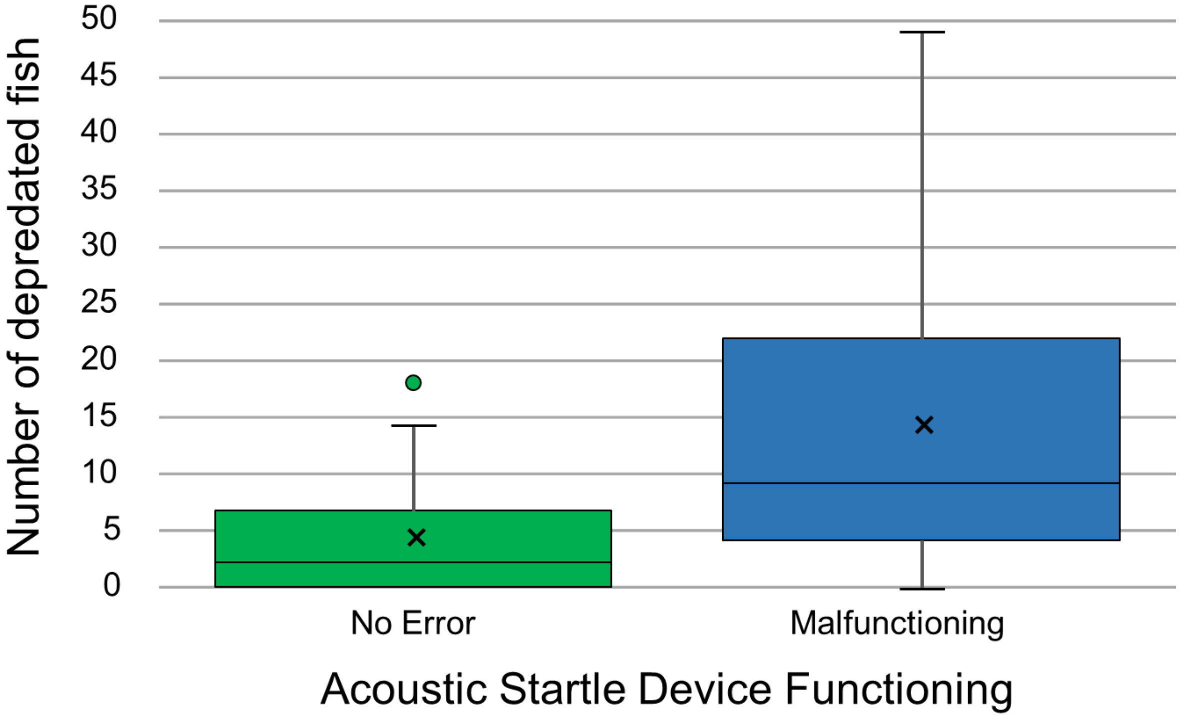


5.3.3 Effect on level of depredation

The use of the ASD did not appear to significantly affect the number of depredated fish found in the nets. Seal-damaged fish were found on occasions in both the control and the test nets. However, errors in the functioning of the device(s) appeared to have a significant impact[8], with 240% more depredated fish found in both nets when the units had an error, compared to when the devices were working as normal (Figure 15). It should be noted that the study was not able to record numbers of fish removed completely from the nets by seals.

[8] This was significant, p=0.003.

Figure 15: Number of depredated fishes in nets when ASDs were working as intended (no error) and when they were malfunctioning



6 Conclusions and next steps

Positive effect of the ASD
The ASD shows promise for increasing catches and reducing seal depredation in the static net fishery in Torbay. It should be possible to increase the positive effect on catches further by adjusting the duty cycle and the number of units deployed per net.

High variability
There was considerable variability in catches throughout the trial. This likely reflects the variability in fishing and the presence or absence of fish in the area, as well as technical errors with the devices during the trials, which reduced their effectiveness. In some cases, the increase in catch with the ASDs was minimal and may not be particularly noticeable, and/or would not compensate for the additional handling time involved in using the devices.

Application to other fisheries
The predicted increases in catch with the ASD may not be generalisable to different locations or fisheries, particularly given the unique characteristics of the fishery in the trial and current technical capabilities of the ASD. Therefore, further trials are needed to confirm the effectiveness and applicability of the ASD as a possible solution to seal depredation in English static net fisheries more generally.

Fine-tuning the devices
The challenge will be to find an optimal combination of the number of units and duty cycle for the whole setup. The introduction of noise to the marine environment can have impacts on other animals, and therefore the noise emitted (duty cycle) needs to be carefully balanced against this. The ASD tested operates at a lower volume and lower duty cycle than other ADDs, and also uses a pitch to which porpoise hearing is less sensitive than seals, helping to minimise impacts on other animals.

Improvements to the devices
The trial has highlighted a number of developments and modifications to the equipment that would be beneficial, to improve its robustness, make it easier to handle, and extend its application to other fisheries. Further work is needed to:

- ensure the robustness of the devices for regular handling and deployment at sea
- adapt the configuration of the devices for ease of handling and deployment by fishermen (e.g. incorporation of the battery and pod into a single unit, integration into a surface buoy, reduce size of speaker unit as far as possible)
- determine optimal duty cycles of one or multiple devices for effective seal deterrence whilst minimising additional noise in the marine environment
- further test the devices in other fisheries to confirm their effectiveness for a range of locations, depths, gear types and target species.

The cost of the devices, and the number of devices that would need to be deployed per net, would have to be considered against the potential increase in catch that the fishermen may achieve, for them to make a decision about whether it would be a cost-effective investment for them to make.

Provision of funding support, or the creation of efficiencies in production to bring the price to a level that is accessible for inshore fisheries, would support the potential for its adoption. There is also likely to be a trade-off between ‘ease of use’ for the fishermen and the number of units deployed to give adequate coverage of the net.

In its current state of development, the ASD (and other ADDs) is not market-ready for many wild capture fisheries and may not be economically feasible (particularly if multiple devices are required to ensure coverage of the full net) for individual static net fishers in England. Further improvements and testing are required for it to be considered a viable non-lethal deterrent, however this project has demonstrated that it shows promise and such further development should be explored. Interactions between seals and fisheries are likely to continue as seal populations increase, and a viable solution is needed for the benefit of both the fishermen and the seals.

7 References

Cosgrove, R., Cronin, M., Reid, D., Gosch, M., Sheridan, M., Chopin, N., and Jessopp, M. (2013). Seal depredation and bycatch in set net fisheries in Irish waters. Fisheries Resource Series Vol.10. 38pp

Cosgrove, R., Gosch, M., Reid, D., Sheridan, M., Chopin, N., Jessopp, M. and Cronin, M. (2016). Seal bycatch in gillnet and entangling net fisheries in Irish waters. *Fisheries Research* 183: 192–199.

Fjälling, A., Wahlberg, M., and Westerberg, H. (2006). Acoustic harassment devices reduce seal interaction in the Baltic salmon-trap, net fishery. *ICES Journal of Marine Science*, 63: 1751–1758.

Gosch, M., Horne, M., Jessopp, M., Cosgrove, R. and Luck, C. (2018). Mitigation of interactions between seals and fishing gears. Bord Iascaigh Mhara (BIM).

Gosch, M., Luck, C., Cosgrove, R., Götz, T., Tyndall, P., Jessopp, M., Cronin, M. (2017). Development of an acoustic deterrent device to mitigate seal fisheries interactions. Bord Iascaigh Mhara (BIM).

Götz, T. and Janik, V. M. (2013). Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series*, 492: 285-302.

Götz, T. and Janik, V. M. (2010). Aversiveness of sounds in phocid seals: psycho-physiological factors, learning processes and motivation. *Journal of Experimental Biology*, 213, 1536-1548.

Götz, T. and Janik, V. (2016). Non-lethal management of carnivore predation: long-term tests with a startle reflex-based deterrence system on a fish farm. *Animal Conservation*, 19(3): 212–221.

Götz, T. and Janik, V. (2011). Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. *BMC Neuroscience*, 12(1). 12-30

Götz, T. and Janik, V. (2015). Target-specific acoustic predator deterrence in the marine environment. *Animal Conservation*, 18(1): 102–111.

Graham, I. M., Harris, R. N., Denny, B., Fowden, D. and Pullan, D. (2009). Testing the effectiveness of an acoustic deterrent device for excluding seals from Atlantic salmon rivers in Scotland. *ICES Journal of Marine Science*, 66: 860–864.

Jacobs, S. R. and Terhune, J. M. (2002). The effectiveness of acoustic harassment devices in the Bay of Fundy, Canada: seal reactions and a noise exposure model. *Aquatic Mammals*, 28: 147–158.

Kastelein, R. A., van der Heul, S., van der Veen, J., Verboom, W. C., Jennings, N., de Haan, D. and Reijnders P. J. H. (2007). Effects of acoustic alarms, designed to reduce small cetacean bycatch in gillnet fisheries, on the behaviour of North Sea fish species in a large tank. *Marine Environmental Research* 64: 160−180.

Mate, B. R. and Harvey, J. T. (1987). Acoustical deterrents in marine mammal conflicts with fisheries. ORESU-W-86-001, Oregon State University Sea Grant College Program, Newport, OR.

Ramp, D., Foale, C. G., Roger, E. and Croft, D. B. (2011). Suitability of acoustics as non-lethal deterrents for macropodids: the influence of origin, delivery and anti-predator behaviour. *Wildlife Res*earch, 38: 408–418.

SCOS. (2011). Scientific advice on matters related to the management of seal populations: 2010. Special Committee on Seals.

SCOS. (2017). Scientific advice on matters related to the management of seal populations: 2017. Special Committee on Seals.

SCOS (2018). Scientific advice on matters related to the management of seal populations: 2018. Available at http://www.smru.st-andrews.ac.uk/files/2019/05/SCOS-2018.pdf. Accessed 28 November 2019. Special Committee on Seals.

Thomas, L. (2013). Estimating the size of the UK grey seal population between 1984 and 2012, using established and draft revised priors. NERC Special Committee on Seals Briefing Paper 13/2.

Yurk, H. and Trites, A. W. (2000). Experimental attempts to reduce predation by harbour seals on out-migrating juvenile salmonids. *Transactions of the American Fisheries Society*, 129: 1360–1366.