Acoustic Deterrent Device (ADD) Use in the Aquaculture Sector

Parliamentary Report

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Ministerial Foreword

The Scottish Government has a vision of a clean, healthy, safe, productive and biologically diverse marine and coastal environment, managed to meet the long-term needs of nature and people. This involves managing our seas sustainably to protect their rich biological diversity, and to ensure that our marine ecosystems continue to provide economic, social and wider benefits for people, industry and society.

The sustainable development of the aquaculture sector in our coastal waters is significant to Scotland's economy and provides economic and social benefit to Scotland's people. Ensuring that any impacts on Scotland's wildlife, including our iconic marine mammals, are properly managed and safeguarded for future generations are also equally important to achieving our vision. I therefore welcome the requirement under the Animals and Wildlife (Protection, Penalties and Powers) (Scotland) Act 2020 to report to Parliament on the use of acoustic deterrent devices by the Scottish aquaculture sector and the opportunity it offers to inform the best way forward regarding their future use.

In looking at the use of acoustic deterrent devices by the sector, specifically the underpinning evidence base for potential impacts on marine mammals, and how these devices are currently used, regulated and monitored, it is evident that further work is required. This report identifies a number of conclusions that require focus and action in the coming months, in order to achieve our collective vision for a 'safe, productive and biologically diverse oceans and seas.'

However, the Scottish Government cannot do this alone. Progress can only be made by collaboratively working with others. Through this report, the Scottish Government is committed to working in close partnership with the aquaculture sector and other stakeholders across Scotland and beyond, bringing together the necessary expertise and knowledge to take forward these conclusions and deliver tangible progress to ensure the protection of our iconic marine wildlife, alongside the sustainable growth of important marine sectors.

I look forward to further progress as we deliver the outcomes of this report.

Ben Macpherson MSP
Minister for Rural Affairs and the Natural Environment

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Purpose of the Report

The aim of this document is to report to the Scottish Parliament on the use of acoustic deterrent devices by the Scottish aquaculture sector at finfish farms as required by section 15 of the Animals and Wildlife (Penalties, Protection and Powers) (Scotland) Act 2020.

In accordance with section 15 of that Act, this report will consider the following factors:

- information on the use made of acoustic deterrent devices on Scottish finfish farms,
- any known impacts that the use of acoustic deterrent devices has on marine mammals,
- consideration of whether the use of acoustic deterrent devices on Scottish finfish farms is sufficiently monitored,
- consideration of whether existing provision on protection of animals and wildlife in relation to the use of acoustic deterrent devices on Scottish finfish farms is sufficient, and
- any future plans for regulation of the use of acoustic deterrent devices.

Chapter 1. Acoustic deterrent devices as a management tool within aquaculture

1. Introduction

The Scottish Government has a vision of a clean, healthy, safe, productive and biologically diverse marine and coastal environment that meets the long terms needs of people and nature. This includes managing our seas sustainably to protect their rich biological diversity and to ensure that our marine ecosystems continue to provide economic, social and wider benefits for people, industry and society. We also recognise that there is a need for a strong, dynamic and productive economy which creates wealth and employment across Scotland, but that this must be environmentally sustainable, inclusive and benefit all of our people and communities. The aquaculture sector is an essential component of the Scottish economy, contributing to sustainable economic growth in rural and coastal communities. In 2018, Scottish aquaculture and its wider supply chain contributed £880 million GVA to the Scottish economy and supported over 11,700 jobs (Scottish Government, 2020a).

In addition to its impact on the economy, Scotland's position at the edge of the north-west European continental shelf has a huge influence on the natural condition of our coasts and seas, creating productive and abundant marine life (Scottish Government, 2018). The seas around Scotland are internationally important for marine biodiversity, supporting a wealth of wildlife including 22 species of marine mammals, including cetaceans and two species of pinnipeds (grey and harbour seals).

However, marine mammal populations inevitably interact to some extent with marine industries, and these interactions can prove to be negative to both wild animals and the affected sectors. One of the most significant interactions which has been documented since the 1980s (Northridge et al., 2010) occurs between the aquaculture sector and grey and harbour seals, for which Scotland has an increasing population of around 122,500 grey seals and a minimum population of 26,900 harbour seals (Special Committee on Seals, 2019).

2. The challenge and need for effective solutions

Farmed fish are sentient animals and can experience physical and mental suffering. Seals interacting with finfish farms can cause serious welfare problems through direct predation on fish, injury and stress to farmed fish caused by unsuccessful attacks or damage to cages or nets, as well as loss of stock. Several literature reviews, workshops and questionnaire-based documents have addressed the issue of seal depredation at aquaculture sites (Northridge et al., 2010; Coram et al., 2014), with some providing specific context in terms of costs to the sector. Northridge et al. (2013) reported that almost 1.4 million fish were lost to seals at 87 sites over a 129 month period, equating to a conservative farm gate value of around £26,000 per site per year, while evidence from the sector has shown that in the year to May 2020 the sector lost in the region of 560,000 salmon to seal predation at a cost of £13 million.[1]

As well as directly causing injury and mortality, the presence of seals close to nets can cause severe stress to farmed fish which is a welfare concern and can cause a significant reduction in growth rate and reduced tolerance to disease. This is of particular concern to fish farm managers who have legal duties to ensure containment, prevent escape of fish and to maintain the welfare of fish under the Aquaculture and Fisheries (Scotland) Act 2007 and Animals and Welfare (Scotland) Act 2006, respectively, while ensuring compliance with existing legal provisions on the protection of animals and wildlife.

A combination of lethal and non-lethal measures have historically been employed to address interactions between finfish farms and seals (Coram et al., 2014; Thompson et al., *in prep*), with earlier actions largely focused on the lethal removal of seals. However, the introduction of the Marine (Scotland) Act 2010 was an important landmark in this context, by putting in place a seal licensing regime which sought to achieve an appropriate balance between seal conservation and sustainable marine activities by allowing limited lethal removal of individual seals.

Since the introduction of the seal licensing system in 2011, there has been a decline in the number of seals granted on licences and the number of seals subsequently shot under licence by approximately 80% (Scottish Government, 2020b). This trend is most likely driven by a number of factors including the efficacy of management measures, availability of alternative non-lethal methods and technologies and increased awareness of seal-aquaculture conflicts. Indeed, records show that there has been an increase in the use of alternative non-lethal measures across the aquaculture industry since the first review of the seal licensing system in 2015 (Scottish Government, 2015) which has contributed to a reduction in numbers of seals shot in some areas (Scottish Government, 2020b).

Amendments to the Marine (Scotland) Act 2010, which came into force on 1 February 2021, have removed two licensing grounds on which Scottish Ministers can

[1] Producers in warning over seal predation threat – Fish Farmer Magazine

grant licences authorising the taking or killing of seals. Aimed at improving the welfare and conservation prospects for seals in Scotland, due to these amendments, the aquaculture sector can no longer obtain a licence to kill seals for the purpose of preventing serious damage to finfish farms or to protect the health and welfare of farmed fish. Alternative and more effective non-lethal measures will therefore be required to address seal interactions with farmed fish in the future.

3. Acoustic deterrent devices as a non-lethal management tool

In Scotland, one of the most widely used non-lethal measures to address the risks associated with predators is Acoustic Deterrent Devices (ADDs). ADDs operate by introducing loud, low frequency sound (usually 1 to 20 kHz) into the marine environment and are considered one of the few practical measures available to deter seals from approaching finfish farms (Coram et al., 2014; Thompson et al., *in prep*) therefore enabling the sector to protect the welfare of their farmed fish which can be negatively impacted by seal circling cages.

Devices vary in their design, duty cycle and acoustic properties (McGarry et al., 2020) with farms often adopting different methods of use depending on the level of predator risk. Nevertheless, the efficacy of these devices in deterring seals has not been widely studied (Northridge et al., 2010, Coram et al., 2014) with the exception of a few species-specific devices (Götz & Janik, 2016), and opinion amongst fish farm managers as to their effectiveness is largely mixed (Coram et al., *in prep*). However, a significant number of finfish farms in Scotland use these devices; the second seal licensing review reported ADD use at 60 to 70% of sites seeking a seal licence between 2015 and 2020 (Scottish Government, 2020b).

This is a particular concern given the increasing body of scientific evidence which shows that conventional ADDs can have unintended consequences for non-target species, particularly cetaceans (Coram et al., 2014; Sparling et al., 2015; McGarry et al., 2020) which are listed as European Protected Species (EPS) under Schedule 2 of the Conservation (Natural Habitats &c.) Regulations 1994. While the evidence for impacts of ADDs on marine mammals will be explored in more detail later in the report (Chapter 2), there would appear to be a need for more targeted and effective measures in moving forward.

In recent years, newer generation ADDs have been developed that reduce sound outputs at the frequencies most likely to cause disturbance to cetaceans. These devices work by specifically tailoring signals to produce avoidance responses in seals at lower sound pressure levels thereby greatly reducing the potential for impacts on non-target species (Götz & Janik, 2016). In addition, methods to reduce the sound output of existing ADDs have also been explored including reducing the source levels (loudness of sound) and duty cycles (changing the length of time the device is on or off), and reducing the number and duration of transmission sequences by transmitting signals only when seals are present (Thompson et al., *in prep*). However, there are still questions regarding the efficacy of these devices in deterring seals and the potential for impacts on non-target species, therefore further research and development is still required in this area.

4. Alternative non-lethal management measures to address the risk of seal damage and fish welfare

There is no single solution which can fully address all the challenges that exist in seal-finfish farm interactions and a combination of measures is most likely to provide the most appropriate future approach. The effectiveness of measures is also likely to vary between locations and circumstances due to the complexity of local environmental and logistical constraints.

Existing management measures

Physical exclusion can prevent predators from interacting directly with finfish farms and measures to improve fish containment such as improved nets have assisted with reducing or preventing seal damage and welfare issues (Northridge et al., 2010). However, there still remains a concern that predators can circle nets and thereby cause stress, and ultimately mortality, to the enclosed fish.

The expansion in the use of appropriately tensioned nets, anti-predator nets or more robust netting materials (e.g., Seal Pro HDPE nets) across the industry in recent years has helped to reduce seal predation in some areas.[2] For example, Cooke Aquaculture, Scottish Sea Farms and Greig Seafoods have all reported the use of HDPE anti-predator nets at some of their sites in recent years with evidence of success (Thompson et al., *in prep*). This is supported by a Scottish Government report (Scottish Government, 2020b) which found that the use of anti-predator netting at Scottish finfish farms has increased from around 20% in 2016 to over 40% in 2020, although it is likely that some of this use could be attributed to more robust netting material (e.g., HDPE netting) (Thompson et al., *in prep*). Companies are currently expediting programmes of net replacement, although the speed with which HDPE nets can be deployed is limited by their availability from manufacturers, as

[2] Salmon farmer's £5.7m investment to protect stock and seals paying off

well as that of additional infrastructure improvements including tensioning weights and new pen structures engineered to accommodate such equipment (pers. Comm. Scottish Salmon Producers Organisation). It is therefore expected that these trends will assist in further reducing the risk of seal predation.

Good husbandry practices by finfish farm managers in terms of improved attention to the frequency of the removal of dead fish (‘morts’) and the use of seal blinds[3] and false-bottomed nets (on the basis that seal attack on the base of the net was twice as likely as on the wall of the net (TEP, 2010)) have also helped to reduce the potential for attracting seals and therefore predation risk. However, in some cases seal blinds and false-bottomed nets can reduce the water flow through the net base which may cause issues for fish health (Thompson et al., *in prep*). It is clear, however, that these measures have not eliminated the risk of seal predation and other complementary measures are required.

Management measures under development

While it is expected that the increasing trend towards the introduction of stronger nets for most sites in the future may assist in further reducing the risk of seal predation, other measures are still under development. For example, electric field deterrent systems (barriers) have been developed for use at finfish farms, but these have not been widely applied with only a single trial undertaken at a finfish farm in Scotland (Whyte, 2015).

Designed to reduce the environmental impact of finfish farms and reduce issues with sea lice, closed and semi-enclosed containment systems could also reduce seal interactions. The performance and cost effectiveness of such containment systems are under investigation (Global Aquaculture Advocate, 2018) and trials are still ongoing.

In contrast, larger cages with the same level of stock biomass offer a more immediate solution to the risk by enabling fish to remain further away from the cage extremities thereby minimising the potential for seal interactions. Larger cages can also be designed to be more robust in structure, incorporating more effective barrier systems and supportive technology. The Town and Country Planning (General Permitted Development and Use Classes) (Scotland) Amendment Order 2020, which has now been laid in Parliament and is expected to come into force on 1 April 2021, extends permitted development rights to enable the deployment of bigger finfish pens, with no increase in biomass, without having to submit a formal application for

[3] Seal blinds are thicker netting which covers the bottom of nets to disguise dead fish.

planning permission to the local planning authority. This is expected to act as a counter measure to mitigate seal predation to some extent.

While physical exclusion can help address the effects of direct mortality, stress-related effects to fish due to seal presence in the vicinity of cages cannot be immediately rectified (with the exception of some closed containment systems). As a result, alternative, or complementary measures are required. To date many options have been reviewed in terms of direct harassment, acoustic deterrents, and condition aversion, however for some of these measures further development is required in terms of their effectiveness or deployment practicalities.

Future research

A partnership project between Crown Estate Scotland (CES) and Marine Scotland has investigated the problem of seal predation in river fisheries and at finfish farms. The research (Thompson et al., *in prep*), which reviewed current and emerging non-lethal measures for addressing seal interactions within the aquaculture and wild fisheries sector, reported that while some measures are currently available for use, it is clear that they would benefit from further research and development and consideration by the industry in terms of their practicality, ahead of specific recommendations on measures suitable for future trials and deployment.

It is clear that further work is required across all fronts to ensure that a suite of tools are available to the industry to address risks associated with seal-finfish farm interactions while ensuring that marine wildlife are provided with protection afforded through our environmental obligations.

Chapter 2. Evidence of impact on marine mammals from acoustic deterrent device use

1. Introduction

There is growing concern that both target species (e.g., seals) and non-target species (e.g., whales, dolphins and porpoises) could be disturbed and/or at risk of auditory injury through exposure to noise from Acoustic Deterrent Devices (ADDs) used at finfish farms. The currently available scientific evidence of impacts to marine mammals in terms of disturbance, temporary hearing change (TTS) and permanent hearing change (PTS) is reviewed and summarised here. This review focuses on ADDs that have been, or are known to be, used in the aquaculture industry. Where an ADD is used in a different industry and there is potential for the device to be used in aquaculture (i.e. if the device could be employed to prevent depredation by seals), this evidence has also been included for completeness. Where a custom built ADD with similar acoustic properties to a known ADD has been reviewed, this has been highlighted.

Disturbance to marine mammals is difficult to define and quantify, but is often regarded as a change in the normal behaviour of an animal. Examples of disturbance include changes in distribution, breathing, breeding, nursing, feeding and/or resting as well as disruption to communication. Many of these responses could cause an increase in energy consumption, which could lead to increased vulnerability of an individual to predators or physical stress. This in turn may reduce their survival or reproductive success, potentially resulting in population-level effects. Currently, there is not an accepted sound threshold level for behavioural disturbance to marine mammals.

Marine mammals exposed to intense sound, either instantaneously or over time, have the potential to exhibit reduced hearing sensitivity (termed “threshold shift”). This may be at a particular frequency or over a range of frequencies. The frequency at which it occurs will determine the extent to which an animal suffers detrimental consequences, depending on how important those frequencies are to the animal for communication or foraging. Hearing changes that recover after exposure are termed a temporary threshold shift (TTS) in hearing. Hearing changes that do not recover are termed a permanent threshold shift (PTS) in hearing, which is considered to be an auditory injury (Southall et al., 2007). Physical harm to a marine mammal, such as damage to the physical structures of the hearing system by extremely loud noises, would also be considered to be an injury.

TTS or PTS can occur by two means; instantaneously, through exposure to sudden onset loud noise (e.g. from pile driving, seismic surveys or explosives), or cumulatively through repeated exposure of sound over time. Cumulative TTS or PTS result through a combination of the level of the noise and the duration of time that the animal is exposed to it. This is assessed with a metric called the sound exposure level (SEL), which is the accumulated sound energy an animal is exposed to over time (usually calculated over 24 hours). The sound energy is weighted for different species groups because they each have different hearing sensitivities over a range of frequencies. The calculated SEL is then compared against internationally recognised threshold levels. The sound levels produced by ADDs would not, at recommended operating source levels, pose a risk of instantaneous PTS. However, due to the ongoing nature of sounds produced by ADDs, there is a risk of PTS through cumulative exposure.

Studies on potential impacts of ADDs on non-target species and their efficacy in relation to reducing seal depredation are few in number and show inconsistent results. It is important to note that a large number of factors are potentially influential in the responses of marine mammals to ADDs. These include factors relating to the ADDs themselves (e.g., source level, duty cycle, number of devices used, frequency content), factors relating to the animals (e.g., context, body condition, age of individual, experience of individual) and factors relating to the manner in which the local environment affects sound propagation through the water (e.g. depth, presence of land, water temperature, sea state). Studies into the effects of ADDs typically vary in location, the manner in which the device is used and whether there is motivation (e.g. the presence or absence of prey) for animals to remain within an area, which makes it challenging to assess and compare the evidence base in some cases. The signals from most ADDs are not a constant tone, but rather a complex combination of frequency-specific pulses.

The following sections cover disturbance, TTS, and PTS, across the four different marine mammal hearing groups. These are low frequency cetaceans (e.g., minke whale, *Balaenoptera acutorostrata*) high frequency cetaceans (e.g. bottlenose dolphin, *Tursiops truncatus*), very high frequency cetaceans (e.g. harbour porpoise, *Phocoena phocoena*) and seals. For seals, disturbance is incorporated in a section that reviews the evidence for efficacy of ADDs because the purpose of ADDs used around finfish farms is typically to disturb seals to keep them away from the fish. Following this, a section outlining the key knowledge gaps has been provided.

2. Summary of Evidence

This section reviews currently available scientific evidence of impacts to marine mammals in terms of disturbance, TTS and PTS. To note, a number of previous studies have also summarised the existing evidence of ADD effectiveness, including potential impacts on non-target species (e.g., Gordon and Northridge, 2002; Coram et al., 2014; Sparling et al., 2016; McGarry et al., 2020).

More detailed information on the studies reviewed here can be found in the Appendix in Tables A1-1 to A1-11. Only the ADD manufacturer is stated in the following review and not the specific model type because the studies reviewed do not adopt a consistent approach in naming devices. Further information on the device type used in each of the studies reviewed can be found in the relevant tables within the Appendix.

Disturbance to cetaceans

As the most abundant and sensitive non-target species, harbour porpoises have been the focus of a number of studies reporting adverse behavioural responses to sound from ADDs (Table 2-3). Captive experiments with harbour porpoise have demonstrated the types of response that may be seen as a result of exposure to different ADDs (e.g., Kastelein et al., 2010 & 2015a). These behavioural responses included increases in surfacing rate (closely linked to respiration rate), respiration force, moving away from the sound source, swim speed and jumping behaviour.

Within studies on free-ranging harbour porpoise, experimental design, source levels, topography and ambient noise levels all vary, which makes direct comparisons difficult. The majority of field trials with wild harbour porpoises have shown displacement and/or exclusion as a result of exposure to the sound either from, or resembling that of, Airmar ADDs (e.g., Johnston 2002; Kyhn et al., 2015; Northridge et al., 2010; Olesuik et al. 2002) or Lofitech ADDs (e.g. Brandt et al., 2012 & 2013; Dähne et al., 2017; Mikkelsen et al., 2017). Lofitech ADDs have not been reported to be in use at Scottish finfish farms (see Chapter 3 of this report), but are used in other industries to deter animals from activities that could injure them (e.g. blasting and impact pile driving). The one published field study using a Terecos device showed reduced detections along a distance gradient from the device, but overall reported a weak or minimal response from harbour porpoise (Northridge et al., 2013). However, even as regards the devices for which there are multiple studies describing the effects on harbour porpoise, there is considerable variation in the frequency and scale of responses, both within and between studies.

In one field study in the Inner Hebrides, using echolocation click detectors (T-PODs), harbour porpoises were detected feeding within 200 m of ten active Airmar ADDs that had been in use at the site for several months (Northridge et al., 2010), with the authors concluding that these devices did not completely exclude all harbour porpoise from the vicinity. In a neighbouring area, data gathered using towed passive acoustic monitoring (PAM) were used to compare harbour porpoise distribution in 2008, when an Airmar ADD was installed, to the two previous years. The number of acoustic detections in the area was significantly lower in 2008 (following the introduction of the ADD) than 2006-2007, and there were no porpoises detected within 4.3 km of the ADD site in 2008 (Northridge et al., 2010). However, this was not a controlled study and there is the potential that other factors, such as prey availability affected harbour porpoise use of the site.

A field study in Denmark ran two consecutive trials using Airmar ADDs. The first involved periodic activation of ADD sound over 47 days, where the devices were activated and deactivated for periods of between two and nine days (Kyhn et al., 2015). After a recovery period of 40 days, the same area was then exposed to ADD sound continuously for 28 days. For the periodic exposure trial, the study reported a strong aversive response by porpoises (displacement away from the ADDs) to the first and second exposures, but this response was reduced in subsequent periodic exposures. Conversely, when continuously exposed to the ADD sound there was no evidence of a reduced response over the 28 day exposure period (i.e., patterns in displacement were maintained over time). The study reported that both periodic and continuous use of these ADDs led to areas of porpoise displacement no greater than 2.5 km. Interpretation of these findings is challenging; the decreasing response over time may be the result of harbour porpoise no longer considering the ADD to be a threat, or may be because they were compelled to use the area due to a lack of foraging opportunities elsewhere.

Benjamins et al. (2018) developed an example ADD signal, based upon those generated by several ADDs available on the market, including Airmar, Lofitech and Ace Aquatec. They produced both a low and high frequency version of the signal (1-2kHz and 8-18kHz respectively) to represent the current ADD market (high frequency) and the market trend towards lower frequency devices, intended to avoid disturbance to harbour porpoise. They observed responses by harbour porpoise to both signals, using a sound source level that was on average approximately 20-35 dB re 1 μPa lower than the commercially available ADDs. They reported that porpoise detections were substantially reduced within 1 km of the sound source with no significant difference in detections between the low and high frequency playbacks

(1-2 kHz and 8-18 kHz, respectively), indicating that lower frequency devices might not reduce disturbance to harbour porpoise.

For the other two cetacean hearing groups, low frequency and high frequency cetaceans, the evidence for disturbance effects is less clear, with very few controlled scientific studies published. For low frequency cetaceans much of the evidence is either anecdotal, collected opportunistically as a by-product of research on other species, or suffers from very small sample sizes (e.g., Fairbairns et al., 1994; Götz & Janik, 2016). The two exceptions to this reported differing responses for two species of baleen whale when exposed to sounds from the Lofitech ADD. This device was reported to have deterred minke whales (McGarry et al., 2017) but had no observable impact on humpback whale (*Megaptera novaeangliae*) behaviour (Basran et al., 2020). The methodologies used in these two experimental exposure trials, despite having very small sample sizes (7 and 15 animals, respectively), were very similar, however the source levels differed considerably. The measured source level was 10 dB re 1 μPa @ 1 m (RMS) lower in the Basran et al. (2020) study compared with the McGarry et al. (2017) study, which is likely to have affected the responses observed.

For high frequency cetaceans, the evidence base for disturbance from active ADDs is also lacking and the few studies that do exist mainly concern Airmar ADDs. For example, observations from ongoing long-term abundance studies (rather than controlled field trails) suggest that Airmar ADDs have caused habitat exclusion of killer whales (*Orcinus orca*, Morton and Symonds, 2002) and Pacific white-sided dolphins (*Lagenorhynchus obliquidens*, Morton, 2000). Desk-based modelling suggests that the sounds from Airmar ADDs, as well as Terecos and Ace Aquatec ADDs, are audible to whales, dolphins, porpoises and seals at ranges up to tens of kilometres, depending on ambient underwater noise levels (Todd et al., 2019). However, these figures should be interpreted with a degree of caution, as the modelling methodology used was relatively simple and did not include environmental factors, which would lead to greater attenuation of the sound at distance. It is therefore likely that the distances presented in Todd et al. (2019) may be overestimates.

The GenusWave device, referred to as a Target Acoustic Startle Technology (TAST) device, which is targeted for seal hearing at frequencies lower than those to which harbour porpoises are sensitive, has been the focus of two published field studies (Götz and Janik, 2015 & 2016). These studies concluded that there was a negligible effect of the device use on porpoise abundance and distribution. Given that these devices operate at lower frequencies, there is a notable knowledge gap regarding the potential for disturbance, temporary hearing changes (TTS) and cumulative permanent hearing changes (PTS) in low frequency cetaceans.

Temporary Threshold Shift (TTS) in marine mammal hearing

Temporary Threshold Shift (TTS) involves a reduction in an animal's hearing sensitivity at particular frequencies, from which the animal subsequently recovers. The likelihood of TTS being induced in a marine mammal as a result of exposure to noise from ADDs is heavily dependent upon the animal's behaviour. If the animal moves away from the noise then TTS is unlikely to occur. However, if the animal remains within the area, then there is the possibility of longer durations of noise exposure which can accumulate to produce a TTS. Animals may choose to stay in areas with higher noise levels depending upon motivation, such as the availability of prey within the area.

There are few published studies detailing instances of a TTS in marine mammal hearing as a result of sound emitted by ADDs, due to the difficulty in measuring this physiological effect in free ranging animals. The evidence compiled for TTS in this report constitutes mainly desk-based underwater noise modelling exercises. The modelled scenarios involve instantaneous exposure or cumulative exposure scenarios, and estimate the time and/or distance at which a marine mammal would be predicted to experience TTS due to ADD noise exposure. As the studies use different modelling techniques, criteria for assuming TTS onset, and weightings to account for animals' hearing ability, it is difficult to compare the results.

Götz and Janik (2013) estimated the potential for TTS in marine mammals through a modelling exercise, assuming that an animal remained stationary for a period of time in the vicinity of three different ADD types; Airmar, Lofitech and Terecos. Distances and durations of exposure at which TTS onset were predicted to occur for a range of marine mammal species were presented. The study incorporated a number of criteria for assessing sound exposure levels that may induce TTS. Some of these were internationally recognised thresholds (e.g., Southall et al., 2007; Lucke et al., 2009), while others were unique to this study. A novel method of auditory weighting was applied to the sound sources based on the most sensitive part of the marine mammal groupings' audiograms, which may be more conservative than weightings such as Southall et al. (2007 & 2019), so caution should be noted in comparing the results with other studies.

Though the effects will vary depending on the source level, number of ADDs and specific duty cycles, Götz and Janik (2013) reported that TTS could be induced after a very short exposure period to all three devices tested. The time taken for onset of TTS ranged from under a minute (Airmar, four devices, duty cycle of 200%), up to 47 minutes (Terecos, one device at a duty cycle of 11%). Distances to TTS onset varied across species and also depending on the TTS threshold criteria used. For example, TTS onset was predicted to occur in harbour seals at 10 m (using Southall et al., 2007 threshold criteria), harbour porpoise from 89 m (using Lucke et al., 2009 threshold criteria) up to 345 m (using SEL_{SENS}, the threshold criteria developed by the authors of this study), bottlenose dolphin from 2.5 m (using Southall et al., 2007 threshold) up to 175 m (using SEL_{SENS} threshold criteria) and killer whale at 784 m (using SEL_{SENS} threshold criteria). The publication did not attribute these distances directly to a particular device, rather a source level of 193 dB re 1 µPa for 10 seconds. As noted, these calculations are also based on a scenario where an animal remained stationary, which is considered to be unrealistic, although it does provide a precautionary worst case scenario.

In a later modelling study of the GenusWave device, which differs from other ADDs in that it produces a short sound intended to startle seals, Götz and Janik (2015) predicted that TTS would only occur in unrealistic exposure scenarios. For example, in order to experience cumulative TTS, harbour porpoise would have to stay within 1 m of the sound source for 21 minutes, or within 20 m of the sound source for five to six days, due to the low duty cycle used.

For low frequency cetaceans, a single modelling-based study (McGarry et al., 2017) estimated no risk of TTS due to either instantaneous or prolonged exposure to a Lofitech ADD (which is not in use at Scottish finfish farm – see Chapter 3 of this report), even at very close distances of 25 m from the device, assuming that the animal moved away from the ADD.

A rare example of TTS directly measured in a marine mammal as a result of exposure to ADD sound was reported by Schaffeld et al. (2019). A captive harbour porpoise exposed to Lofitech signals experienced significant TTS, with subsequent simple noise modelling predicting this effect could occur at distances between 200 m for deep water and 6 km for a shallow water scenario, using different sound propagation spreading values. It should be noted here that the sound propagation used to calculate these distances is very simplified and does not take into account environmental factors. These distances are predicted for instantaneous TTS, the authors did not calculate the potential for cumulative SEL TTS onset.

Permanent Threshold Shift (PTS) in marine mammal hearing

Permanent Threshold Shift (PTS) is similar to TTS in that it involves a reduction in hearing sensitivity at particular frequencies. The difference is that this reduction in sensitivity is not recovered over time and becomes a permanent change to the animal's hearing ability. The frequencies of hearing affected will determine how significant that change is for the animal. As with TTS, the risk of PTS is heavily dependent on the behavioural response of the animal to the ADD, which can greatly reduce or increase exposure time. The risk of instantaneous PTS injury from ADDs is negligible, so long as the devices are operated as recommended. The risk of PTS injury from cumulative exposure over time is the main consideration here.

The evidence base for PTS in marine mammal hearing is, similarly to that for TTS, dominated by modelling studies. This is due to the difficulty in measuring this physiological effect in free ranging animals, but also due to the ethical issues involved in deliberately inducing permanent hearing changes to an animal. Indeed, empirical studies of threshold shifts in captive marine mammals measure TTS, and then apply corrections to estimate the levels required to induce PTS (Southall et al., 2007), rather than directly inducing PTS.

Two studies that have contributed most in this respect are Götz and Janik (2013) and Lepper et al. (2014). The studies are not directly comparable, because many variables, such as the models used, source levels and devices, threshold criteria and auditory weightings differed between them.

Götz and Janik (2013) estimated that a harbour porpoise exposed to sounds from multiple Airmar devices set to the highest duty cycle could experience cumulative PTS at a distance of under 10 m in under one minute. However, they also showed that for species with less sensitive hearing (seals, low frequency and high frequency cetaceans), exposed to lower power devices or lower duty cycles, the exposure scenarios required to induce cumulative PTS were unrealistic, requiring multiple days of exposure at extremely close range (Götz and Janik, 2013). McGarry et al. (2017) modelled the potential for cumulative PTS in minke whales at various distances from a single Lofitech device. The authors concluded that there was no risk of cumulative PTS, even at close proximity (within 25 m) to the ADD.

Lepper et al. (2014) modelled a number of different ADDs using a sophisticated modelling methodology that included environmental parameters which affect propagation of sound. They used Southall et al. (2007) auditory weightings and thresholds which, at the time of publishing, were based on the best available science (these have since been updated in Southall et al., 2019). Lepper et al. (2014) concluded that there was a credible risk of exceeding injury criteria for the cumulative sound exposure level PTS threshold for seals if they remained within 100 m of a device for periods of several hours and, for harbour porpoise, over a similar time period at distances up to 500 m. The modelling simulated a stationary animal which was noted in the report as being unrealistic.

Consideration of multiple finfish farms in an area deploying ADDs is required, as this may lead to larger areas that are emitting sound, resulting in greater potential for extended durations of exposure. From the available PTS evidence base for some devices, if the animal does not move away from the sound source then there is a risk of cumulative PTS onset. This risk will be increased in situations where multiple ADDs are operating.

3. Evidence for efficacy of acoustic deterrent devices in deterring seals

ADDs are used in several marine industry sectors, with purposes ranging from deterrence of seals to reduce predation of fish, to mitigation of auditory injury around marine construction. Their efficacy is therefore defined according their intended use. Few desk-based modelling studies have considered the potential for disturbance, TTS or PTS on seals from ADD sounds (but see Tables A1-7 and A2-1 in the Appendix). Given the context of this report, the studies included in the review below are from those that are relevant to the efficacy of ADDs in reducing seal depredation at aquaculture sites. Information has been included where it may be possible that the ADD could be used for this application. Efficacy metrics presented in the studies include increases in fish yields, reductions in numbers of damaged fish and reductions in the numbers of seals in the vicinity of a farm or fishery. The studies considered to inform this Section are summarised in Tables A3-1, A3-2 and A3-3, in the Appendix.

There is considerable disparity in the reported responses of seals to ADDs. For example, most field trials of the Airmar device (Gordon et al., 2015; Götz & Janik, 2010; Yurk & Trites 2000) and the Lofitech device (Gordon et al., 2015; Götz & Janik, 2010; Graham et al., 2009; Harris et al., 2014) reported a deterrence effect, although the extent of the response and deterrence ranges vary widely between studies. There are also examples from studies that have reported no significant effect when using the Airmar device (Jacobs & Terhune, 2002) and one study using the Lofitech device suggested an attraction effect (Mikkelsen et al., 2017). In field trials with wild seals, Götz & Janik (2010) found no significant deterrence range for the Terecos device, in contrast to other devices tested, where deterrence ranges of 60 m, 60 m and 40 m were reported for the Ace-Aquatec, Lofitech and Airmar devices, respectively. Captive experiments carried out on small numbers of seals, such as those by Kastelein et al. (2010 & 2015b) and Götz and Janik (2010), demonstrated behavioural responses, including displacement, increased swim speed and increased surfacing rate resulting from exposure to signals from Airmar, Terecos, Lofitech and Ace Aquatec ADDs.

Field trials of the GenusWave device reported a startle response and deterrence effect on seals (Götz and Janik, 2015). A later trial of the same device reported that, despite observing a smaller change in the number seals surfacing close to the device, there was still a significant reduction in depredation of over 90% (Götz and Janik, 2016). With respect to peer-reviewed literature investigating the efficacy of ADDs in relation to deterring seals from finfish farms, the majority of publications are focussed on the GenusWave device. Additional peer-reviewed studies would improve our understanding of the efficacy of this, and other devices used in reducing depredation at finfish farms.

Another type of commercially available TAST device is FaunaGuard, which has several models available, depending on the species of interest. For the model used to deter seals, evidence on the efficacy of this device is currently limited to just one published study using two captive harbour seals. Both individuals did demonstrate significant changes in behaviour by keeping their heads out of the water or hauling out when the device was operational at received sound pressure levels (SPL) above 160 dB re 1 μPa, however when 'jumping' behaviour was included, the behavioural response threshold was estimated to be approximately 142 dB re 1 μPa (Kastelein et al., 2017). Using the maximum sound source level of the device, the authors predicted the device had an effective deterrent range of 500 -1000 m. The FaunaGuard device has not been reported to be used at finfish farms in Scotland (see Chapter 3 of this report).

Often adverse sounds, such as those from an ADD, will initially induce a reaction from an animal, but when an individual is repeatedly exposed to the sounds (either continuously or periodically), their response may diminish. This occurs more frequently where there is a motivation for the animal to tolerate the sound, such as the presence of food. Following captive experiments with grey and harbour seals, Götz and Janik (2010) reported that when motivated by the presence of food, seals tolerated the sounds produced by Airmar, Ace-Aquatec and Lofitech ADDs. This reduction in the response of seals to ADDs over time is widely considered one of the main difficulties in using acoustic signals to deter seals from predating finfish farms, with over 80% of farms reporting this as an issue when using ADDs (Northridge et al., 2013); see also Table A2-3, which provides brief summaries of questionnaires on perceived efficacy of ADDs completed by industry.

4. Knowledge Gaps

There remain a number of knowledge gaps which will require both empirical data collection and modelling studies to fill. This section does not aim to detail all potential knowledge gaps, but to give an overview of areas where further work will be required.

There are three key areas of challenge to understanding the impacts and efficacy of ADDs:

1. While several modelling studies suggest the potential for disturbance, TTS, and cumulative PTS to cetaceans from ADDs in situ at finfish farms in Scotland, there is limited (in the case of disturbance) and lacking (in the case of TTS and cumulative PTS) empirical evidence for this. There is no evidence that wide scale exclusion of cetaceans from areas where finfish farms are sited is occurring, but no definitive quantitative mapping and modelling has been carried out to assess this. There is also a knowledge gap relating to the individual consequences of any behavioural response or displacement, or the effect this may ultimately have at a population level.

2. Predicting the likelihood of auditory injury is often constrained through a lack of information on the source level and frequency spectrum of the ADDs being used, as well as the way in which they are used (e.g., duty cycling). With good management practices and well controlled studies, these variables can be recorded and their effect on the likelihood of impacts to marine mammals better understood. However, the behaviour of animals in relation to the ADDs is much less straightforward to control or predict and will have the greatest bearing on whether an animal is exposed to sounds sufficient to cause auditory injury. Measuring environmental variables that could affect animal motivation to be in an area during exposure studies may help to better predict behavioural responses.

3. For a number of reasons, the ability to quantify empirically the occurrence and impact of TTS and PTS remains extremely challenging. The ability to conduct hearing tests on animals is currently very limited, and would likely be restricted to animals in captivity.

More specifically, the review of evidence demonstrates that further work is required to:

- Gather empirical data on sound propagation from ADDs to investigate the impact of different parameters (e.g., water depth, substrate, sea state, number of ADDs) upon sound propagation in realistic usage settings.
- Better understand the noise levels that animals are exposed to both instantaneously and cumulatively. Such information could be gathered through studies that track marine mammals moving around acoustically monitored finfish farms with and without ADDs operating to allow realistic estimates of noise exposure to be calculated.
- Better understand the way in which ADDs potentially impact on a wider range of cetacean species. For the most part, the focus has been on harbour porpoise, and even for this species, significant uncertainties regarding responses and impacts remain. However, there is the potential for impact to other species, and with respect to those devices operating in the lower frequencies, for an impact to low frequency cetaceans, such as minke whale and humpback whale.
- Better understand whether there are population level consequences of displacement of cetaceans around finfish farms. Modelling frameworks for this already exist, but there would be a requirement for empirical data to understand whether there is broad scale displacement of animals and their effects.
- Better understand the reasons why individual seals show different responses to ADDs and the circumstances and deployment methods under which ADDs are likely to be most effective. This will need to focus on variables that affect seal behaviour in the vicinity of finfish farms, not just the type or deployment method of ADD.
- Better define and understand the efficacy of ADDs. This could be considered through a multi-faceted approach assessing size of yields, occurrence of damaged fish, distribution and density of seals in the vicinity of a farm or fishery. The information on fish (yield and damage) is routinely kept by farms. Additional, contemporary records of ADD use (e.g., locations, times the devices were in use, duty cycle, frequency, source level), and seal presence would add a great deal of value to our understanding of how well ADDs work to deter seals and how the effects of deterrence change over time.

5. Conclusion

The review of evidence has concluded that while studies have investigated the potential for impacts from ADD used at finfish farms on marine mammals, a number of knowledge gaps still exist. Current regulatory processes acknowledge these gaps, and make precautionary assumptions based on the best available science to ensure that marine mammals are protected and environmental obligations fulfilled. However, improving the evidence base over time through additional research and/or monitoring will enable a better understanding of ADDs and the manner in which marine mammals interact with them. This will improve the evidence available for any future decision making and policy.

To allow this to happen, **Scottish Government will work with industry, Statutory Nature Conservation Bodies and other relevant stakeholders to identify research and/or monitoring programmes required to improve the evidence base, building on the outcomes of the review**. By bringing together science, industry and environmental interests, this will allow the scientific evidence base for decision making to improve over time, facilitating transparency and efficiency in the licensing process and support the sustainable development of aquaculture in Scottish waters.

Chapter 3. Extent of acoustic deterrent device use in the aquaculture sector

1. Introduction

The Scottish Government commissioned research in 2019 to improve understanding of the extent and efficacy of ADD use in the aquaculture sector. One objective of the research was to undertake an assessment of the extent of ADDs used at Scottish finfish farm sites. Consequently the information presented in this chapter comes from an analysis of data collected between 2014 and 2019 and winter 2019/20 (as outlined in Coram et al., *in prep*). However, the way in which farmers use seal management measures, including ADDs, is continually evolving, and there are likely to have been some changes in the use of ADDs across finfish farms since the period of data collection ended. As a result, a supplementary section has been included in this chapter to provide a summary of recent changes in ADD use that has been reported by the industry.

2. Data sources used to provide information on the extent of ADD use

To provide an assessment of ADD use across Scottish finfish farms, information was collated from four main sources: (a) finfish producers; (b) seal licensing database; (c) ADD manufacturers and; (d) RSPCA accreditation scheme. The information collected included: ADD type and usage, mode of operation, number of transducers used, seal depredation rate and use of alternative measures. There was considerable variation in the amount, quality and content of data collected from these sources and often a degree of overlap existed which is explained in more detail in Coram et al. (*in prep*). To provide wider context in terms of the number of active finfish sites and the days each site was stocked, information was taken from the Scottish Government data portal (Scotland’s Aquaculture, 2020). This assessment only considered sites producing finfish in seawater, with shellfish and freshwater farms excluded.

Finfish sites have been categorised into regional groups according to their local authority area (see Figure 3.1) in order to consider the regional distribution of the information included. Finfish sites in the Firth of Clyde around Arran are included in Argyll and Bute.

When interpreting the results below, a distinction is required to be made between ADDs that are deployed at the finfish farm site and those that are actively used (i.e., switched on). For example, it is clear that in some instances, ADDs are deployed but not activated. It should also be noted that the information in this report reflects usage of ADDs at the time of the research; this may not necessarily be the case now as referred to later on in this chapter.

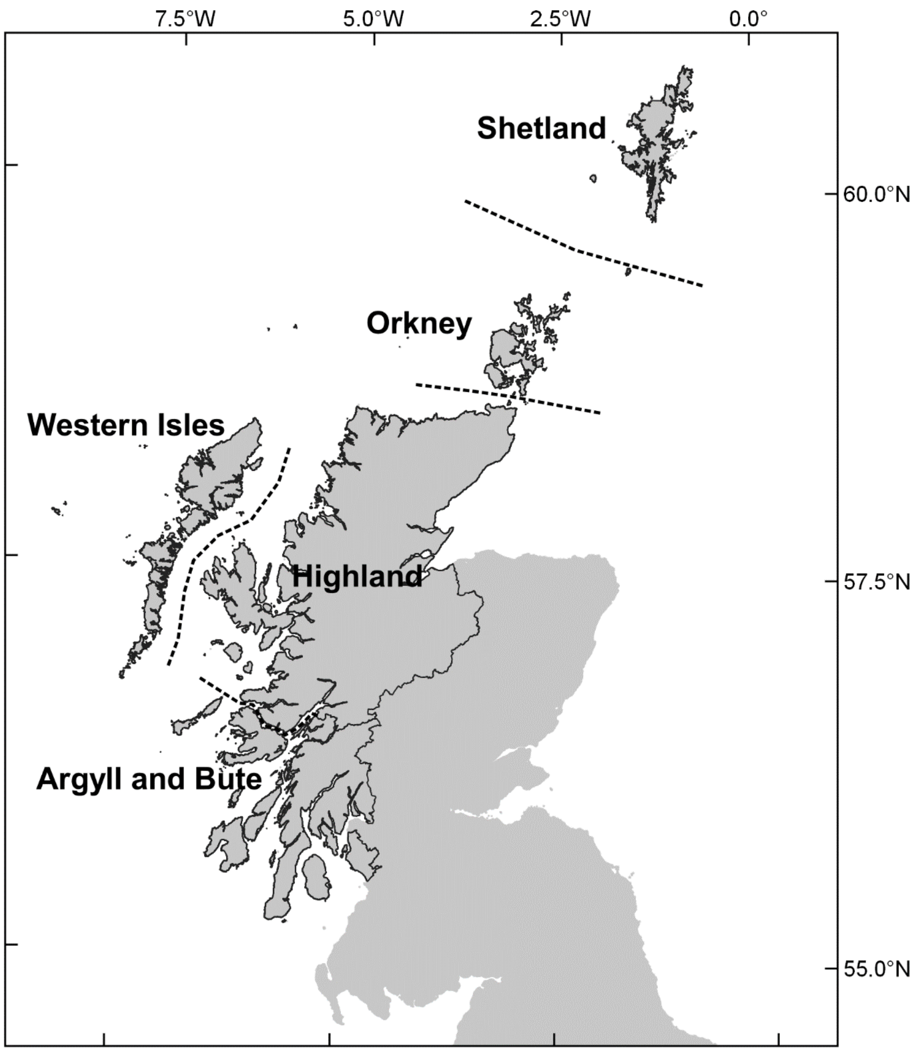

Figure 3.1. Regional categorisations of finfish farms according to local authority area

3. Assessment of ADD use at finfish farms between 2014 and 2019

This section provides an assessment of the extent of ADD use at finfish farms between October 2014 and October 2019. In particular this section focuses on the number and proportion of finfish farms deploying and using ADDs, the types of ADDs used and their spatial and temporal spread.

Extent of ADD deployment and use at finfish farms

From 2014 to 2016 there was an increase in the number of finfish sites that reported deploying ADDs from 119 to 154 sites. After a relatively consistent period between 2016 and 2018, there was a slight decrease in sites which reported deploying ADDs with a total of 146 finfish sites in 2019, representing 68% of the total number (216) of active finfish farm sites across Scotland (Figure 3.2).

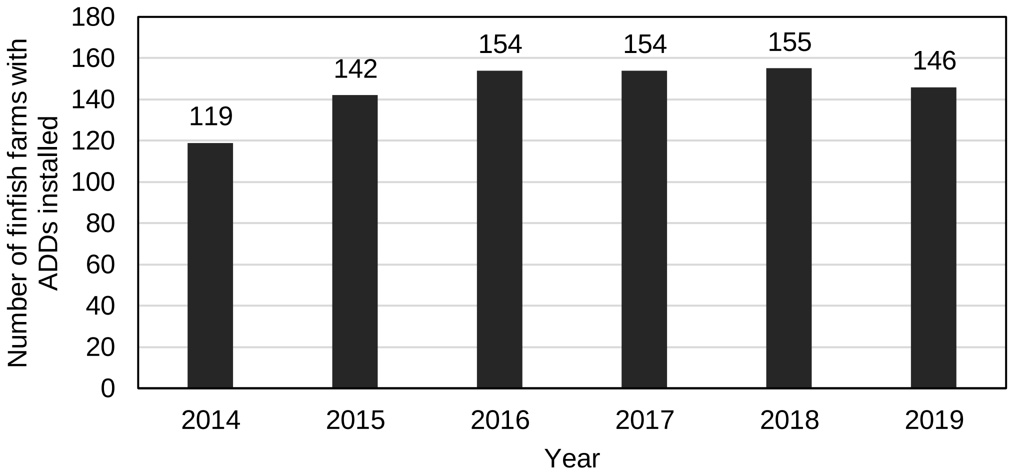

Figure 3.2. Number of finfish farms with ADD deployed from 2014 to 2019

These changes between 2014 and 2019 are broken down by region in Table 3.1. The highest proportion of finfish sites deploying ADDs has been in the Western Isles and Highland. The proportion of sites with ADDs increased in all regions except Argyll and Bute from 2014 to 2019. In Highland, Shetland, Argyll and Bute, and the Western Isles, there was an increase from 2014 until around 2017. Orkney has the lowest number and proportion of finfish farm sites deploying ADDs, but this increased in 2019. The average totals have varied between 60 to 71 % of all active finfish sites deploying ADD systems.

Table 3.1. Number of finfish farm site deploying ADDs per year and per region (and percentage of active finfish farms sites in that region and year with ADDs)

Region	2014		2015		2016		2017		2018		2019	
Highland	41	78.8%	44	72.1%	50	82.0%	51	85.0%	52	85.2%	50	82.0%
Orkney	2	9.5%	4	17.4%	4	17.4%	2	8.3%	2	8.3%	8	36.4%
Shetland	11	21.2%	18	33.3%	22	41.5%	23	48.9%	24	54.5%	16	36.4%
Argyll and Bute	38	88.4%	44	84.6%	44	86.3%	42	82.4%	42	84.0%	37	72.5%
Western Isles	27	77.1%	32	82.1%	34	85.0%	35	94.6%	34	89.5%	34	91.9%
Total	119	58.3%	142	61.7%	154	67.2%	154	70.3%	155	71.1%	146	67.6%

Of the total number of fish farm sites deploying ADDs, only a proportion of these are reported as being actively used (i.e., switched on) on any particular day (Figure 3.3). Despite fluctuations over time and slight changes in some regions, between 2014 and 2019, the overall total number of finfish farm sites across Scotland with ADDs switched on remained consistently between 80 and 100 (apart from one period in 2016 where numbers dropped below 80). This shows that while approximately two thirds of sites deploy ADDs as a seal management measure not all sites are actively using them at any one point in time.

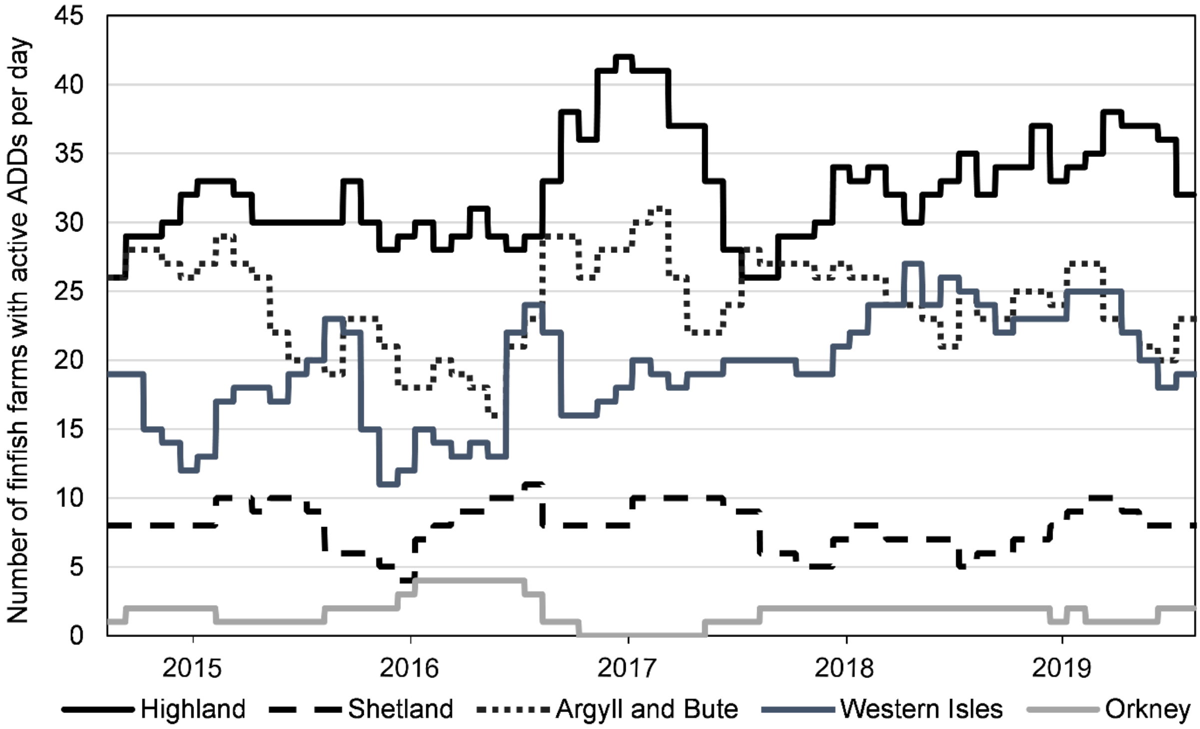

Figure 3.3. Number of finfish farms with active ADDs over time, per region

However, where sites are actively using ADDs, they are generally switched on for a considerable proportion of the time that the farm is stocked. For example, between 2017 and 2019, when ADDs were used they were reportedly switched on at farms for around 90% of the time (Table 3.2).

Table 3.2. Percentage of stocked days with ADD switched on, per year (including only finfish farms with ADDs installed and days where ADD status is known)

Year	2014	2015	2016	2017	2018	2019
Total	93%	88%	77%	89%	89%	90%

Number of transducers deployed at finfish farms

As well as changes in the number of finfish farm sites deploying ADDs, between 2014 and 2019 there have also been changes in the number of units (or transducers) deployed, and how many of these have been in active use. Figure 3.4 shows the change over time in the number of transducers on finfish farm sites across Scotland.

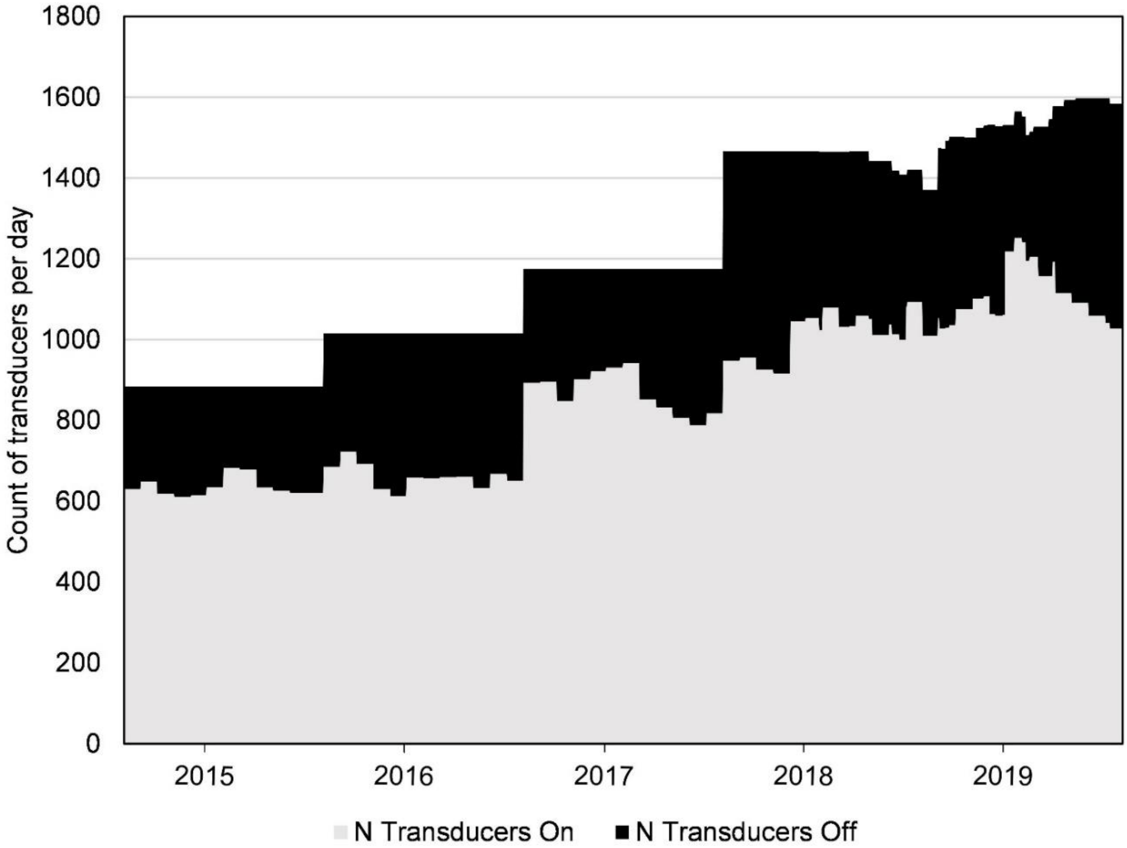

Figure 3.4 Count of ADD transducers per day at finfish farm sites (2014 - 2019) and their status (Grey: On, Black: Off)

From 2014 to 2016, the number of transducers increases in line with the total number of finfish farms using ADDs, but after 2016, when the number of farms with ADDs peaked and began to decline, the number of transducers continued to increase. The increase continued until the end of 2019, when 1,583 individual transducers were present on farms, although the rate of increase appears to have slowed since 2017.

Since early 2019, a gradual reduction in the proportion of transducers being actively used appears to have occurred, reducing from 72% in February 2019 (1,107 out of 1,532) to 65% (1,027 out of 1,583) in October 2019.

Types of ADDs deployed at finfish farms

The term acoustic deterrent device covers a wide range of device types in terms of frequency, patterns of emission, and different devices are used in different circumstances (e.g. pingers used for minimising bycatch in capture fisheries, to devices used for pre pile driving mitigation). In a comprehensive review of commercially available acoustic devices in UK waters, McGarry et al. (2020) reported that a total of 28 devices were available for marine industries. However, only seven types of ADDs were routinely recorded as being used at finfish farm sites between 2014 and 2019 (Table 3.3). Where records indicate that an ADD is deployed, but do not specify the ADD type, and where this information could not be verified, they have been recorded as ‘unknown’. More detailed information on each of these devices can be found on the manufacturers websites.

Table 3.3. The key features of the ADDs reported deployed between 2014 and 2019

Device	Comment
Airmar dB Plus II	These devices are different iterations of the original Airmar dB II Plus, which emit the same signal types but may have small differences in operating features.
Gael Force Sea Guard	
MohnAqua MAG Seal Deterrent	
Ace Aquatec US3	This includes records of older devices listed as US2 which is also made by Ace Aquatec.
Ace Aquatec RT1	A low-frequency device produced by Ace-Aquatec.
Terecos DSMS-4	No longer in production but still in use
OTAQ Seal Fence	The system operates on two modes – protect mode or patrol mode.

Between 2014 to 2019 there was a shift in the main types of ADDs reported as being deployed at finfish farm sites (Figure 3.5). In 2014, the Airmar and MohnAqua systems, both of which emit the same sound signal were the dominant devices deployed. Use of Terecos and Ace Aquatec US3 were also reported but in lower numbers. In contrast, the OTAQ device was the most dominant device in 2018 and 2019 suggesting that it is slowly replacing the Airmar, MohnAqua and Terecos systems which have all shown a gradual decrease over the last five years. GaelForce and Ace Aquatec RTI have also shown increases since 2017. The Lofitech device was not reported as being used at finfish farms.

From these results, it is clear that there is a gradual shift in ADD system choice by the aquaculture sector in recent years. This is likely driven by a range of factors including adaptive seal management approaches and ongoing development of the devices under manufacture.

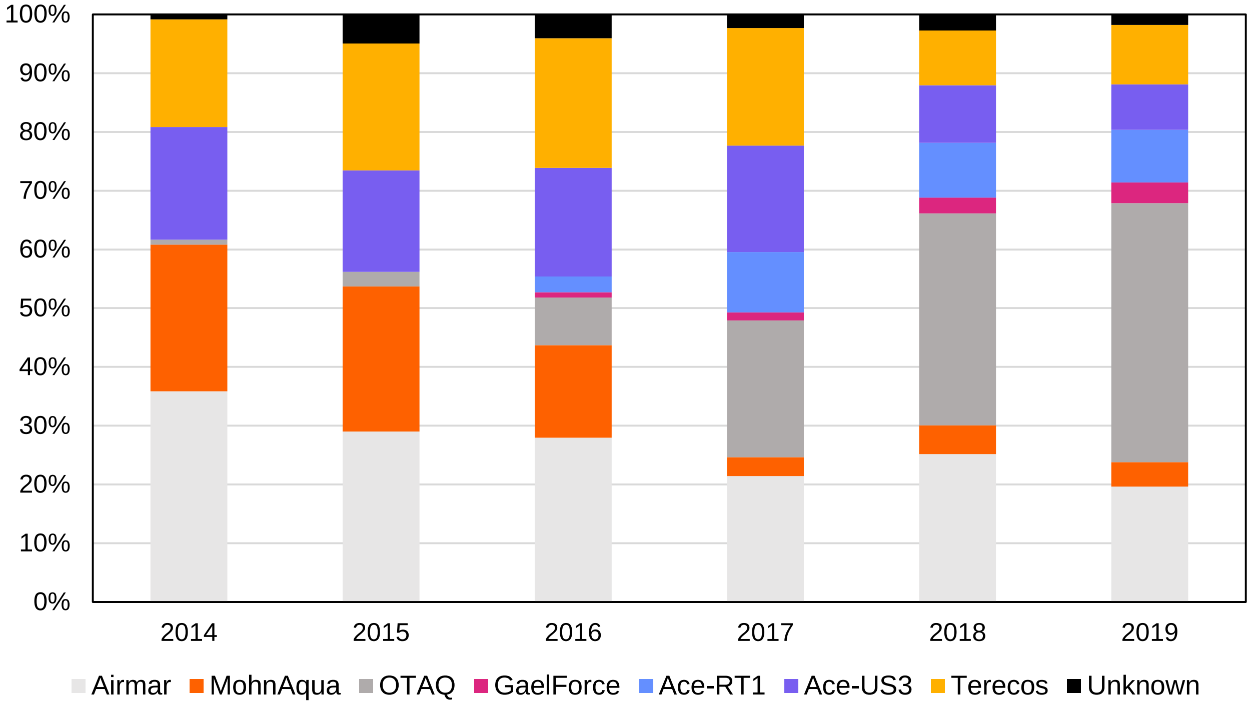

Figure 3.5. The percentage of finfish farms deploying each type of ADDs each year between 2014 and 2019.

Conclusions

The following summarises the conclusions for this section regarding ADD extent between 2014 and 2019:

- The number of sites deploying ADDs increased between 2014 and 2018, peaking at 155 in 2018 which was around 71% of active farms, before decreasing slightly in 2019.
- The total number of farms where ADDs were reported as actively used (i.e., switched on) remained between 80 and 100 for most of the period between 2014 and 2019.
- There was a change in the ADD types reported deployed at sites over time. In 2014 the ‘Airmar’ type ADDs (Airmar, MohnAqua and latterly GaelForce) were the most widely deployed devices. By 2019 the OTAQ device was the most commonly deployed device.

4. Snapshot of ADD extent at finfish farms (2019/20)

In addition to presenting an assessment of the extent of ADD use at finfish farms between 2014 to 2019, this report also provides a snapshot of ADD extent to reflect the most current timeframe available, drawing on all available data sources as outlined in Coram et al. (*in prep)* and in section 2 of this chapter. The period covered in this snapshot was October 2019 to April 2020, with information available for 193 finfish farm sites representing 89.4% of the 216 active sites.

Extent of ADD deployment and use at finfish farms

The total number of finfish farm sites which reported deploying ADDs over winter 2019/2020 was 132 sites, representing 68% of sites. In contrast, 61 finfish farms (32%) reported not having an ADD deployed over the same time period. This proportion varied by region (Figure 3.6), with Shetland and Orkney Isles having relatively low numbers of ADDs deployed as a proportion of the number of sites. The highest proportion was found in the Western Isles, with 32 out of 35 sites (91%) reported deploying ADDs.

In additional to regional differences in the deployment of ADDs, there are also significant regional differences in the type of ADDs being deployed at finfish farms across Scotland. Figure 3.7 shows the regional distribution of ADD type deployed at sites in 2019/2020.

Airmar, GaelForce and MohnAqua devices are distributed across all regions, with the largest proportions of farms with these devices in Shetland, Orkney and Highland regions. OTAQ equipment in contrast is not generally deployed in the Northern Isles, but makes up the largest proportion of finfish farm sites in the Western Isles, Highland and Argyll and Bute. The largest proportion of ADDs in the Northern Isles is the Ace-Aquatec RT1.

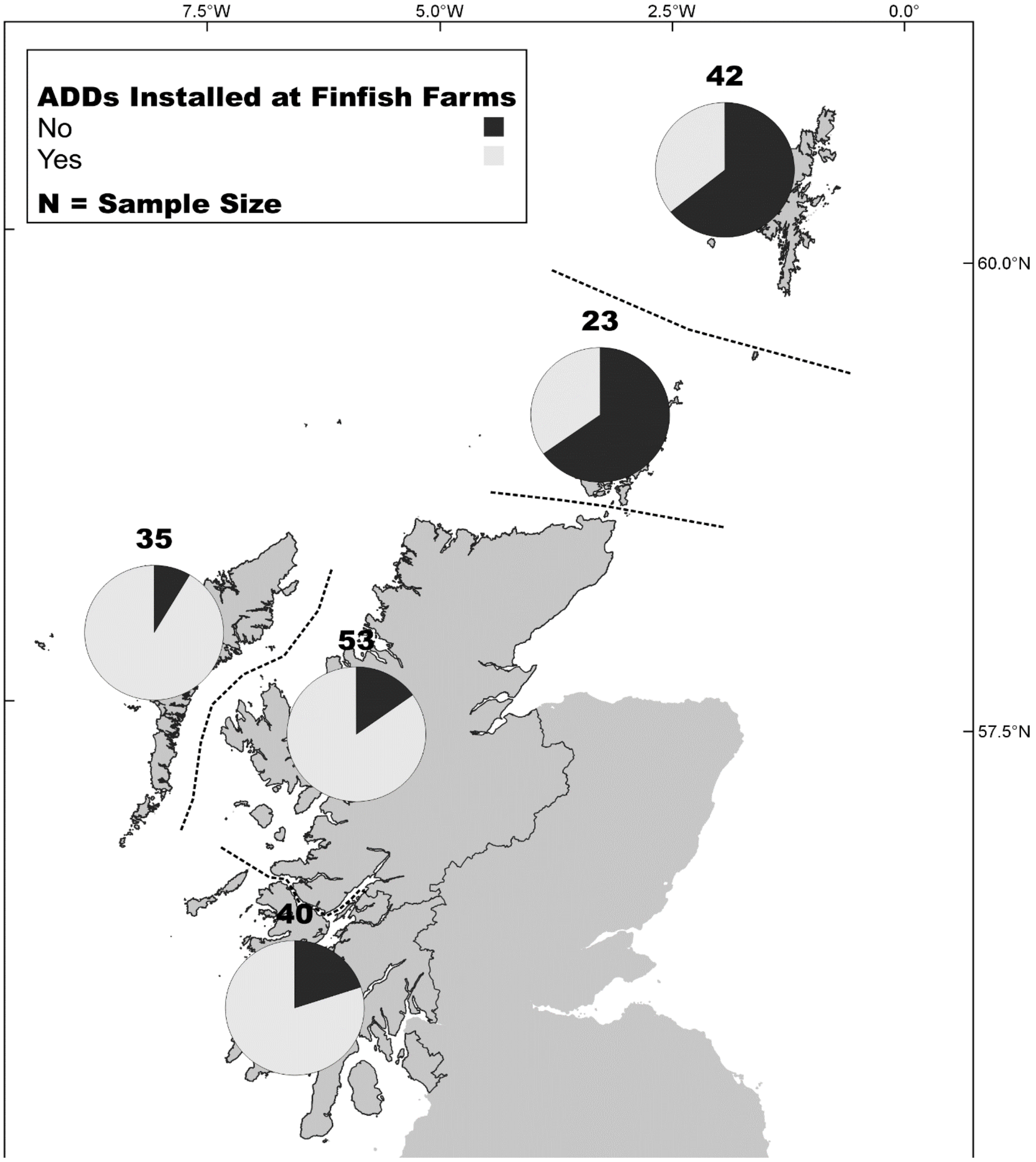

Figure 3.6. Regional proportion of finfish farms with ADDs installed and not installed in winter 2019/2020 (with sample size)

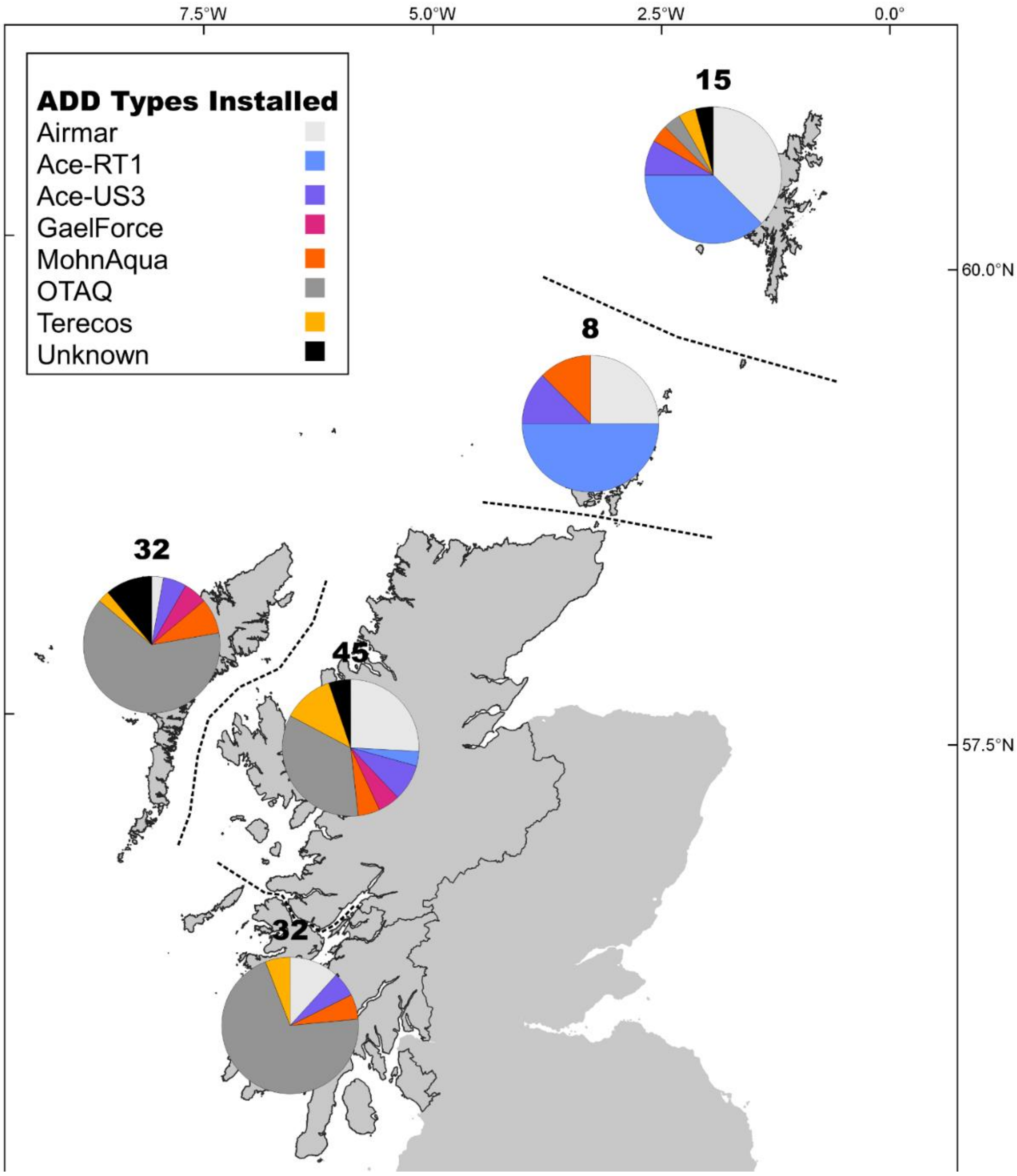

Figure 3.7. The proportion of the different ADD types deployed across each region during winter 2019/2020 (with sample sizes)

Conclusions

A snapshot of ADD extent in winter 2019/2020 reported that:

- ADDs were deployed at 68% of Scottish finfish farms, with significant regional variation.
- Highest levels of ADD deployment were recorded in the Western Isles, where 91% of farms reported deploying ADDs. Lowest levels were recorded in Orkney and Shetland with 35% and 36% of farms deploying ADDs respectively.
- The most commonly deployed ADD type during this time was the OTAQ, which was deployed at 31% of active farms. While this varied between regions, the OTAQ device was prevalent in deployment across farms in Argyll and Bute and in the Western Isles. In the Northern Isles the Ace-Aquatec RT1 and the Airmar devices were most commonly reported.

5. Changing position in ADD use

The way finfish famers use seal management measures, including ADDs, is a continually evolving process. During 2020/21 the industry reported a reduction in the overall number of ADDs in operation across all farming regions. Where used, the industry states that ADDs are operated within an adaptive management framework, typically switched on reactively in response to a specific seal predation risk, rather than being continually turned on. Such management frameworks also incorporate a range of approaches that seek to further minimise the amount of sound entering the marine environment, with the use of “soft start” technology (where the sound generated by the ADD increases slowly rather than abruptly), synchronised duty cycles to reduce overall sound propagation, and triggered devices (systems being manually controlled in response to the presence or absence of seals). In addition, the sector also report an increase in the use of low frequency devices (pers. Comm, Scottish Salmon Producers Organisation).

Some of these management strategies are already seen in the results from the data sources collected between 2014 and 2020 and are highlighted in sections 3 and 4 of this chapter.

6. Summary and conclusions

This chapter has provided information on the extent of ADD use at Scottish finfish farms from a range of data sources over a specific time series. Below is a summary of the main findings:

- There is no single, comprehensive source of information on the nature and extent of ADD deployment and use at finfish farms in Scotland. Through research undertaken by Coram et al. (*in prep*), a collated dataset covering the period 2014 to 2020 was produced, combining information on ADDs from a variety of discrete data sources, to provide an assessment of patterns in ADD deployment and use over time and between regions, and provide the best possible description of recent industry practices. The dataset was collated from a variety of sources, none of which were complete, verifiable or systematic. Therefore it has proven very difficult to determine the actual level of ADD use across the sector and the results should be interpreted with a degree of caution.
- The most recent information available was examined to indicate levels of recent ADD deployment and use (winter 2019/2020), including regional differences, while data on historic use (2014 to 2019) was examined to determine changes in use over time. The extent to which different ADD devices were used and how this varied between regions and over time was also examined.
- During 2020/21 the industry has reported further changes to their use of ADDs which is an evolving and highly dynamic situation.

In light of the information presented in this section, **the Scottish Government will work with the sector and regulators to establish a more systematic process for gathering information on ADDs where they are used at Scottish finfish farms.** Gathering such information would allow for a greater understanding of the distribution of ADD noise sources, thereby allowing an assessment of trends in usage as well as understanding of the potential for disturbance impacts on marine mammals. Such an approach would be consistent with monitoring of other noise sources in the marine environment where information is gathered for licenced activities.

Chapter 4. Sufficiency of monitoring acoustic deterrent device use within the aquaculture sector

1. Introduction

Monitoring can be defined in a number of ways but for the purpose of this section we consider monitoring as being the collection of information on ADD use at finfish farms for a specific purpose.

As stated in the previous chapter ("Extent of ADD use in the aquaculture sector"), no central database exists where information on ADD use at Scottish finfish farms is held. Instead, information is largely limited to a number of discrete and disparate data sources held by the industry itself and regulatory or planning organisations for a specific function. As part of these processes, data may be gathered, and some cases reported upon, although how this takes place is determined by the relevant authority.

This chapter provides an overview of current processes with a requirement to gather and hold data on ADD use. The sufficiency of these processes will be considered in terms of their ability to understand the distribution of ADD use (and as a secondary function to assess the potential for impacts on seals and cetaceans). Where improvements could be made, these will be set out.

2. Fish Farming Businesses (Record Keeping) (Scotland) Order 2008

Requirement to hold information in relation to containment measures

The Fish Farming Businesses (Record Keeping) (Scotland) Order 2008 sets out the records which must be compiled and retained by those engaged in the business of fish farming in respect of each site in which they farm fish. Schedule 2 of that Order addresses the records which must be kept in relation to containment, prevention and recovery of escape of fish. Schedule 2, paragraph 8 requires finfish farms to retain records concerning anti-predator measures undertaken, providing specifically that records must address:

> "A record of any anti-predator measures undertaken including-
> (a) the type and location of each net, fence and scarer deployed;
> (b) the use of lethal means by any person involved in operations on the site; and
> (c) any assessment of risk of escape of fish carried out."

Records pertaining to Schedule 2 are required to be kept for at least three years and must be available for inspection by Fish Health Inspectors who are appointed by the Scottish Ministers to act as inspectors under the Aquatic Animal Health (Scotland) Regulations 2009 and Aquaculture and Fisheries (Scotland) Act 2007.

Practical application of Schedule 2

At inspection, measures for the containment and prevention of escape of fish are checked for compliance with the Aquaculture and Fisheries (Scotland) Act 2007. Inspections are not restricted to any particular point in production. Farms are inspected according to a risk based surveillance scheme primarily to measure compliance with the Aquatic Animal Health (Scotland) Regulations 2009 (with regard to the risk of incidence or spread of listed diseases), although containment and sea lice inspections are carried out concurrently where appropriate. Targeted cases regarding containment, on up to 10% of fish farm sites annually, are carried out where escapes have occurred or where there is considered to be an increased risk of loss of containment. The criteria used to measure the risk of containment issues arising are:

- Subscription to the industry's Code of Good Practice for Scottish Finfish Aquaculture;
- Incidences of previous escape events or circumstances which give rise to a significant risk of escape on or in the vicinity of the site;
- Incidences of previous escape events or circumstances which give rise to a significant risk of escape on or in the vicinity of the sites operated by the business;
- Incidences of damage to site equipment by predators.

Both on-site observations and examination of records are used to undertake this requirement. The information is recorded on a digital form and both current and historical case information is available.

In terms of information held in relation to Schedule 2 of the Fish Farming Businesses (Record Keeping) (Scotland) Order 2008, the underlying records from the farm are not routinely held by fish health inspectors either historically or currently. Instead, only information on whether the records were maintained and available for inspection, along with any deficiencies which may require remedial action, is held.

3. Town and Country Planning (Scotland) Act 1997 (as amended)

ADDs, as a non-lethal management measure used to address seal predation are, when placed for the purposes of fish farming, considered as equipment under the Town and Country Planning (Scotland) Act 1997 (as amended) and their installation is a key consideration of the planning process and usually taken into account when determining applications. However, in the past, ADDs were sometimes considered to be a part of the equipment set-up that in some circumstances could be changed, or added, to finfish farms as a non-material variation. In these circumstances, such changes may therefore have not been recorded within the planning process.

As will be discussed in more detail in the following sections, some planning authorities apply specific conditions in relation to the use of ADDs (or wider non-lethal measures) in planning consent. For example, some authorities include specific conditions on the planning consent regulating the use of ADDs (e.g., adherence to deployment plans, no ADDs permitted in certain areas, or only specific devices permitted) while others include no specific conditions.

Historically, where planning conditions relevant to ADDs have been included, there has not been a requirement to hold and submit information in relation to these planning conditions. However, with regard to sites within/adjacent to the Inner Hebrides and the Minches SAC for harbour porpoise for example, local authorities are increasingly using planning conditions requiring the development of an ADD deployment plan and a requirement to submit information on ADD use to the local authority, either at a specified point in time or upon the request of the local authority. These deployment plans are largely in their infancy and it is not clear whether planning authorities have sought inspection of any log for ADD activity. Some local authorities may face challenges in effectively monitoring such returns due to a lack of resource and the necessary in-house technical expertise.

4. Additional sources of information

This section considers the circumstances in which information on ADDs has been provided to date for a specific function, or where ADD data may be provided in the future.

Marine (Scotland) Act 2010

The Animals and Wildlife (Penalties, Protection and Powers) (Scotland) Act 2020 amended Part 6 of the Marine (Scotland) Act 2010, removing two licensing grounds on which Scottish Ministers could grant licences authorising the taking or killing of seals and making other, associated amendments. The repealed licensing grounds were contained previously within section 110(1)(f)-(g) of the Marine (Scotland) Act 2010 and related to the protection of the health and welfare of farmed fish, and the prevention of serious damage to fisheries or finfish farms, respectively. As a consequence of this amendment, section 110(2)-(3) of the Marine (Scotland) Act 2010 was also repealed, as it related to the information that the Scottish Ministers were to have regard to before granting a seal licence under section 110(1)(g).

Before it was repealed, section 110(2)(b) of the Marine (Scotland) Act 2010 had required the Scottish Ministers before granting a seal licence under section 110(1)(g)[4] to have regard to any information that they had in relation to:

"the effectiveness of non-lethal alternative methods of preventing seal damage to the fishery or fish farm concerned or to any other fishery or fish farm which is in the vicinity of, or which is of a similar type to, the fishery or fish farm concerned."

In order to fulfil this function, applicants for a seal licence under section 110(1)(g) were required to provide Marine Scotland-Licensing Operations Team, acting on behalf of Scottish Ministers, with information on such non-lethal measures for the purposes of assisting them to decide whether to grant the seal licence.

This information was not used to monitor the use of ADDs, but rather to assist in informing seal licensing decisions. Following the repeal of section 110(2), which came into force on 1 February 2021, this information will no longer be collected in relation to finfish farms.

The Conservation (Natural Habitats, &c.) Regulations 1994

In accordance with regulation 44 of the Conservation (Natural Habitats, &c.) Regulations 1994 (the Habitats Regulations), in certain circumstances licences may be granted by the appropriate authority for an application to undertake activities which would normally constitute an offence against EPS.

To the extent that the Scottish Government may grant any EPS licences concerning the use of ADDs, consideration needs to be given as to the inclusion of a licence condition concerning the reporting of information on ADD usage.

[4] For the purpose of preventing serious damage to fisheries or finfish farms.

5. Conclusions

As described, certain processes are already in place for finfish farms to collect and hold information on the use of non-lethal deterrents, including ADDs, and to provide sight of this information to the relevant authority as requested. The level of information required to be held varies depending on the specific purpose.

On that basis, the existing processes in place to gather and inspect information (e.g., measures for the containment and prevention of escape of fish which are checked for compliance with the Aquaculture and Fisheries (Scotland) Act 2007) are sufficient for the specific purposes of these processes.

However, the level of information gathered through these processes is insufficient to determine the distribution of ADD use at finfish farms, which is required to monitor trends in usage as well as understanding the potential for disturbance impacts on marine mammals. **The Scottish Government will therefore work with the sector and regulators to establish a more systematic process for gathering information on ADDs where they are used at Scottish finfish farms.**

Chapter 5. Sufficiency of the current regulatory and legislative framework for marine mammals in relation to the use of acoustic deterrents in the aquaculture sector

1. Introduction

The Scottish Government is committed to ensuring protection for marine mammals. The Marine (Scotland) Act 2010 was an important landmark for seal conservation in Scotland and the Conservation (Natural Habitats, &c.) Regulations 1994 provides robust protection for cetaceans from deliberate and reckless disturbance in the Scottish marine area, together with other protections.

However, stakeholders involved in the conservation and protection of marine mammals have raised concerns about the regulation and management of the use of ADDs at finfish farms, arguing that their widespread use is resulting in disturbance and potential injury to non-target species, particularly cetaceans which are European Protected Species (EPS).

This section explores the current regulatory framework relating to the protection of marine mammals both domestically and internationally (where applicable) to examine whether the legislation and underpinning processes are sufficient to address the impacts of ADD use in aquaculture on seals and cetaceans. It will also consider wider licensing requirements where relevant, and legislative measures in relation to the protection of farmed fish. Where further measures could be beneficial these will be outlined.

2. Regulatory and legislative framework for the protection of marine mammals (species and site protection)

Marine mammals in the Scottish marine area are provided with protection through measures specific to the species, site-based measures and wider seas measures under a series of regulatory and legislative provisions. A number of key pieces of legislation pertaining to marine mammals should therefore be examined when considering the use of ADDs by the aquaculture sector and the potential for impacts on marine mammals. A summary of the legislation in relation to the impact of ADD use on cetaceans and seals is provided in Table 5.1.

Species Protection

The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) (the "Habitat Regulations") apply in Scotland, including in the Scottish marine area (out to 12 nautical miles (nm)) and include protections for cetaceans. Animals listed in Schedule 2 of the Habitats Regulations whose natural range includes any part of the UK are known as European Protected Species (EPS) in need of strict protection. All cetacean species are EPS, and under regulation 39(1) and (2), it is an offence to deliberately or recklessly capture, injure, kill or harass a wild animal of EPS, and deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean). Table 5.1 provides an overview of the key offences in relation to cetaceans.

The Scottish Government has published guidance in relation to the protection of marine EPS from injury and disturbance in Scottish inshore waters (July 2020).[5] This guidance provides advice to marine users undertaking activities in the marine environment which have the potential to deliberately or recklessly kill, injure or disturb a marine EPS. The guidance can also be used by regulators, nature conservation agencies, enforcement authorities and competent authorities when considering whether an activity will cause deliberate or reckless injury or disturbance to a marine EPS.

Under regulation 44 of the Habitat Regulations, certain activities which would normally constitute an offence against EPS may be permitted to be carried out under a licence granted by the appropriate authority.[6] When considering an activity that could potentially result in an offence being committed in respect of an EPS, consideration should be given as to whether the impact can be fully or partially mitigated, therefore removing the need for a licence. However, where this cannot be partially or fully mitigated, a licence will be required.

A licence may only be granted provided that: (a) the proposed activity falls within one of the licensable purposes listed in regulation 44(2); (b) there must be no satisfactory alternative(s); and (c) the action(s) authorised must not be detrimental to the maintenance of the population of the species concerned at favourable conservation status in their natural range. An application for a licence will fail unless all of these three tests are met. A licence granted may include a requirement for mitigation aimed at minimising potential impacts to species listed on the licence application.

[5] Marine European protected species: protection from injury and disturbance

[6] In the case of sub-paragraphs (a) to (d) the appropriate authority is the relevant nature conservation body, while Scottish Ministers are the appropriate authority for (e) to (g).

Adherence to mitigation measures can form a condition of the licence, with licence holders responsible for ensuring compliance with any conditions.

It is ultimately the responsibility of the person(s) carrying out an activity to determine if an EPS licence is required, and to seek the licence from the appropriate authority. In practice, the need for an EPS licence is often identified during existing licensing processes, for example, through marine licences which are required for certain activities carried out in Scottish waters. However, some activities are either licensed by other regulators (e.g., consent for finfish farming is granted by the local planning authority)[7] or have no over-arching licensing mechanism. In these situations, EPS applications may be received directly to the Scottish Government.

Part 6 (Conservation of Seals) of the Marine (Scotland) Act 2010 provides for the protection of seals by making it an offence under section 107 to kill, injure or take a live seal, intentionally or recklessly. Exceptions to these offences are for the purpose of alleviating suffering (under section 108) or under licence (in accordance with section 109), although both of these exceptions include rigorous reporting requirements. Licences may be granted by Scottish Ministers authorising the taking or killing of seals in certain limited circumstances, as provided in section 110. Amendments to the Marine (Scotland) Act 2010 which came into force on 1 February 2021 removed two licensing grounds which had previously applied in relation to the protection of the health and welfare of farmed fish and prevention of serious damage to fisheries and finfish farms.

Section 117 of the Act also provides for additional protection for seals from reckless and intentional harassment when they are hauled up on land at designated haul-out sites. A total of 195 sites have been designated as haul-out sites for both harbour and grey seals around Scotland's coast, with these covering significant harbour and grey seal haul-out sites and significant grey seal breeding colonies identified using a standard methodology.[8] Due consideration should be given to activities that have the potential to negatively affect seals at designated haul-out sites as part of the initial assessment process. The Scottish Government has published guidance on the offence of harassment at seal haul-out sites.[9] In addition, conservation areas are established for seals and these should be taken into account when considering activities that could result in an offence under the Marine (Scotland) Act 2010. Table 5.1 provides the key offences in this regard in relation to seals.

[7] In some limited cases Scottish Government provide planning consent.
[8] Method used to identify key seal haul-out sites in Scotland for designation under the Marine (Scotland) Act Section 117
[9] Guidance on Haul-Outs

Table 5.1. Summary of offences in relation to seals and cetaceans

Regulation	Offences in Scotland for seals and cetaceans
The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended)	**Cetaceans** Under regulation 39 (1) of the Habitat Regulations it is an offence to deliberately or recklessly: • capture, injure or kill an animal which is an EPS; • harass a wild animal or group of animals which is an EPS; • disturb such an animal while it is occupying a structure or place used for shelter or protection; • disturb such an animal while it is rearing or otherwise caring for its young; • obstruct access to a breeding site or resting place, or otherwise deny an animal use of a breeding site or resting place; • disturb such an animal in a manner or in circumstances likely to significantly affect the local distribution or abundance of the species; • disturb such an animal in a manner or in circumstances likely to impair its ability to survive, breed or reproduce, or rear or otherwise care for its young; • disturb such an animal while it is migrating or hibernating; Regulation 39(2) makes it an offence to deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean).
Part 6 (Conservation of Seals) of the Marine (Scotland) Act 2010	**Seals** Under section 107 of the Marine (Scotland) Act 2010 it is an offence to intentionally or recklessly kill, injure or take a live seal at any time. The only exceptions are to alleviate suffering (section 108) and under licence (section 109). It is also an offence under section 117 to intentionally or recklessly harass a seal at a haul-out site as designated by the Scottish Ministers. The Protection of Seals (Designation of Seal Haul-out Sites) (Scotland) Order 2014 designated such haul-out sites.

Site Protection

A network of well-managed marine protected areas (MPAs) has been established to meet national objectives to help to deliver a coherent MPA network, contributing to the protection and enhancement of the Scottish marine area. The network for marine mammals specifically comprises MPAs and European sites, which make a significant contribution to the protection, enhancement and health of the Scottish marine area.

Sites designated as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) make up the Natura 2000 network of protected areas and are defined as **European Marine Sites**. SACs have been designated for a range of species and habitats, including harbour and grey seals, harbour porpoise and bottlenose dolphins, and are given legal protection by the Habitats Regulations.

Regulation 48 of the Habitats Regulations requires that any plan or project which is not directly connected with or necessary to the management of a European site, but which would be likely to have a significant effect on such a site, either individually or in combination with other plans and projects, shall be the subject of an appropriate assessment (AA) of its impacts, in view of the site's conservation objectives. Habitats Regulations Appraisal (HRA) is a rigorous, precautionary procedure that examines the potential negative effects on European sites resulting from a plan or project, and is designed – with the precautionary principle at its core - to ensure the protection of European sites against plans and projects that may harm their integrity. Any plan or project should therefore only be authorised where an AA has concluded that it will not adversely affect the integrity of a European site.

It is for the competent authority to determine whether a plan or project is likely to have significant effects (LSE) on the European site, usually on the basis of advice from NatureScot. A competent authority must not authorise a plan or project unless it can show that the plan or project will not adversely affect the integrity of a European site. The competent authority must decide whether there is enough evidence to conclude that the proposals won't have adverse effects on a site's integrity.

A derogation is available for authorities to approve plans or projects which could adversely affect the integrity of a Natura site if: (1) there are no alternative solutions, (2) there are imperative reasons of overriding public interest, including those of a social or economic nature, and (3) compensatory measures are provided to ensure that the overall coherence of the Natura network is protected. If an authority wishes to use this derogation, Scottish Ministers must be notified.

Proposed SACs are afforded the same level of protection (i.e., sites which have been approved by Scottish Ministers for formal consultation but which have not yet been designated) as are sites which have been designated. Text box 1 provides examples of the manner in which ADDs have been considered in relation to the Habitats Regulations.

Examples of consideration of ADDs in relation to planning decisions

Inner Hebrides and Minches SAC for harbour porpoise. The position of NatureScot is that the use of ADDs at finfish farms within the SAC (including within 3 km of the SAC boundary) could result in an LSE on the site. Where an LSE is identified the applicant is required to submit information demonstrating how the use of ADDs will be managed appropriately to ensure that the site conservation objectives will not be compromised. In most cases ADD deployment plans include information on the manner in which ADDs will be deployed, as well as a hierarchical process by which anti-predator measures will be implemented, and form a condition of the planning consent with reporting conditions.

Other SACs. In some instances ADD use may not be permitted within or adjacent to a European site due to potential impacts on qualifying species. For example, in Yell Sound SAC, ADDs are not permitted due to potential impacts on harbour seals which are exhibiting some significant local population declines. Such an approach has been developed through a local management agreement between the planning authority, NatureScot and the companies operating within the SAC.

Marine Protected Areas (MPAs) are sites designated under Part 5 of the Marine (Scotland) Act 2010 in the Scottish marine area (within 12 nm) and Part 5 of the Marine and Coastal Access Act 2009 in the Scottish offshore region (beyond 12 nm) (collectively referred to as the “Marine Acts”) to protect features of importance to Scotland. There is duty in the Marine Acts to contribute to an ecologically coherent network of sites. MPAs are identified according to guidelines on the selection and development of the MPA network. In 2020, three sites were designated for the protection of cetaceans, the Sea of the Hebrides and Southern Trench MPAs for minke whale and the North-east Lewis MPA for Risso’s dolphin. MPAs have stated conservation objectives, developed by nature conservation advisors, NatureScot.

The Marine Acts place a duty on regulators to ensure that there is no significant risk of hindering the achievement of the conservation objectives of an MPA before giving consent to an activity. Public authorities may consult with NatureScot if they believe there is a risk of the activity affecting a protected feature of an MPA, other than insignificantly. In order to assist public authorities in making these decisions, NatureScot develops management advice for each site.

In the case of MPAs protecting cetaceans, the conservation objectives are to maintain the protected features in favourable condition. Therefore, in general, public authorities must not authorise any activity which NatureScot advise may hinder the achievement of these objectives. A public authority may authorise an activity which causes a risk to the achievement of the conservation objectives if it is satisfied that there is no alternative option with a lower impact, the benefit to the public outweighs the potential damage and arrangements will be made for measures of equivalent environmental benefit.

The three MPAs protecting cetaceans were designated on 3 December 2020. As these three sites have been newly created, the consideration of these sites in decision making has not yet had the opportunity to become well established. However, the process by which public authorities regulating the use of ADDs should consider the use of these devices in consultation with NatureScot is already in place.

Wider seas measures

The **Marine Strategy Regulations 2010** set out a framework for assessing, monitoring and taking action across UK waters to achieve the vision for clean, healthy, safe, productive and biologically diverse seas. It requires the production of a Strategy to ensure that action is taken to achieve or maintain Good Environmental Status (GES). The Strategy consists of three components – Part 1: an assessment of marine waters, objectives for GES and targets and indicators to measure progress towards GES; Part 2: a monitoring programme to monitor progress against the targets and indicators; and Part 3: a programme of measures for achieving GES. These are reviewed and updated on a six yearly cycle.

To help assess progress made in achieving GES, 11 qualitative descriptors are defined in the Strategy, including Descriptor 1 Biological diversity (including seals and cetaceans) and Descriptor 11 – Introduction of energy, including underwater noise. The high level objections for each of these descriptors are in Table 5.2.

The third part of the Strategy, the programme of measures, which sets out actions the UK is taking to achieve GES across all descriptors, including in relation to seals, cetaceans and underwater noise, is currently being updated and is due for publication in 2021.

Table 5.2. Marine Strategy Descriptors and high level objectives for GES

Descriptor	High level objective for GES
Underwater Noise	Loud, low and mid frequency impulsive sounds and continuous low frequency sounds introduced into the marine environment through human activities are managed to the extent that they do not have adverse effects on marine ecosystems and animals at the population level.
Seals	The population abundance and demography of seals indicate healthy populations that are not significantly affected by human activities.
Cetaceans	The population abundance of cetaceans indicates healthy populations that are not significantly affected by human activities.

Published in 2015, the **National Marine Plan**[10] sets out the way in which Scottish Ministers intend marine resources to be used and managed in a sustainable manner across all of Scotland's seas (out to 200 nm). It adopts sustainable development as its guiding principle and application of its policies ensure that consented development or activity can be regarded as sustainable. General policies are included in relation to natural heritage (GEN 9) and noise (GEN 13).

3. Planning requirements

In addition to the legislative provisions already discussed, certain activities in the marine environment will require a licence or consent before they can be carried out in Scotland's seas. Such activities include aquaculture and the planning aspects should therefore be considered when assessing the regulatory framework for the use of ADDs by the aquaculture sector.

Town and Country Planning (Scotland) Act 1997 (as amended)

The principal planning Act in force in Scotland is the Town and Country Planning (Scotland) Act 1997. Amendments made by the Water Environment and Water Services (Scotland) Act 2003, and by the Planning etc. (Scotland) Act 2006, together with related subordinate legislation including the Town and Country Planning (Marine

[10] Scotland's National Marine Plan

Fish Farming) (Scotland) Order 2007, brought marine aquaculture under planning control from 1 April 2007, subject to certain transitional arrangements. This requires all new developments and the majority of modifications to existing developments to have planning permission from the relevant planning authority.

Applications for most finfish farms require screening to determine whether assessment is required under the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended). The EIA process is intended to improve environmental protection, and informs the decision making processes by the planning authorities to determine whether certain projects should go ahead. Under these Regulations, a planning authority cannot grant planning permission for development unless they have first established and taken into account the LSE of the development on the environment[11]. HRA are also a rigorous requirement of the process, and where required, the HRA and EIA assessments must be co-ordinated.

Application of the Town and Country Planning Act in relation to the use of ADDs at finfish farms

In accordance with section 26 of the Town and Country Planning (Scotland) Act, the placing or assembly of any equipment in marine waters for the purposes of fish farming, and any material change of use of such equipment, constitutes development requiring planning permission. Most planning authorities consider ADDs deployed at finfish farms to be classed as equipment under these regulations, and their installation is an important consideration in the planning process. However, it is worth noting that in the past, in some instances ADDs were considered a part of the equipment set-up that, in some circumstances, could be changed or added to finfish farms as non-material variations, which were not recorded within the planning process.

Where proposed, ADDs form a component of the predator control measures, which are submitted by the applicant as part of their planning application. NatureScot as the relevant statutory consultee advises the planning authority on proposed predator control measures and potential interactions with wildlife at the relevant stages of the planning process. The planning authority considers this advice in reaching a decision on the application and any associated advisory notes or planning conditions.

[11] An HRA is also required where there is potential for proposed activity to affect qualifying features of a SAC or a SPA.

There is a level of variation between planning authorities regarding the manner in which ADDs are considered and dealt with through the planning process. Some aspects of this can be explained by the presence of nature conservation designations, while in other cases it is a response to local procedures and practices in place. In summary:

- The planning process allows for a degree of management and regulation of ADDs, but there are variations in approach across planning authorities, based on different factors. For example, some authorities include specific conditions on the planning consent regulating the use of ADDs (e.g., adherence to deployment plans within SACs to avoid any LSE on the European site,[1] no ADDs permitted in key areas, or only specific devices permitted) while others include no specific conditions.

- Advances are being made by some planning authorities through the development of ADD deployment plans regarding ADD use. However, these are still relatively recent initiatives and are generally applied to developments within, or adjacent to, European sites.

- There is uncertainty about whether the information on ADD use provided in the planning application reflects the current usage as there is no requirement to report on changes in predator control measures unless specifically stated in the planning consent, unless such changes are considered to constitute further development. This may be an issue for developments that have not been subject to the planning process for a period of time.

- There is limited resource and expertise within planning authorities to enforce conditions where they are applied and the planning process is not well suited to the day-to-day management of fish farm practices.

Whilst local authorities, following the transferral of responsibility for marine aquaculture developments, take on the role of planning authority for any new and modified fish farm developments, the Scottish Government on behalf of Scottish Ministers is also responsible for issuing planning consent for the operation of finfish and shellfish farm developments which pre-date the application of the planning regime. These consents include standard conditions agreed with the local authority.[12]

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[12] To note that the consent granted on behalf of Scottish Ministers is solely for the operation of finfish farms using equipment which was in place prior to the responsibility for marine aquaculture developments transferring

4. Wider legislative considerations

In addition to the species, site and wider sea based measures outlined above, there are other domestic and international provisions that have consequences in relation to the use of ADDs at finfish farms. The most relevant to the use of ADDs at Scottish finfish farms are considered in this section.

The US Marine Mammal Protection Act 1972

The US Marine Mammal Protection Act 1972 (as amended) (MMPA) provides protection to marine mammals in US waters by prohibiting, with certain exceptions, the "taking'" of marine mammals, where the terms "taking" means "to harass, hunt, capture, or kill, or to attempt to harass, hunt, capture or kill any marine mammal" (as per MMPA, section 3(13).[13]

The US has introduced provisions into the MMPA to address the incidental mortality and serious injury of marine mammals in both domestic and foreign commercial fisheries with the intention to reduce it to insignificant levels approaching zero mortality and serious injury rate. These US provisions require countries exporting commercial fish and fish products to the US to be held to the same standards as US commercial fisheries. Consequently, any fishery whose operations result in the killing or serious injury of marine mammals in excess of US standards or caught in a manner not permitted under US rules, will not be allowed to export to the US after 1 January 2023.

To meet these US import restrictions, exporting nations must demonstrate that they have prohibited the intentional mortality and serious injury of marine mammals in commercial fisheries, and that for those fisheries which have a higher than remote likelihood of mortality or serious injury, that there is a regulatory programme in place which is comparable in effectiveness to the equivalent US regulatory programme.

<u>Deterrence measures</u>
Under section 104(a)(4) of the MMPA, deterrence measures may be permitted in certain circumstances, "so long as such measures do not result in the death or

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to local authorities (and in a limited number of additional circumstances). Any equipment placed in the water since then would require planning permission from the local authority in accordance with the regular process.

[13] Harassment is defined within section 3(18)(A) of the MMPA as including "any act of pursuit, torment or annoyance which – (i) has the potential to a injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

serious injury of a marine mammal." Such measures include action taken by owners or employees of fishing gear or catch in order "to deter a marine mammal from damaging the gear or catch" or by owners/employees of private property in order "to deter a marine mammal from damaging private property."

However, only specific measures may be used to deter marine mammals, with section 101(a)(4) of the MMPA obliging the US Secretary, following a public process, to publish a list in the US Federal Register "of guidelines for use in safely deterring marine mammals" which is to include recommendations of "specific measures which may be used to non-lethally deter marine mammals." Furthermore, if the US Secretary determines "that certain forms of deterrence have a significant adverse effect on marine mammals," following a public process, the US Secretary may prohibit such deterrence methods.

Implications for Scotland

Where ADDs and other non-lethal measures can result in "significant adverse effects on marine mammals" their use may be prohibited in the US and therefore captured under the MMPA import provisions. To ensure continued access of Scottish fisheries to the US market, there is therefore a need for a regulatory mechanism by which to control ADD use in the aquaculture (and wider fisheries sector where required).

Animal Health and Welfare (Scotland) Act 2006

Part 2 of the Animal Health and Welfare (Scotland) Act 2006 ("2006 Act") promotes the welfare of animals and makes it an offence to cause a protected animal unnecessary suffering or to fail to take reasonable steps to ensure the welfare of animals for which a person is responsible (duty of care). The Scottish Government has issued guidance on the animal welfare provisions in Part 2 of the 2006 Act.[14]

Sections 16 and 17 of the 2006 Act establish a definition for "protected animals" and the conditions that they need to satisfy to meet the criteria. Farmed fish are protected animals under the 2006 Act as they are under control of man. Section 18 of the 2006 Act also distinguishes the duties of the person(s) who are responsible for the animal, although this responsibility can be shared by another person who is in charge of the animal. An example of shared responsibility is where a livestock owner employs a livestock manager. The owner has responsibility to ensure that the person employed is competent and knowledgeable about the livestock under his or her control.

[14] Animal Health and Welfare (Scotland) Act 2006: guidance

Unnecessary suffering

Section 19 of the 2006 Act contains offences in relation to unnecessary suffering of a protected animal. Unnecessary suffering may be caused by taking action which causes unnecessary suffering, or by failing to take steps to prevent unnecessary suffering.

It is an offence for any person, by an act, to cause unnecessary (physical or mental) suffering to a protected animal where the person committing the act knew or ought reasonably to have known, that the act would cause, or would be likely to cause, suffering. In addition, where a person is responsible for an animal, an offence would be committed if unnecessary suffering was caused to the animal by their act or omission, or if they permitted it to occur or failed to take such steps as are reasonable in the circumstances to prevent it happening.

Furthermore, when determining whether suffering is unnecessary, a number of factors need to be taken into consideration. These include whether the suffering could reasonably have been avoided or reduced; compliance with any relevant enactment, licence or code of practice issued on a statutory basis; the purpose of the conduct; the proportionality of the suffering to the purpose; and whether the conduct was that of a reasonably competent and humane person.

Ensuring the welfare of animals

Under section 24 of the 2006 Act, a person commits an offence if “the person does not take such steps as are reasonable in the circumstances to ensure that the needs of an animal for which the person is responsible are met.” Section 24(3) defines the needs of the animal, which include “its need to be protected from suffering, injury and disease.”

Ultimately, where a person is responsible for an animal, they have a positive duty to do all that is reasonable in all the circumstances to ensure that needs of the animal are met to the extent required by good practice.

Summary and application in relation to ADDs

As described above, offences under sections 19 and 24 of the 2006 Act generally apply to farmed fish which are protected animals under the 2006 Act. As a result, finfish farm operators must ensure that they protect the welfare of farmed fish in relation to their anti-predator measures.

ADDs are considered one of the few practical ways that the sector uses to keep seals away from approaching cages and therefore meeting their duty of care to ensure the welfare of their farmed fish by reducing apparent stress and any associated consequences (i.e., reduction in growth rate and tolerance to disease) which can have significant implications for the health and welfare of farmed fish.

5. Summary of the sufficiency of the regulatory and legal frameworks in relation to the protection of marine mammals

This section considers the sufficiency of the current regulatory framework relating to the protection of marine mammals to examine whether the legislation and underpinning processes are sufficient to address the impacts of ADD use in aquaculture on seals and cetaceans. Where improvements can be made to existing measures, these will be outlined.

Marine mammal protection provisions

The existing legal and regulatory framework, as laid out in sections 2 to 4 of this chapter, collectively provide a high level of individual and site-based protection measures for marine mammals in Scottish waters.

The Habitats Regulations afford a high level of strict protection for all cetaceans by prohibiting their deliberate or reckless capture, injury, disturbance and killing, while seals are protected through the Marine (Scotland) Act 2010 from intentional or reckless injury, taking and killing. There are only limited exceptions to these offences including for the purpose of alleviating suffering and under strict licensing provisions and there are significant penalties associated with harming them in line with the most serious wildlife offences.

These species protection measures are further enhanced through site based measures (e.g., MPAs, European sites, designated seal-haul outs) for certain species. Under these measures rigorous, precautionary processes are in place to ensure that marine activities do not result in significant effects on sites which are designated for these species, and that actions can be taken where required. These activities include aquaculture developments (where ADDs may be proposed as a predator measure) and are proportionate with the principles of the National Marine Plan.

The current regulatory framework for marine mammals as delivered through the Marine (Scotland) Act 2010 and Habitats Regulations therefore provides a wide-ranging level of protection for marine mammals in Scotland. Table 5.3 provides a summary of the regulatory framework and its sufficiency.

Measures to manage ADD use at finfish farms

Under the Marine (Scotland) Act 2010, Scottish Ministers are responsible for marine licensing and enforcement in the Scottish marine area, with specific activities requiring a marine licence under Part 4 of the Act before they can be conducted. As part of this process, activities that have the potential to result in offences to marine mammals or designated areas are identified and actioned accordingly. However, deposits in the sea (as defined in the 2010 Act) in the course of cultivation and propagation of fish can be exempt from requiring a marine licence under certain circumstances, for example where they do not pose a risk to navigation. As a result, whilst marine licences are issued for marine farms, such licences are confined to navigational controls and, therefore, environmental effects are wholly regulated through the planning process either by the local planning authority or by the Scottish Government.

ADDs deployed at finfish farms are generally classed as equipment under planning regulations, and their installation is therefore an important consideration in the planning process. There is however, a level of variation between planning authorities as to the manner in which ADDs are considered and dealt with through the planning process, which is set up to deal with the development itself. Some of this variation can be explained by the presence of nature conservation designations, while in other cases it is a response to local procedures and practices in place.

Furthermore, where conditions are placed on planning consents in relation to ADD use, there may be resource and technical limitations in terms of monitoring compliance. The planning process is also limited to consideration of new or modified finfish farm developments and not for older developments where ADD use may not be recorded within the planning process. So while the planning process allows for some management and regulation of ADDs, there is a level of variation in how this approach is considered across planning authorities based on different factors.

In addition to planning regulation, the Habitats Regulations provide for a robust process by which activities that have the potential to result in an offence to an EPS (in this case cetaceans) that cannot be partially or fully mitigated, can only be carried out legally under a licence granted by the appropriate authority.

Conclusions

This report has noted that a level of variation exists as to the manner in which local planning regulations are applied in relation to the use of ADDs. It has also noted the comparability requirements of the US MMPA which have yet to be finalised by the US administration. In light of this **Scottish Ministers will now consider the requirement for additional measures on the use of ADDs at finfish farms that may be needed in light of local variation and the MMPA legislation once finalised, and which can be applied consistently across all sites**. Any requirement for additional measures would be consulted on later in 2021.

Table 5.3. Summary of the sufficiency of the current regulatory framework for marine mammals in relation to ADD use.

Regulation	**Sufficiency of provisions for marine mammals**
Species Protection	
Habitat Regulations (European Protected Species licensing)	The Conservation (Natural Habitats, &c.) Regulations 1994 (the Habitats Regulations) provide a high level of protection to cetaceans in Scottish waters. These regulations prohibit the deliberate and reckless capture, injury disturbance and killing of EPS and set out the legal process for considering licences to dis-apply an offence. The Habitat Regulations also go beyond the specific provisions in the Habitats Directive in terms of widening the offence of disturbance in relation to cetaceans. It is ultimately the responsibility of the person(s) carrying out an activity to determine whether their activity could result in an offence under the regulations and to consider their actions accordingly (including seeking a licence from the appropriate authority). Since this can often be difficult for marine users or managers to interpret, guidance has been issued by the Scottish Government and the European Commission. In practice however, the need for an EPS licence is often identified during existing licensing processes. However, this is not always the case and some activities are either licensed by other regulators or have no over-arching licensing mechanism. With action taken by the Scottish Government in relation to the Habitats Regulations and ADD use at finfish farms, the approach taken for EPS is proportionate to the consideration of other activities in the marine environment which have the potential to result in potential offences to marine mammals. Factors to note: • Activity is not always identified during existing licensing processes, therefore the onus is on marine users to determine the requirement.

Part 6 (Conservation of Seals), Marine (Scotland) Act 2010	The Marine (Scotland) Act 2010 provides for a high level of protection to seals. It prohibits the intentional and reckless taking, injury and killing of seals, with limited exceptions in which seals can be taken or killed for the purpose of alleviating suffering or in certain circumstances under licence. The Act also provides protection to seals at designated haul-out sites when they can be particularly vulnerable to harassment. These haul-out sites cover the areas where the greatest proportion of seals are hauled out. In the case of marine activities (including aquaculture development), their potential to adversely affect a designated seal haul-out site is considered as part of the planning process.
Site-based protection	
Habitats Regulations (European Marine Sites)	Regulation 48 of the Habitats Regulations provides a rigorous, precautionary procedure for examining the potential negative effects on European sites resulting from a plan or project, and is designed to ensure the protection of European sites against plans and projects that may harm their integrity. This includes some consideration of ADD use where their use is determined by NatureScot to have a LSE on a European site. This requirement only applies to new or modified developments, therefore earlier developments may not have been captured through these measures. However, such an approach is proportionate to how other plans or projects are considered through the Habitat Regulations. Factors to note: • Covers new or modified developments (and for qualifying species) therefore earlier developments will not be captured through these provisions. • ADD use may only be considered by authorities when it is raised as an issue as part of the aquaculture development.

Marine (Scotland) Act 2010 - Marine Protected Areas	Public authorities have a duty to ensure that activities they carry out or authorise do not hinder the achievement of the stated conservation objectives. Public authorities may consult with NatureScot if they believe there is a risk of the activity affecting a protected feature of an MPA, other than insignificantly. A public authority may authorise an activity which creates a risk to the achievement of the conservation objectives if it is satisfied that there is no alternative option with a lower impact, the benefit to the public outweighs the potential damage and arrangements will be made for measures of equivalent environmental benefit. The process by which public authorities regulating the use of ADDs should consider the use of the devices in consultation with NatureScot is already in place. Factors to note: • Only covers new or modified developments (for qualifying species) therefore earlier developments will not be captured through these provisions. • ADD use may only be considered by authorities when it is raised as an issue as part of the aquaculture development.
Wider seas measures	
Marine Strategy	Provides a framework for assessing, monitoring and taking action across UK waters to achieve or maintain Good Environmental Status (GES). Specific measures are seals and cetaceans (e.g., healthy populations that are not significantly affected by human activities) and marine noise (e.g., impulsive sounds and continuous low frequency sounds introduced into the marine environment through human activities are managed to the extent that they do not have adverse effects on marine ecosystems and animals at the population level).

Chapter 6. Summary and future plans for regulation of the use of acoustic deterrent devices

This report has considered the use of acoustic deterrent devices by the Scottish aquaculture sector at finfish farms in accordance with section 15 of the Animals and Wildlife (Penalties, Protection and Powers) (Scotland) Act 2020. Specifically it has fully considered the following factors:

- information on the use made of acoustic deterrent devices on Scottish finfish farms,
- any known impacts that the use of acoustic deterrent devices has on marine mammals,
- consideration of whether the use of acoustic deterrent devices on Scottish finfish farms is sufficiently monitored,
- consideration of whether existing provision on protection of animals and wildlife in relation to the use of acoustic deterrent devices on Scottish finfish farms is sufficient, and
- any future plans for regulation of the use of acoustic deterrent devices.

Drawing on the body of the report, three key conclusions have been reached:

1. **Known impacts on marine mammals from the use of acoustic deterrents** - the Scottish Government will work with industry, Statutory Nature Conservation Bodies and other relevant stakeholders to identify research and/or monitoring programmes required to improve the evidence base, building on the outcomes of the review.
2. **Sufficiency of monitoring the use of acoustic deterrent devices at Scottish finfish farms** – the Scottish Government will work with the sector and regulators to establish a more systematic process for gathering information on ADDs where they are used at Scottish finfish farms.
3. **Sufficiency of existing provision on protection of animals and wildlife in relation to the use of acoustic deterrent devices on Scottish finfish farms** – this report has noted that a level of variation exists as to the manner in which local planning regulations are applied in relation to the use of ADDs. It has also noted the comparability requirements of the US MMPA which have yet to be finalised by the US administration. In light of this Scottish Ministers will now consider the requirement for additional measures on the use of ADDs at finfish farms that may be needed in light of local variation and the MMPA legislation once finalised, and which can be applied consistently across all sites. Any requirement for additional measures would be consulted on later in 2021.

Glossary

Acoustic Deterrent Device	Non-lethal management measures that work by introducing noise.
Auditory weighting function	Transforms sound measurements, taking into account the frequency-dependent aspects of auditory sensitivity.
dB	Decibels
dB re 1 μPa @ 1 m	Unit for SPL, decibels at reference pressure of 1 micro Pascal, usually referred from measurements back to 1 meter from the sound source.
dB re 1 μPa^{2}s	Unit for SEL, the integral over time for squared sound pressure.
CEE	Controlled Exposure Experiment
Fundamental frequency	The lowest frequency for a given sound.
Good Environmental Status (GES)	Seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations.
HF	High Frequency
Hz / kHz	Hertz / kiloHertz
LF	Low Frequency
Pa / μP	Pascals / microPascals
PAM	Passive Acoustic Monitoring
Predictive habitat modelling	The use of computer algorithms to predict the distribution of a species across geographic space and time, based on absence/presence and environmental data.
PTS	Permanent Threshold Shift

RL	Received Level
RMS	Root Mean Square
Sensation Level	A measure in decibels of the intensity of a sound that is above an individual's minimum hearing threshold.
SEL	Sound Exposure Level The metric assessed for the accumulation of sound exposure (usually measured over 24 hours), this takes into account the duration and the source level as well as the hearing sensitivity of marine mammal through auditory weighting.
SEL_{SENS}	Sound exposure sensation level; The SEL referenced to the test subject’s hearing threshold, from Götz and Janik (2013).
Signal	In the context of the report, the artificial sounds produced by an ADD that have specific frequency content, pulse rate and rise time.
SL	Source Level
SPL	Sound Pressure Level
Startle response	An unconscious defensive response to sudden or threatening stimuli, such as sudden noise.
TAST	Targeted Acoustic Startle Technology
TTS	Temporary Threshold Shift
VHF	Very High Frequency

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Appendix

The following tables summarise the studies that are available on ADDs in relation to different marine mammal groups. Details of the ADD technical specifications should be taken from the original study text because these may have changed over time through innovations by the manufacturers.

Table A1-1: Summary of studies investigating and/or documenting disturbance impacts from ADDs on low frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report.

Device	Species	Study type	Study Summary	Reference(s)
Airmar **'dB Plus II'**	Minke Whale	Anecdotal	There is anecdotal evidence in Fairbairns et al. (1994; taken from Gordon and Northridge, 2002) that a minke whale was not displaced or deterred by an Airmar ADD. In this case, a minke whale entered a small sealoch on the Isle of Lewis and remained there for ten weeks, apparently feeding on dense schools of fish. A fish farm within the loch used an ADD, which had a signal that closely matched that of an Airmar dB Plus II device (Gordon and Northridge, 2002). The ADD was not active when the whale entered the loch, and when activated, behavioural observations suggested the animal changed from a resting to a feeding mode but still continued to use all areas of the Loch and even appeared to investigate the device on one occasion. This event suggests that the minke whale was not deterred by the presence of an active device, although this was not a controlled study. Furthermore, the acoustic characteristics of the device are unknown and the observation relates to a single animal.	Fairbairns et al., 1994; Gordon & Northridge 2002
GenusWave **'Unknown'**	Minke Whale	Anecdotal / Field Study	During field trials of the GenusWave device at a fish farm on the west coast of Scotland, six minke whales were sighted during sound exposure periods and one during control periods. The closest observed approach for a minke whale was 1109 m during sound exposure and this whale was observed heading into the bay where the fish farm was located. This study provides limited data for minke whales due to the sample size, but found there was no evidence for any impacts at distances of more than 1 km. However, the RL at the distance of the closest observed approach was relatively low (125 dB re 1 µPa (RMS)).	Götz & Janik, 2015
Lofitech **'Seal Scarer'**	Minke Whale	Field Study	A controlled exposure experiment (CEE) using the Lofitech device in Iceland tracked the behaviour of minke whales during control, treatment and post-treatment phases. During each experimental exposure, a whale was visually observed for 30 mins to record baseline	McGarry et al., 2017

			behaviour (control phase), then a single ADD was lowered into the water for 15 mins (exposure phase), then finally the whale was observed for a final 30 minutes once following the removal of the ADD (post-exposure phase). In all 15 cases of the ADD being deployed at a distance of 1 km, the focal animal moved away from the sound source. There was a significant increase in net swim speed (7.4 kmh^{-1}) and directionality during deployment. Notably trials deploying the device at a closer distance of 500 m resulted in such strong aversive reactions that some focal animals disappeared too rapidly to be tracked for the remainder of the CEE (n=4). The SL was measured at 198 dB re 1 µPa @ 1 m (RMS), with a fundamental frequency of 14.6 kHz and an average pulse length of 752 ms. This SL is much higher than the manufacturers stated SL (191 dB re 1 µPa @ 1 m) and much higher than the Basran et al., 2020 study below (188 dB re 1 µPa @ 1 m).	
	Humpback Whale	Field Study	Boat-based studies of humpback whales in Iceland examined behavioural responses to a Lofitech device. The device had a measured SL of 188 dB re 1 µPa @ 1 m (RMS), with a fundamental frequency of 14.5 kHz and a frequency range between 10 to 20 kHz, for pulses of 500 ms duration at random intervals of 5 to 60 s. During each experimental exposure, a whale was visually observed for 30 mins to record baseline behaviour (control phase), then a single ADD was lowered into the water for 15 mins (exposure phase), then finally the whale was observed for a final 30 mins following the removal of the ADD (post-exposure phase). There were seven exposures for six individuals (one individual tested twice, with 18 months between exposures). There were no significant behavioural changes observed in swim speed and directness, breathing rate or dive time, and this was consistent across all seven exposures.	Basran et al., 2020

Table A1-2: Summary of studies investigating and/or documenting disturbance impacts from ADDs on high frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report.

Device	Species	Study Type	Study Summary	Reference(s)
Ace-Aquatec 'Silent Scrammer'	Killer Whale & Bottlenose Dolphin	Noise Modelling	Desk-based noise modelling of different types of ADD on the west coast of Scotland estimated audibility ranges for different marine mammal species. The maximum audible range was based on a sea state of 0 and water depths of 10-50 m. SL of the ADDs were based on Lepper et al. (2014). Modelling suggested that the Ace-Aquatec ADD sound was audible, to killer whales between 33-70 km and to bottlenose dolphins between 33-63 km, depending on sea state and water depth. While audible does not directly infer disturbance, the authors suggested that noise from the ADDs could reach a behavioural disturbance level (defined as 140–180 dB re 1 µPa (RMS)) (Southall et al., 2007) within a radius of 1.3 km.	Todd et al., 2019
Airmar 'dB Plus II'	Killer Whale & Bottlenose Dolphin	Noise Modelling	Desk-based noise modelling by Todd et al. (2019) of different types of ADD on the west coast of Scotland estimated audibility ranges for different marine mammal hearing groups. The maximum audible range was based on a sea state of 0 and depths of 10-50 m, and SL for the ADDs were based on Lepper et al. (2014). Modelling suggested that the Ace Aquatec ADD sound is audible to killer whales between 30-78 km and to bottlenose dolphins between 31-58 km, depending on sea state, and the sounds could potentially reach a behavioural disturbance level (140–180 dB re 1 µPa (RMS)) (Southall et al., 2007) within a radius of 1.3 km.	Todd et al., 2019
Airmar 'Unknown'	Killer Whale	Field Study	Two long-term studies in British Columbia, Canada monitored killer whale presence between 1985-2000 in two adjacent areas that had stable killer whale populations. Four Airmar ADDs with a SLs of 194 dB re 1 µPa @ 1 m at a frequency of 10 kHz were deployed between 1993-1999 at existing salmon farms in one of the areas. In the control area where no ADDs were deployed, sightings were not significantly different during the years of ADD activity (mean = 192.40, s.d. = 8.26, n = 5) to those of both pre-exposure (mean = 166.78, s.d. = 30.85, n = 9) and post-exposure (mean = 169.00, s.d. = 15.56, n = 2) periods, but did show a slight increase during the exposure period. This is in contrast to the exposure area, where sightings were significantly lower (by a factor of 3) during the years of ADD activity (mean = 9.80, s.d. = 4.97, n = 5), than those of both the pre-exposure (mean = 33.00, s.d. = 12.35, n = 9) and post-exposure (mean = 31.50, s.d. = 3.54, n = 2) periods. The authors suggest that animals were displaced from the exposure area into the control area during the six years where the	Morton & Symonds, 2002

Device	Species	Study Type	Study Summary	Reference(s)
			ADDs were deployed, with killer whale presence then returning to pre-exposure levels once the devices were removed in 1999.	
	Pacific White-sided Dolphin	Field Study	Surveys of Pacific white-sided dolphins in British Columbia, Canada between 1984-1998 reported that the abundance of dolphins declined following introduction of Airmar ADDs into the study area. Different methods were used to detect dolphins including passive acoustic monitoring (PAM) (55% sightings), reports from vessels (19%) boat searches (18%) and visual scans (8%) between 1984-1998 (14 years). The authors state that the reduction in sightings in the latter part of the study period (from 1994 through 1998) corresponded with a general decline in sightings of other cetacean in the Broughton Archipelago since January 1994. This trend was noted to have coincided with the introduction of four Airmar ADDs to the area (described above in Morton & Symonds 2002, with the acoustic characteristics described in more detail by Haller and Lemon 1994) by the salmon farming industry.	Morton, 2000
GenusWave **'Unknown'**	Harbour Porpoise	Field Study	Field trials with the GenusWave ADD (SL: 176–179 dB re 1 µPa @ 1 m) at a fish farm on the west coast of Scotland found no significant effect of sound exposure on the number of harbour porpoise surfacings observed within 200 m from the closest ADD, and overall porpoise abundance remained unaffected. At 20 m, none of the 1/3 octave bands exceeded the hearing threshold of a porpoise by more than 72 dB re 1 µPa (typically insufficient for eliciting significant startle responses in mammals). Given that these results demonstrate that harbour porpoise abundance was unaffected by the sound exposure, the authors expect that there would be similarly negligible effects for other odontocetes such as bottlenose dolphins and pilot whales. However there has been no research, either in captivity or in the field, on the effect of the GenusWave device on high-frequency cetaceans.	Götz & Janik, 2015 & 2016
Terecos **'DSMS-4'**	Killer Whale & Bottlenose Dolphin	Noise Modelling	Desk-based noise modelling by Todd et al. (2019) of different types of ADD on the west coast of Scotland estimated audibility ranges for different marine mammal species. The maximum audible range was based on a sea state of 0 and water depths of 10-50 m and SLs for the ADDs were based on measurements from Lepper et al. (2014). Models suggest the Terecos ADD sound is audible to killer whales between 37-110 km and to bottlenose dolphins between 37-89 km, depending on sea state, and the sounds could potentially reach a behavioural disturbance level (140–180 dB re 1 µPa (RMS)) (Southall et al., 2007) within a radius of 1.3 km.	Todd et al., 2019

Table A1-3: Summary of studies investigating and/or documenting disturbance impacts from ADDs on very high frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Species	Study Type	Study Summary	Reference(s)
Ace-Aquatec 'Silent Scrammer'	Harbour Porpoise	Noise Modelling	Desk-based noise modelling by Todd et al. (2019) of different types of ADD on the west coast of Scotland estimated audibility ranges for different marine mammal species. The maximum audible range was based on a sea state of 0 and depths of 10-50 m and SLs for the ADDs were based on Lepper et al. 2014. Models suggest the Ace Aquatec ADD sound is audible to harbour porpoise between 34-68 km, depending on sea state, and the sounds could potentially reach a behavioural disturbance level (140–180 dB re 1 µPa (RMS)) (Southall et al., 2007) within a radius of 1.3 km.	Todd et al., 2019
Ace-Aquatec 'Seal Scrammer'	Harbour Porpoise	Captive Study	Playback experiments with captive harbour porpoise estimated the audibility and behavioural response to signals from different ADD types. The effect of different received broadband SPLs were identified; a level that did not cause a behavioural change (77 dB re 1 µPa), a level that caused a small change in the surfacing rate and swimming pattern (117 dB re 1 µPa) and a level that caused the porpoise to swim away from the ADDs (i.e., exhibit displacement) (139 dB re 1 µPa). Depending on sea conditions and based on noise modelling, the Ace Aquatec ADD was expected to be audible to porpoise between 14-91 km and likely to deter porpoises at ranges between 0.2-1.2 km based on porpoise hearing thresholds (stimulus levels resulting in a 50% detection rate).	Kastelein et al., 2010
	Harbour Porpoise	Captive Study	Another captive study of the ability of porpoise to hear ADD sounds was carried out with two types of ADD, including the Ace-Aquatec. As the mean received SPL was increased in the pool, displacement occurred with increased surfacing, swimming speed and jumping for the captive porpoise. These behavioural reactions occurred above SPLs of 117 dB re 1 µPa (RMS) for the Ace Aquatec ADD. At exposure levels of 139 ± 2 dB re 1 µPa, the animal exhibited strong avoidance behaviour. Strong deterring effects were observed at sensation levels of 84 dB for the Ace Aquatec device.	Kastelein et al., 2015a
	Harbour Porpoise	Noise Modelling	A review of behavioural response studies involving porpoise and ADDs. The study used acoustic propagation calculations, the sound properties of the device in question, and the behavioural response thresholds reported in the reviewed studies to estimate deterrence	Hermannsen et al., 2015

			ranges. Using the minimum behavioural response threshold reported in Kastelein et al. (2015a; 117 dB re 1 µPa (RMS)) for the Ace Aquatec ADD, Hermannsen et al. predicted this RL could be experienced by porpoises at distances of up to 4 km. The threshold for the strong avoidance behaviour reported by Kastelein et al. (139 dB re 1 µPa) corresponded to distances between 380-590 m.	
Airmar **'Unknown'**	Harbour Porpoise	Field Study	Northridge et al. (2010) used PAM to study the short-term effects of an Airmar ADD on porpoise density around finfish farms on the west coast of Scotland. Data suggested no significant difference in detection rates across all distances (200 m to 8 km) from ADDs. Porpoises were also detected feeding at distance of 200 m from an active device. However, detection rates were significantly reduced at the four sites closest to an ADD (all within 1 km). Some click trains were still detected at all sites when ADDs were active, including those closest to the sound source, demonstrating partial rather than complete exclusion of porpoises from the affected areas. Detection rates recovered as soon as ADDs were turned off. In the same study, further analysis of broader scale PAM data was used to examine the long term effects of ADD introduction on the west coast of Scotland over two years. This analysis reported that porpoise detections were considerably lower in years when ADDs were active. No porpoise were detected within 4.3 km from an ADD. At other sites, porpoise were detected within 1-2 km of the active ADDs. However, subsequent predictive habitat modelling did not reveal ADD RL as a significant predictor of harbour porpoise distribution	Northridge et al., 2010
	Harbour Porpoise	Field Study	An experiment in Denmark used two models of ADD to examine the displacement of wild porpoise by both continuous and periodic exposure to ADDs. As this was a fisheries-based study, rather than a number of ADDs concentrated around a small area as seen in aquaculture, 55 ADDs were spread out at 100 m spacing to cover an area of approximately 0.6 km^2. The Airmar ADDs emitted a 300 ms signal every 4 s at 10 kHz with a nominal SL of 132 dB re 1 µPa (RMS). There was a 40-75% reduction in porpoise detection rate when the ADD was active. During continuous-exposure, detection rate was reduced by 65% throughout the 28-day trial; effective to 2.5 km but there was no effect between 2.5 and 5 km, suggesting porpoises were displaced out to either 2.5 km or 5 km. There was some evidence of habituation in the periodic exposure trial, with a strong aversive response to the first and second exposures and a weakened response to subsequent exposures.	Kyhn et al., 2015
	Harbour Porpoise	Field Study	Changes in harbour porpoise abundance when exposed to an Airmar ADD was assessed at site in British Columbia, Canada. Abundance reduced by >90% within 3.5 km, with no porpoise sightings within 200 m whilst the device was on (minimum deterrence distance). The local topography meant that 3.5 km was the maximum range at which observations could be made therefore this range may not represent the full extent of effects. There was no sign of	Olesuik et al., 2002 & Hermannsen et al., 2015

			habituation or a reduction in the size of effects over the three week duration of the trials. However, sighting rates recovered within a few days of the ADD being switched off. This was with an older version of the device with a SL of 194 dB re 1 µPa @ 1 m (p-p) focussed at 10 kHz, with a pulse duration 1.8 ms, 40 ms intervals, grouped into 2.3 s trains separated by 2.1 s (measured by Haller and Lemon 1994). A subsequent review of the work by Olesuik et al. (2002) by Hermannsen et al. (2015) calculated that at the minimum deterrence range of 200 m, the RL would have been approximately 148 dB re 1 µPa (p-p).	
Airmar 'dB Plus II'	Harbour Porpoise	Field Study	The effects on harbour porpoise due to a single Airmar dB II Plus ADD (fundamental frequency of 10 kHz and a SL approximately 180 dB re 1 µPa @ 1 m)) was studied in the Bay of Fundy, Canada. Harbour porpoise abundance reduced by 92% in close vicinity. Closest average approach to the device when on was 991 m compared to 6 m when off. Total exclusion from an area of up to 645 m from the device and significantly fewer sightings within 1.5 km when active. Using the 645 m minimum deterrence distance, noise modelling suggested that porpoises avoided the area when SPLs exceeded 128 dB re 1 µPa (p-p). Using zones of disturbance and discomfort for porpoises reported by Taylor et al. (1997; 130 dB re 1 µPa), Johnston calculated that this RL would be reached with the Airmar ADD at a range of approximately 532 m from the device.	Johnston, 2002
	Harbour Porpoise	Noise Modelling	Desk-based noise modelling by Todd et al. (2019) of different types of ADD on the west coast of Scotland estimated audibility ranges for different marine mammal species. The maximum audible range was based on a sea state of 0 and depths of 10-50 m and SLs for the ADDs were based on Lepper et al. (2014). Models suggest the Airmar ADD signal is audible to harbour porpoise between 32-64 km, depending on sea state, and the sounds could potentially reach a behavioural disturbance level (140–180 dB re 1 µPa (RMS)) (Southall et al., 2007) within a radius of 1.3 km.	Todd et al., 2019
GenusWave 'Unknown'	Harbour Porpoise	Field Study	Field trials were carried out at a fish farm on the west coast of Scotland with the GenusWave ADD (SL: 176–179 dB re 1 µPa @ 1 m (RMS)). There was no significant effect of sound exposure on the number of harbour porpoise surfacings observed within 200 m from the closest ADD and porpoise abundance remained unaffected. At 20 m, none of the 1/3 octave bands exceeded the hearing threshold of a porpoise by more than 72 dB re 1 µPa (typically insufficient for eliciting significant startle responses in mammals).	Gotz & Janik, 2016
Lofitech 'Seal Scrammer'	Harbour Porpoise	Field Study	In the German Bight in the North Sea, bubble curtains (to reduce sound levels) and ADDs were used to mitigate the impact on harbour porpoise of pile driving noise during construction of a wind farm. A Lofitech ADD (0.5 s pure tone pulses at about 14 kHz and a SL of approximately 189 dB re 1 µPa @ 1 m). By monitoring porpoise echolocation activity, the ADD was shown to have deterred porpoise out to at least 12 km and possibly out to 18 km. Largest decrease in	Dahne et al., 2017

			porpoise echolocation was at the closest range (1.5-3 km) where detections fell to around 0.5% (from baseline levels of 4-6%). Reaction to the ADD was equal to or greater than that predicted from pile driving (with a bubble curtain).	
Lofitech ‘Seal Scarer’	Harbour Porpoise	Captive Study	Playback experiments with captive harbour porpoise estimated the audibility and behavioural response to signals from different ADD types. The effect of different received broadband SPLs were identified; a level that did not cause a behavioural change (91 dB re 1 µPa), a level that caused a small change in the surfacing rate and swimming pattern (121 dB re 1 µPa) and a level that caused the porpoise to swim away from the ADDs (i.e., exhibit displacement) (151 dB re 1 µPa). Depending on sea conditions and based on noise modelling, the Lofitech ADD was expected to be audible to porpoise between 18-91 km and likely to deter porpoises at ranges between 0.2-1.2 km based on porpoise hearing thresholds (stimulus levels resulting in a 50% detection rate). This study demonstrates the specific SPLs that can induce averse behavioural responses in harbour porpoise.	Kastelein et al., 2010
	Harbour Porpoise	Captive Study	A captive study investigating the ability of porpoise to hear sounds from different ADDs, including the Lofitech device was carried out. As the mean received SL increased, displacement occurred with higher numbers of surfacings, swimming speed and jumps for the captive porpoise. These behavioural reactions occurred above SLs of 121 dB re µPa (RMS) for the Lofitech ADD. At exposure levels of 151 ± 6 dB re 1 µPa, the animal exhibited strong avoidance behaviour. Strong deterring effects were observed at sensation levels of 96 dB for Lofitech device.	Kastelein et al., 2015a
	Harbour Porpoise	Noise Modelling	A review of behavioural response studies involving porpoise and ADDs, summarised where available or modelled where not. The study used acoustic propagation calculations, the sound properties of the device in question and the behavioural response thresholds reported in the reviewed studies to estimate deterrence ranges. Using the minimum behavioural response threshold reported in Kastelein et al. (2015a; 121 dB re 1 µPa (RMS)) for the Lofitech ADD, Hermannsen et al. predicted this received level could be experienced by porpoises at distances of up to 2 km. The threshold for the strong avoidance behaviour reported by Kastelein et al. (151 dB re 1 µPa) corresponded to distances between 40-150 m.	Hermannsen et al., 2015
Lofitech ‘Unknown’	Harbour Porpoise	Field Study	A study in the German North Sea used PAM and aerial surveys to study deterrence effects of a Lofitech seal scarer (SL: 189 dB re 1 µPa) on harbour porpoise. Significant deterrence effect on harbour porpoise was reported out to 7.5 km, with likely deterrence effect beyond this distance that could not detected due to the sampling methodology (no PAM recorders were placed beyond this distance). RLs at the deterrence distance of 7.5 km were estimated to be 113 dB re 1 µPa. At a distance of 750 m from the ADD, porpoise activity decreased significantly with 92%, whereas at 0 m no porpoises were detected. These results indicate that	Brandt et al., 2012

			all porpoises were deterred from an area of 350 m around the ADD (estimated RL: 146 dB re 1 µPa), while no clicks were detected at 1.5 km recorder indicating that most animals were deterred from an area of approximately 1.9 km around the ADD.	
	Harbour Porpoise	Field Study	A further study was carried out by Brandt et al. (2013) to investigate the zone of reaction for porpoises exposed to Lofitech ADD sounds in Denmark using land-based observers. Clear deterrence effect (100% displacement) were observed up to 1.9 km, with deterrence 50% of the time between 2.1 to 2.4 km. There was a clear reduction in sighting rates within a 1 km radius around the ADD (relating to a minimal RL of ~129 dB re 1 µPa RMS) and in most cases porpoises immediately disappeared when exposed to the ADD at distances of 300 to 1100 m (relating to RLs between 128 and 143 dB re 1 µPa (RMS)). Closest observed porpoise to device was 798 m (RL - 132 dB re 1 µPa (RMS)) and the furthest avoidance reaction was recorded at 2.4 km (RL - 119 dB re 1 µPa (RMS) at the porpoises' location). However, this study had quite low sample sizes.	Brandt et al., 2013
	Harbour Porpoise	Field Study	In the Moray Firth, during the initial construction phase of the Beatrice offshore wind farm, an integrated study was carried out to evaluate mitigation strategies for marine mammals from impact pile driving activities. A PAM array was installed to measure the acoustic output of the construction work and ADDs, and to measure the responses of harbour porpoises to these sounds. Lofitech ADDs were used, with a measured SPL of 187.2 dB re 1 µPa @ 1 m (p-p) at an observed peak frequency of 12,840 Hz. The study reported a strong behavioural response and far-field disturbance from the Lofitech ADD, with porpoise detections decreasing along a gradient of ADD exposure following a 15 minute exposure period. The length of time that it took animals to return to exposed areas following ADD use was determined from the time elapsed between the end of the ADD exposure and the time of the first porpoise detection. There was ≥50% chance of detecting harbour porpoises in the 3 hour period following the ADD playback at distances up to 21.7 km from the ADD, in the 6 hour period this was reduced to distances up to 13.8 km and in the 12 hour period this was reduced further, to distances up to 3.9 km. The minimum time to the first porpoise detection within 1 km following 15 min ADD playback was 133 min.	Thompson et al., 2020
Lofitech **'Simulated signals'**	Harbour Porpoise	Field Study	In Denmark, wild harbour porpoises were exposed to simulated ADD sounds that resemble a Lofitech ADD but with a reduced SL (165 dB re 1 µPa p-p); compared with 189 dB re 1 µPa (RMS) of a real Lofitech) to allow closer exposure to visual tracking. The ADD deterred all porpoises to 190 m, and the majority of porpoises within 525 m (corresponding to median RL 98 dB re 1 µPa). There were mixed behavioural reactions between 350 to 525 m. All porpoises avoided the sound source when RLs exceeded 107 dB re 1 µPa. A single animal approached to a distance of 157 m before leaving the area, corresponding to a RL of 107 dB re 1 µPa.	Mikkelsen et al., 2017

Terecos **'DSMS-4'**	Harbour Porpoise	Field Study	Field trials of a Terecos device investigated the impact on porpoise activity proximal to a fish farm in Loch Hourn, Scotland. PAM was used to record porpoise echolocation as a proxy for porpoise activity. The study concluded that there was little evidence of any reduction in porpoise activity associated with the Terecos device being on, although the sites where porpoise activity was reduced during active periods were generally those closest to the device. Porpoise activity was reduced by 9.9% at 300 m, 7.4% at 438 m, 4.3% at 855 m and 1.4% at 1169 m. Data suggest only a weak or minimal response in harbour porpoise activity, though this response was proportional to the distance from the device. Sites beyond 1.2 km experienced slightly elevated levels of echolocation when the device was on, potentially suggesting animals were displaced out to this distance.	Northridge et al., 2013
	Harbour Porpoise	Noise Modelling	Desk-based noise modelling by Todd et al. (2019) of different types of ADD on the west coast of Scotland estimated audibility ranges for different marine mammal species. The maximum audible range was based on a sea state of 0 and depths of 10-50 m and SLs for the ADDs were based on Lepper et al. 2014. Models suggest the Terecos ADD sound is audible to harbour porpoise between 37-99 km, depending on sea state.	Todd et al., 2019
Bespoke ADD signals (i.e. not from a specific manufacturer)	Harbour Porpoise	Field Study	In an experimental field study with harbour porpoise, a high frequency test signal was designed using single frequency tonal bursts between 8 – 18 kHz, similar to signals produced by the Airmar, Lofitech and Ace Aquatec devices (the random frequency sequencing and the pulse width and duty cycle of the Ace Aquatec were also adopted). A low frequency test signal was also made up of pulsed continuous wave sinusoidal tonal bursts at one of 11 randomly switching fundamental frequencies between 1 – 2 kHz and frequency intervals at 100 Hz. This signal was designed to produce outputs comparable to those from the Ace Aquatec US3 low frequency variant ADD. The source levels used were lower (up to approximately 170 dB re 1 μPa @ 1 m (RMS)) than manufactured devices. Porpoise detection rates at most moorings were substantially lower during both high frequency and low frequency signal emissions than during silent control periods, suggesting that emission of both signals reduced the probability of porpoise detections. No significant differences in porpoise detection rates could be demonstrated between low frequency and high frequency signals.	Benjamins et al., 2018

Table A1-4: Summary of studies investigating and/or documenting Temporary Threshold Shift (TTS) impacts from ADDs on low frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Species	Study Type	Study Summary	Reference(s)
Lofitech **'Seal Scarer'**	Minke Whale	Field Study	During controlled exposure experiments on minke whales in Iceland, the acoustic properties of a Lofitech ADD were characterised in the field and noise modelling was undertaken to compare the acoustic output of the device with known thresholds for TTS (in this case, those estimated by NMFS, 2016). The model incorporated conservative swim away speeds of 2.5 ms^{-1} and an ADD deployment duration of 30 minutes. The SL was measured as 198 dB re 1 μPa @ 1 m (RMS) which is below the thresholds of 213 dB re 1 μPa (0-p) for low frequency cetaceans TTS. SEL were also modelled, with the threshold for a cumulative dose at 179 dB re 1 μPa^2s and for starting distances of 500 m, 100 m, and 25 m from the ADD, there was no exceedance of the TTS threshold for minke whales. This modelling work suggests that even at extremely close distances (25 m), there is no realistic risk of TTS to minke whales from a Lofitech ADD.	McGarry et al., 2017

Table A1-5: Summary of studies investigating and/or documenting Temporary Threshold Shift (TTS) impacts from ADDs on high frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference(s)
Ace-Aquatec **'Silent Scrammer'**	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory TTS SEL thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SEL to the species hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of an Ace Aquatec device was used to estimate impact zones and corresponding durations to achieve TTS for bottlenose dolphins and killer whales. Using impact criteria reported by Southall et al. (2007), and with calculations based on a total of three ADDs with a SL of 193 dB re 1 μPa at 10 kHz (RMS) and a 30% duty cycle; the TTS threshold would be reached after 2 mins 37 s at 2.5 m (SEL: 203 dB re 1 μPa^2s) for bottlenose dolphins, and for	Götz & Janik, 2013

			the same duration but at a distance of 748 m, for killer whales using the SEL_{sens} criteria. This could be extended to 7 mins 52 s at 2.5 m / 748 m if switching to a 10% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve TTS with bottlenose dolphins would occur within an impact zone of 175 m.	
Airmar **'dB Plus'**	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used either auditory thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SEL to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of an Airmar device was used to estimate impact zones and corresponding durations to achieve TTS for bottlenose dolphins and killer whales. For the nominal SPL of 198 dB re 1 µPa, using impact criteria reported by Southall et al. (2007), and with calculations based on a total of 4 ADDs each with a 50% duty cycle (total duty cycle = 200%); the TTS threshold would be reached after 45 s at 2.5 m (SEL: 203 dB re 1 $\mu Pa^2 s$) for bottlenose dolphins, and for the same duration but at a distance of 748 m for killer whales using the SEL_{sens} criteria. This could be extended to 3 mins at 2.5 m / 748 m if switching to one ADD and a 50% duty cycle. However, calculations using a lower measured sound pressure level for the Airmar device (192 dB re 1 µPa), with 4 ADDs each with a 50% duty cycle (total duty cycle = 200%); the TTS threshold would be reached after 3 mins (at 2.5 m for bottlenose dolphins and 748 m for killer whales). This could be extended to 11 mins 49 s, if using just one ADD and switching to a 50% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve TTS with bottlenose dolphins would occur within an impact zone of 175 m.	Götz & Janik, 2013
Airmar **'dB Plus II'**	Bottlenose Dolphin & Beluga	Noise Modelling	Calculations estimating theoretical risk of TTS induced by an ADD were reported by Gordon and Northridge, using older criteria for TTS in bottlenose dolphins and belugas (Schlundt et al., 2000) with a 1 s tone of 192 dB re 1 µPa. The Airmar signal consists of 32 18.5 ms pulses equal to a single transmission of 592 ms. Thus at the specified output level for an Airmar dB Plus II (194 dB re 1 µPa @ 1 m) a similar degree of TTS would be expected after exposure to a single transmission at a SL of 194 dB re 1 µPa at ranges of 1 m or less.	Gordon & Northridge, 2002
Lofitech **'Universal / Seal Scarer'**	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used either auditory thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SEL to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of a Lofitech device was used to estimate impact zones and corresponding durations to achieve TTS for bottlenose dolphins and killer whales. Using impact criteria reported by Southall et al. (2007), and with calculations based on a 25% duty	Götz & Janik, 2013

			cycle; the TTS threshold would be reached after 8 mins 45 s at 2.5 m (SEL: 203 dB re 1 μPa^2 s) for bottlenose dolphins, and for the same duration but at a distance of 748 m for killer whales using the SEL_{sens} criteria. This could be extended to 17 mins 29 s at 2.5 m / 748 m if switching to a 12% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve TTS with bottlenose dolphins would occur within an impact zone of 175 m.	
Terecos **'DSMS-4'**	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used either auditory thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SEL to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of a Terecos device was used to estimate impact zones and corresponding durations to achieve TTS for bottlenose dolphins and killer whales. Using impact criteria reported by Southall et al. (2007), and with calculations based on an array of 3 ADDs and 33% duty cycle; the TTS threshold would be reached after 15 mins 58s at 2.5 m (SEL: 203 dB re 1 μPa^{2}s) for bottlenose dolphins, and for the same duration but at a distance of 748 m, for killer whales using the SEL_{sens} criteria. This could be extended to 47 mins 55 s at 2.5 m / 784 m if switching to just one ADD and an 11% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve TTS with bottlenose dolphins would occur within an impact zone of 175 m.	Götz & Janik, 2013

Table A1-6: Summary of studies investigating and/or documenting Temporary Threshold Shift (TTS) impacts from ADDs on very high frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference(s)
Ace-Aquatec 'Silent Scrammer'	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Ace Aquatec device to estimate impact zones and corresponding durations to achieve TTS for a porpoise. Using impact criteria reported by Lucke et al. (2009), and with calculations based on a total of 3 ADDs and a 30% duty cycle; the TTS threshold would be reached after 2 mins 37s at 89 m (SEL: 203 dB re 1 μPa^{2}s). This could be extended to 7 mins 52 s at 89 m if switching to one ADD and a 10% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SELs to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve TTS would occur within an impact zone of 345 m.	Götz & Janik, 2013
Airmar 'dB Plus'	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Airmar device to estimate impact zones and corresponding durations to achieve TTS for a porpoise. For the nominal SL of 198 dB re 1 μPa, and using impact criteria reported by Lucke et al. (2009), and with calculations based on a total of 4 ADDs each with a 50% duty cycle (total duty cycle = 200%); the TTS threshold would be reached after 45 s at 89 m (SEL: 203 dB re 1 μPa^2 s). This could be extended to 3 mins at 89 m if using just one ADD and switching to a 50% duty cycle. However calculations using a lower measured sound pressure level for the Airmar device (192 dB re 1 μPa), with 4 ADDs each with a 50% duty cycle (total duty cycle = 200%); the TTS threshold would be reached after 3 mins at 89 m, and could be extended to 11 mins 49 s if using just one ADD and switching to a 50% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SELs to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve TTS would occur within an impact zones of 345 m.	Götz & Janik, 2013
GenusWave 'Unknown'	Harbour Porpoise	Noise Modelling	Porpoises exposed to 1.5 kHz pure tones developed significant TTS at a SEL of 190 dB re 1 μPa^{2}s (Kastelein et al. 2013). Therefore the risk of TTS for porpoise from the GenusWave device would be extremely low. They would only be affected when exposed to 50 pulses	Götz & Janik, 2015

			within one meter of the loudspeaker. Given the duty cycle of 0.8%, this means that an animal would have to stay within 1 m of the loudspeaker for almost 21 min. Alternatively, an animal would receive the same noise dose if it was exposed to the equivalent of 4000 s of continuous noise within 20 m of the loudspeaker. Taking the duty cycle and pulse duration into account, such an exposure would only be reached after 5 to 6 days of continuous presence within 20 m, representing a highly unrealistic scenario and therefore suggesting a low risk of TTS.	
Lofitech **'Universal / Seal Scarer'**	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Lofitech device to estimate impact zones and corresponding durations to achieve TTS for a porpoise. Using impact criteria reported by Lucke et al. (2009), and with calculations based on a 25% duty cycle; the TTS threshold would be reached after 8 mins 24 s at 89 m (SEL: 203 dB re 1 μPa^2 s). This could be extended to 17 mins 29 s at 89 m if switching to a 12% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SELs to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve TTS would occur within an impact zone of 345 m.	Götz & Janik, 2013
Lofitech **'Simulated signals'**	Harbour Porpoise	Captive Study	A captive harbour porpoise was exposed to an artificial ADD signal with a peak frequency of 14 kHz. A significant TTS was found, measured by auditory evoked potentials, with an onset of 142 dB re 1 μPa^{2}s at 20 kHz and 147 dB re 1 μPa^{2}s at 28 kHz. Single ADD signals with a (SL) of 193 dB re 1 μPa @ 1 m are assumed to induce a TTS in harbour porpoises up to distances between 211 m (spherical spreading in deep water) and 5.9 km (cylindrical spreading in shallow water), depending on theoretical sound propagation.	Schaffeld et al., 2019
Terecos **'DSMS-4'**	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Terecos device to estimate impact zones and corresponding durations to achieve TTS for a porpoise. Using impact criteria reported by Lucke et al. (2009), and with calculations based on a total of 3 ADDs and a 33% duty cycle; the TTS threshold would be reached after 15 mins 58 s at 89 m (SEL: 203 dB re 1 μPa^{2}s). This could be extended to 47 mins 55 s at 89 m if switching to an 11% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SELs to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve TTS would occur within an impact zone of 345 m.	Götz & Janik, 2013

Table A1-7: Summary of studies investigating and/or documenting Temporary Threshold Shift (TTS) impacts from ADDs on pinnipeds. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference(s)
Ace-Aquatec **'Silent Scrammer'**	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Ace Aquatec device to estimate impact zones and corresponding durations to achieve TTS for a harbour seal. Using impact criteria reported by Southall et al. (2007), and with calculations based on a total of three ADDs and a 33% duty cycle; the TTS threshold would be reached after 2 mins 37 s at 10 m (SEL: 203 dB re 1 μPa^2 s). This could be extended to 7 mins 52 s at 10 m if switched to one ADD and a 11% duty cycle.	Götz & Janik, 2013
Airmar **'dB Plus'**	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Airmar device to estimate impact zones and corresponding durations to achieve TTS for a harbour seal. For the nominal sound pressure level of 198 dB re 1 µPa, using impact criteria reported by Southall et al. (2007), and with calculations based on a total of four ADDs each with a 50% duty cycle (total duty cycle = 200%); the TTS threshold would be reached after 45 s at 10 m (SEL: 203 dB re 1 μPa^2 s). This could be extended to 3 mins at 10 m if switched to one ADD and a 11% duty cycle. However, calculations using a lower measured sound pressure level for the Airmar device (192 dB re 1 µPa), with four ADDs each with a 50% duty cycle (total duty cycle = 200%); the TTS threshold would be reached in 3 mins, with this being extended to 11 mins 49 s if just once ADD and a duty cycle of 50% was used.	Götz & Janik, 2013
Airmar **'dB Plus II'**	Harbour Seal	Noise Modelling	Calculations estimating theoretical risk of TTS induced by an ADD were reported by Gordon and Northridge, using older criteria for TTS in bottlenose dolphins and belugas (Schlundt et al., 2000) with a 1 s tone of 192 dB re 1 µPa. Hearing thresholds for harbour seals are more than 10 dB higher than those of bottlenose dolphins, giving extrapolated instantaneous TTS thresholds for common seals of 204 dB re 1 µPa @1 m for an Airmar transmission. This value is above the devices SLs. The Airmar transmission consists of 32, 18.5 ms pulses equal to a single transmission of 592 ms.	Gordon & Northridge 2002

GenusWave **'Unknown'**	Harbour Seal	Noise Modelling	No empirical measurements, but calculations based on the acoustic output of the GenusWave device demonstrate low realistic risk of TTS. The onset of a TTS occurs at SEL of ~182 dB re 1 µPa^{2}s. The SEL of a single 0.2 s pulse is 173 dB re 1 µPa^{2}s and the cumulative SEL of 5 pulses is 180 dB re 1 µPa^{2}s. Therefore, even if a harbour seal was exposed to five pulses at a distance of 1 m from the loudspeaker; it would not be at risk of TTS.	Götz & Janik, 2015
Lofitech **'Universal / Seal Scarer'**	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Lofitech device to estimate impact zones and corresponding durations to achieve TTS for a harbour seal. Using impact criteria reported by Southall et al. (2007), and with calculations based on a 25% duty cycle; the TTS threshold would be reached after 8 min 24 s at 10 m (SEL: 203 dB re 1 µPa^{2}s). This could be extended to 17 mins 29 s at 10 m if switching to a 12% duty cycle.	Götz & Janik, 2013
Terecos **'DSMS-4'**	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Terecos device to estimate impact zones and corresponding durations to achieve TTS for a harbour seal. Using impact criteria reported by Southall et al. (2007), and with calculations based on an array of 3 ADDs and 33% duty cycle; the TTS threshold would be reached after 15 min 58 s at 10 m (SEL: 203 dB re 1 µPa^{2}s). This could be extended to 47 mins 55 s at 10 m if switching to one ADD and an 11% duty cycle.	Götz & Janik, 2013

Table A1-8: Summary of studies investigating and/or documenting Permanent Threshold Shift (PTS) impacts from ADDs on low frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference(s)
Lofitech ‘**Seal Scarer**’	Field Study	Minke Whale	During CEE in Iceland with minke whales, the acoustic properties of a Lofitech ADD were characterised in the field and noise modelling was undertaken to compare the acoustic output of the device with known thresholds for PTS (in this case, those estimated by NMFS, 2016). The model incorporated conservative swim away speeds of 2.5 ms^{-1} and an ADD deployment duration of 30 minutes. The source peak SPL was measured as 204 dB re 1 µPa @1 m which is below the thresholds of 219 dB re 1 µPa (0-p) for instantaneous PTS (NMFS, 2016). SEL was also modelled, with the threshold of 199 dB re 1 $µPa^2s$ and for starting distances of 500 m, 100 m, and 25 m from the ADD, there was no exceedance of the SEL PTS threshold for minke whales. This modelling work suggests that even at extremely close distances (25 m), there is no realistic risk of PTS injury to minke whales from a Lofitech ADD.	McGarry et al., 2017

Table A1-9: Summary of studies investigating and/or documenting Permanent Threshold Shift (PTS) impacts from ADDs on high frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference
Ace-Aquatec **‘Silent Scrammer’**	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used both auditory thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SEL to the test subject’s hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of an Ace Aquatec device was used to estimate impact zones and corresponding durations to achieve PTS for bottlenose dolphins and killer whales. Using impact criteria reported	Götz & Janik, 2013

			by Southall et al. (2007), and with calculations based on a total of three ADDs and a 30% duty cycle; the PTS threshold would be reached after 3 hours 10 min at 15 m (SEL: 221.6 dB re 1 μPa^{2}s) or after 2 mins 37 s at 2 m (SEL: 203 dB re 1 μPa^{2}s) for bottlenose dolphins, and for the same durations but at distances of 642 m and 79 m, respectively, for killer whales using the SEL_{sens} criteria. This could be extended to 9 hours 30 mins at 15 m / 642 m and 3 mins at 2 m / 79 m if switching to a 10% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve PTS with bottlenose dolphins would occur within impact zones of 150 m and 18 m, respectively.	
Airmar ‘dB Plus’	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used either auditory thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SELs to the test subject’s hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of an Airmar device was used to estimate impact zones and corresponding durations to achieve PTS for bottlenose dolphins and killer whales. For the nominal SPL of 198 dB re 1 μPa, using impact criteria reported by Southall et al. (2007), and with calculations based on a total of four ADDs each with a 50% duty cycle (total duty cycle = 200%); the PTS threshold would be reached after 55 min at 15 m (SEL: 221.6 dB re 1 μPa^{2}s) or after 45 s at 2 m (SEL: 203 dB re 1 μPa^{2}s) for bottlenose dolphins, and for the same durations but at distances of 642 m and 79 m, respectively, for killer whales using the SEL_{sens} criteria. This could be extended to 3 hours 38 mins at 15 m / 642 m and 3 mins at 2 m / 79 m if switching to one ADD and a 50% duty cycle. However, calculations using a lower measured sound pressure level for the Airmar device (192 dB re 1 μPa), with four ADDs each with a 50% duty cycle (total duty cycle = 200%); the PTS threshold would be reached after 3 hours 37 mins at (at 15 m bottlenose dolphins and 642 m for killer whales), or 3 mins (at 2 m for bottlenose dolphins and 79 m for killer whales), depending on the impact zone chosen. This could be extended to 14 hours 29 mins and 11 mins 49 s, respectively, if using just one ADD and switching to a 50% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve PTS with bottlenose dolphins would occur within impact zones of 150 m and 18 m, respectively.	Götz & Janik, 2013
Lofitech	Killer Whale &	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds reported by Southall et al. (2007) or a more conservative approach	Götz & Janik, 2013

'Universal / Seal Scarer'	Bottlenose Dolphin		suggested by the authors that references SELs to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of a Lofitech device was used to estimate impact zones and corresponding durations to achieve PTS for bottlenose dolphins and killer whales. Using impact criteria reported by Southall et al. (2007), and with calculations based on a 25% duty cycle; the PTS threshold would be reached after 10 hours 8 min at 15 m (SEL: 221.6 dB re 1 μPa^{2}s) or after 8 mins 45 s at 2 m (SEL: 203 dB re 1 μPa^{2}s) for bottlenose dolphins, and for the same durations but at distances of 642 m and 79 m, respectively, for killer whales using the SEL_{sens} criteria. This could be extended to 21 hours 7 mins at 15 m / 642 m and 17 mins 29 s at 2 m / 79 m if switching to a 12% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve PTS with bottlenose dolphins would occur within impact zones of 150 m and 18 m, respectively.	
Terecos **'DSMS-4'**	Killer Whale & Bottlenose Dolphin	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used either auditory thresholds reported by Southall et al. (2007) or a more conservative approach suggested by the authors that references SEL to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}). The known acoustic output of a Terecos device was used to estimate impact zones and corresponding durations to achieve PTS for bottlenose dolphins and killer whales. Using impact criteria reported by Southall et al. (2007), and with calculations based on an array of three ADDs and 33% duty cycle; the PTS threshold would be reached after 19 hours 17 min at 15 m (SEL: 221.6 dB re 1 μPa^{2}s) or after 15 mins 58 s at 2 m (SEL: 203 dB re 1 μPa^{2}s) for bottlenose dolphins, and for the same durations but at distances of 642 m and 79 m, respectively, for killer whales using the SEL_{sens} criteria. This could be extended to 57 hours 51 mins at 15 m / 642 m and 47 mins 55 s at 2 m / 79 m if switching to just one ADD and an 11% duty cycle. Using the more conservative SEL_{sens} criteria, the previously mentioned exposure durations to achieve PTS with bottlenose dolphins would occur within impact zones of 150 m and 18 m, respectively.	Götz & Janik, 2013

Table A1-10: Summary of studies investigating and/or documenting Permanent Threshold Shift (PTS) impacts from ADDs on very high frequency cetaceans. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference(s)
Ace-Aquatec 'Silent Scrammer'	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Ace Aquatec device to estimate impact zones and corresponding durations to achieve PTS for a porpoise. Using impact criteria reported by Lucke et al. (2009), and with calculations based on a total of three ADDs and a 30% duty cycle; the PTS threshold would be reached after 3 hours 10 min at 76 m (SEL: 221.6 dB re 1 μPa^{2}s) or after 2 mins 37 s at 9 m (SEL: 203 dB re 1 μPa^{2}s). This could be extended to 9 hours 30 mins at 76 m and 3 mins at 9 m if switching to one ADD and a 10% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SELs to the test species' hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve PTS would occur within impact zones of 295 m and 35 m, respectively.	Götz & Janik, 2013
Ace-Aquatec 'Silent / Universal Scrammer'	Harbour Porpoise	Noise Modelling	Acoustic sensitivity modelling by Lepper et al. (2014) predicted injury thresholds for different marine mammal species based on the output of various models of commercially available ADD. For an Ace Aquatec ADD, the PTS SEL threshold for a porpoise would be exceeded after 8 hours at 500 m from a single device for a very conservative scenario of a stationary animal.	Lepper et al., 2014
Airmar 'dB Plus'	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Airmar device to estimate impact zones and corresponding durations to achieve PTS for a porpoise. For the nominal sound pressure level of 198 dB re 1 μPa, and using impact criteria reported by Lucke et al. (2009), and with calculations based on a total of four ADDs each with a 50% duty cycle (total duty cycle = 200%); the PTS threshold would be reached after 55 mins at 76 m (SEL: 221.6 dB re 1 μPa^{2}s) or after 45 s at 9 m (SEL: 203 dB re 1 μPa^{2}s). This could be extended to 3 hours 38 mins at 76 m and 3 mins at 9 m if using just one ADD and switching to a 50% duty cycle. However, calculations using a	Götz & Janik, 2013

			lower measured sound pressure level for the Airmar device (192 dB re 1 µPa), with 4 ADDs each with a 50% duty cycle (total duty cycle = 200%); the PTS threshold would be reached after 3 hours 37 mins at 76 m or after 3 mins at 9 m. This could be extended to 14 hours 29 mins at 76 m and 11 mins 49 s at 9 m if using just one ADD and switching to a 50% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SEL to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve PTS SEL would occur within impact zones of 295 m and 35 m, respectively.	
Airmar **'dB Plus II'**	Harbour Porpoise	Noise Modelling	Acoustic sensitivity modelling by Lepper et al. (2014) predicted injury thresholds for different marine mammal species based on the output of various models of commercially available ADD. According to calculations presented in Lepper et al. (2014) the PTS threshold would be exceeded after 5.5 hours at 500 m (single device); 2.75 hours at 500 m (two devices); 1.8 hours at 500 m (three devices). However, by reducing the duty cycle from 50% to 2% the PTS SEL injury criteria for a porpoise would not be exceeded even at distances greater than 300 m over a 24 hour period. The animal movement in these calculations is very conservative, a stationary animal remains at source over the exposure.	Lepper et al., 2014
GenusWave **'Unknown'**	Harbour Porpoise	Noise Modelling	The authors reported an extremely low risk of TTS for porpoise, whereby animals would only be affected if exposed to 50 pulses within 1 m of the loudspeaker. Given the duty cycle of 0.8%, this means that an animal would have to stay within 1 m of the loudspeaker for almost 21 min. Alternatively, an animal would receive the same noise dose if it was exposed to the equivalent of 4000 s of continuous noise within 20 m of the loudspeaker. Taking the duty cycle and pulse duration into account, such an exposure would only be reached after 5 to 6 days of continuous presence within 20 m, representing a highly unrealistic scenario and therefore suggesting a low risk of SEL TTS and therefore, and even lower risk of SEL PTS.	Götz & Janik, 2015
Lofitech **'Universal / Seal Scarer'**	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Lofitech device to estimate impact zones and corresponding durations to achieve PTS for a porpoise. Using impact criteria reported by Lucke et al. (2009), and with calculations based on a 25% duty cycle; the PTS threshold would be reached after 10 hours 8 min at 76 m (SEL: 221.6 dB re 1 $\mu Pa^2 s$) or after 8 mins 24s at 9 m (SEL: 203 dB re 1 $\mu Pa^2 s$). This could be extended to 21 hours 7 mins at 76 m and 17 mins 29 s at 9 m if switching to a 12% duty cycle. Using a more conservative approach suggested by Götz and Janik	Götz & Janik, 2013

			that references SEL to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve PTS would occur within impact zones of 295 m and 35 m, respectively.	
Terecos **'DSMS-4'**	Harbour Porpoise	Noise Modelling	Underwater noise modelling by Lepper et al. (2014) predicted injury thresholds for different marine mammal species based on the output of various models of commercially available ADD. For a porpoise, the threshold at 100 m would be exceeded after about 2.5 hours and the safe range for 24 hour exposure was beyond 500 m based on a 6.7% duty cycle (worst case scenario). Other programmes (duty cycle to 1.3% using a 200 ms pulse every 15 s) would increase time before an injury threshold was reached at a fixed distance. In the case of a harbour porpoise for a sandy seabed the injury threshold would be reached in less than 24 hours for ranges less than 200 m at the lower duty cycle compared to greater than 500 m at the higher duty cycle. The animal movement in these calculations is very conservative, a stationary animal remains at source over the exposure.	Lepper et al., 2014
	Harbour Porpoise	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Terecos device to estimate impact zones and corresponding durations to achieve PTS for a porpoise. Using impact criteria reported by Lucke et al. (2009), and with calculations based on a total of three ADDs and a 33% duty cycle; the PTS threshold would be reached after 19 hours 17 min at 76 m (SEL: 221.6 dB re 1 $\mu Pa^2 s$) or after 15 mins 58 s at 9 m (SEL: 203 dB re 1 $\mu Pa^2 s$). This could be extended to 57 hours 51 mins at 76 m and 47 mins 55 s at 9 m if switching to an 11% duty cycle. Using a more conservative approach suggested by Götz and Janik that references SELs to the test subject's hearing threshold (sound exposure sensation level, SEL_{sens}), the previously mentioned exposure durations to achieve PTS would occur within impact zones of 295 m and 35 m, respectively.	Götz & Janik, 2013

Table A1-11: Summary of studies investigating and/or documenting Permanent Threshold Shift (PTS) impacts from ADDs on pinnipeds. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Study Type	Species	Study Summary	Reference(s)
Ace-Aquatec 'Silent / Universal Scrammer'	Grey Seal & Harbour Seal	Noise Modelling	Acoustic sensitivity modelling by Lepper et al. (2014) predicted injury thresholds for different marine mammal species based on the output of various models of commercially available ADD. For an Ace Aquatec ADD, the injury threshold for a seal at 100 m would be exceeded after around 3 hours and the threshold range for 24 hour exposure is around 350 m (worst case scenario duty cycle based on manufactures information of 72, 5 s bursts per hour; 10%). The system allows programming of lower numbers of burst per hour lowering this duty cycle and therefore increasing time for reaching an injury threshold at a fixed distance. The animal movement in these calculations is very conservative, a stationary animal remains at source over the exposure.	Lepper et al., 2014
	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Ace Aquatec device to estimate impact zones and corresponding durations to achieve PTS for a harbour seal. Using impact criteria reported by Southall et al. (2007), and with calculations based on a total of three ADDs and a 33% duty cycle; the PTS threshold would be reached after 19 hours 17 min at 60 m (SEL: 221.6 dB re 1 $\mu Pa^2 s$) or after 15 mins 58 s at 7 m (SEL: 203 dB re 1 $\mu Pa^2 s$). This could be extended to 57 hours 51 mins at 60 m and 47 mins at 7 m if switching to an 11% duty cycle.	Götz & Janik, 2013
Airmar 'dB Plus'	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of an Airmar device to estimate impact zones and corresponding durations to achieve PTS for a harbour seal. For the nominal sound pressure level of 198 dB re 1 µPa, and using impact criteria reported by Southall et al. (2007), and with calculations based on a total of four ADDs each with a 50% duty cycle (total duty cycle = 200%); the PTS threshold would be reached after 55 min at 60 m (SEL: 221.6 dB re 1 $\mu Pa^2 s$) or after 45 s at 7 m (SEL: 203 dB re 1 $\mu Pa^2 s$). This could be extended to 3 hours 38 mins at 60 m	Götz & Janik, 2013

			and 3 mins at 7 m if switching to one ADD and a 50% duty cycle. However calculations using a lower measured sound pressure level for the Airmar device (192 dB re 1 µPa), with four ADDs each with a 50% duty cycle (total duty cycle = 200%); the PTS threshold would be reached after 3 hours 37 mins at 60 m or after 3 mins at 7 m. This could be extended to 14 hours 29 mins at 60 m and 11 mins 49 s at 7 m if using just one ADD and switching to a 50% duty cycle.	
Airmar **'dB Plus II'**	Grey Seal & Harbour Seal	Noise Modelling	Acoustic sensitivity modelling by Lepper et al. (2014) predicted injury thresholds for different marine mammal species based on the output of various models of commercially available ADD. For an Airmar ADD, a seal at 100 m would exceed the threshold after about 3.3 hours for a single device with time decreasing pro rata to 1.6 and 1.1 hours when two and three devices were operational at the site. With single device animals remaining at 400 m for 24 hours would reach the threshold for injury. The animal movement in these calculations is very conservative, a stationary animal remains at source over the exposure.	Lepper et al., 2014
GenusWave **'Unknown'**	Harbour Seal	Noise Modelling	No empirical measurements, but calculations based on the acoustic output of the GenusWave device demonstrate low realistic risk of hearing damage. The onset of a temporary threshold shift occurs at sound exposure levels (SEL) of ~182 dB re 1 μPa^2s. The SEL of a single 0.2 s pulse is 173 dB re 1 μPa^2s and the cumulative SEL of 5 pulses is 180 dB re 1 μPa^2s. Even if a harbour seal was exposed to five pulses at a distance of 1 m from the loudspeaker; it would not be at risk of TTS, therefore the risk of PTS from the device is even lower.	Götz & Janik, 2015
Lofitech **'Universal / Seal Scarer'**	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Lofitech device to estimate impact zones and corresponding durations to achieve PTS for a harbour seal. Using impact criteria reported by Southall et al. (2007), and with calculations based on a 25% duty cycle; the PTS threshold would be reached after 10 hours 8 min at 60 m (SEL: 221.6 dB re 1 μPa^2s) or after 8 mins 24s at 7 m (SEL: 203 dB re 1 μPa^2s). This could be extended to 21 hours 7 mins at 60 m and 17 mins and 29 s at 7 m if switching to a 12% duty cycle.	Götz & Janik, 2013
Terecos **'DSMS-4'**	Grey Seal & Harbour Seal	Noise Modelling	Acoustic sensitivity modelling by Lepper et al. (2014) predicted injury thresholds for different marine mammal species based on the output of various models of commercially available ADD. For a Terecos ADD, the seal injury threshold would be exceeded if seal remained within 100 m of device for 9 hours, or 24 hours within	Lepper et al., 2014

			200 m. The animal movement in these calculations is very conservative, a stationary animal remains at source over the exposure.	
	Harbour Seal	Noise Modelling	A review of the effectiveness and potential impacts on marine mammals of a selection of ADDs was carried out by Götz and Janik (2013). In this paper, they used auditory thresholds and the known acoustic output of a Terecos device to estimate impact zones and corresponding durations to achieve PTS for a harbour seal. Using impact criteria reported by Southall et al. (2007), and with calculations based on a total of three ADDs and a 33% duty cycle; the PTS threshold would be reached after 19 hours 17 min at 60 m (SEL: 221.6 dB re 1 $\mu Pa^2 s$) or after 15 mins 58 s at 7 m (SEL: 203 dB re 1 $\mu Pa^2 s$). This could be extended to 57 hours 51 mins at 60 m and 47 mins at 7 m if switching to an 11% duty cycle.	Götz & Janik, 2013

Table A2-2: Summary of studies investigating and/or documenting efficacy of specific ADDs on pinnipeds. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Species	Use	Study Summary	Reference(s)
Ace-Aquatec ‘Seal Scrammer’	Harbour Seal	Captive Study	Playback experiments with captive harbour seal estimated the audibility and behavioural response to signals from different types of ADD. The effect of different received broadband sound pressure levels were measured; a level which did not cause a behavioural change (109 dB re 1 µPa), a level which caused the seal to haul out very occasionally (124 dB re 1 µPa) and a level which caused the seal to haul out approximately 10% of the time (134 dB re 1 µPa). Depending on sea conditions and based on noise modelling, the Ace Aquatec ADD was expected to be audible to seals between 14-91 km and likely to deter seals at ranges between 0.2-4.1 km based on harbour seal hearing thresholds (stimulus levels resulting in a 50% detection rate).	Kastelein et al., 2010

	Harbour Seal	Captive Study	Captive harbour seals were exposed to playback signals from two models of ADD. Two captive seals responded to the playback of Ace Aquatec sounds by raising their heads (and ears) from the water to some extent, perhaps to avoid the sound. One of the seals also hauled out. Effects on the seals' behaviour were quantified at three SPLs: one which did not cause behavioural changes (109 dB re 1 µPa (RMS)), one which caused one of the seals to haul out occasionally (124 dB re 1 µPa (RMS)), and one which caused one of the seals to haul out more than 10% of the time (134 dB re 1 µPa (RMS)). The seals hauled out more and spent more time with their heads above water as SPLs increased.	Kastelein et al., 2015b
Ace-Aquatec **'Unknown'**	Grey Seal & Harbour Seal	Captive Study & Field Study	Playback experiments with both grey and harbour seals were carried out in captivity and in the wild, with different sound sources including four models of ADD (but with lower SLs). In captivity, food motivation was introduced and mean RLs for all sounds in the pool ranged from 142-147 dB re 1 µPa (RMS). Playback experiments in the wild used broadband SLs of 172 dB re 1 µPa (RMS). A single emission of sounds in the field experiment (10 s burst) would result in a SEL of 182 dB re. 1 $\mu Pa^2 s$ and a single emission (6 s) in the captive trials would amount to a SEL of 156 dB re 1 $\mu Pa^2 s$. In captivity with food motivation, seals did not respond differently to the different sound types and habituation in both grey and harbour seals occurred at RL of 146 dB re 1 µPa (RMS). In the wild, for signals resembling that of an Ace Aquatec ADD (but with a lower SL), the deterrence range was 60 m with an avoidance threshold of 138 dB re 1 µPa.	Götz & Janik, 2010
Airmar **'dB Plus'**	Grey Seal & Harbour Seal	Captive Study & Field Study	Playback experiments with both grey and harbour seals were carried out in captivity and in the wild, with different sound sources including four types of ADD. In captivity, food motivation was introduced and mean received sound levels (RMS) for all ADDs in the pool ranged from 142-147 dB re 1 µPa. Playback experiments in the wild used broadband SLs of 172 dB re 1 µPa (RMS). A single emission of sounds in the field experiment (10 s burst) would result in a SEL of 182 dB re. 1 $\mu Pa^2 s$ and a single emission (6 s) in the captive trials would amount to a SEL of 156 dB re 1 $\mu Pa^2 s$. In captivity with food motivation, seals did not respond differently to the different sound types and habituation in both grey and harbour seals occurred at RL of 146 dB re 1 µPa (RMS). In the wild, for signals resembling that of an Airmar ADD (but with a lower SL), the deterrence range was 40 m with an avoidance threshold of 144 dB re 1 µPa (RMS).	Götz & Janik, 2010
	Harbour Seal	Noise Modelling	In situ measurements of the sound fields of an Airmar ADD were made in the Bay of Fundy, Canada and were compared with hearing thresholds of harbour seals. With a	Terhune et al., 2002

			SL of 195 dB re 1 µPa @ 1 m with 10 kHz pulses, 1.8 ms duration every 40 ms for 2.5 sec, it was predicted with noise modelling that the device could be clearly audible to harbour seals up to 2.9 km depending on ambient noise. Based on the average sea states experienced in the Bay of Fundy, over half of the time conditions would result in an audible range of approximately 2.1 km, with the highest ambient noise levels reducing this further to 1.4 km (approximately 5% of the time).	
	Harbour Seal	Field Study (Aquaculture)	Behavioural response studies in the Bay of Fundy in Canada investigated the reactions of harbour seals to signals from an Airmar ADD around an aquaculture site (but with an array of four ADDs and SL of 172 dB re 1 µPa; 23 dB lower than the maximum operating SL at 195 dB re 1 µPa @ 1 m.). SPLs at 1, 5 and 10 m water depths within the aquaculture cage sites were generally <162 dB re 1 µPa. ADD sounds were predicted through modelling to be audible to harbour seals at ranges of 1.1-20.2 km, depending on the ambient noise levels. Results showed that harbour seals familiar with the Airmar dB Plus II ADD signal showed no behavioural response when switched on; one individual approached within 45 m of the device and seals passed close by to reach a haul-out site. However, the operating SL recorded during the study was lower than the SL stated by the manufacturer. The authors conclude that the ADDs used in the study area were, at the SL recorded, not loud enough to deter the harbour seals, with many seals in the area potentially becoming habituated to the signals.	Jacobs & Terhune, 2002
	South America n Sea Lions	Field Study (Aquaculture)	A controlled study of two finfish farms in southern Chile with similar depredation rates by South American sea lions (*Otaria flavescens*) implemented an ADD at one of the farms for a three month trial period. There were statistically lower levels of predation at the site with the ADD and the site with the ADD experienced significantly less predation than it had done during the same period in the previous year. However, the sample size was small and the period was not long enough to account for any possible habituation.	Vilata et al., 2010
	Harbour Seal	Field Study (Aquaculture)	CEEs to wild seals on the west coast of Scotland using telemetry methods to monitor movement in response to signals from an Airmar device (SL was measured at 195 dB re 1 µPa @ 1 m (RMS)). Typical behavioural changes during responses included restricted area movement, directed movement away from the sound source and diverting of existing movement around the sound source. Over nine CEEs, behavioural responses were observed at ranges up to 1,037 m, with the shortest range at which no response was observed at 653 m. The loudest non-response CEE was estimated at a RL of 138 dB re 1 µPa (RMS) and the quietest responsive CEE	Gordon et al., 2015

			was estimated at a RL of 134 dB re 1 µPa (RMS). Though the small sample size for the Airmar (nine CEEs) device makes it difficult to draw firm conclusions, the authors stated there is no evidence to suggest that the Airmar would be more effective for aversive sound mitigation than the Lofitech ADD (which was trialled in this study and was also shown to be an effective deterrent; see the Lofitech section of this table for further information).	
Airmar **'Seal-Scarer'**	Harbour Seal	Field Study (Salmon River)	Attempts were made in a river in British Columbia, Canada to reduce the depredation of outgoing salmon smolts by harbour seals at night using an Airmar ADD. During short-term field trials, significantly fewer harbour seals fed on outgoing salmon smolts on the seven nights the Airmar device was deployed, compared with seven control nights when no deterrent was used. A mean of 0.4 animals was present during the acoustical tests (range, 0–1) compared with a mean of 8 animals on control nights (range, 0–26). The Airmar ADD prevented seals feeding within a 50 m radius of the ADD (the approximate deterrence range for this study), and displaced seals to a poorer feeding site downstream. However, due to the short period (14 days), no conclusions on long-term efficacy can be drawn.	Yurk & Trites, 2000
FaunaGuard **'Seal Module'**	Harbour Seal	Captive Study	A captive experiment with two harbour seals in a pool investigated the behavioural responses to this device, which produces a signal consisting of 16 different sounds played in succession. The signal consisted of sounds between 200 Hz to 20 kHz with random inter-sound intervals of 3-10 s, mean interval 6.5 s, and duty cycle ~60%. The responses were measured at two ambient noise levels, approximately replicating Beaufort Sea State 0 and 4. Results showed that at a mean RL of 142 dB re 1 µPa the background noise from the higher sea state did not affect the behavioural response. Based on increases in jumping behaviour of both seals, the behavioural threshold SPL was reported to be somewhere between 136 and 148 dB re 1 µPa (mean = 142 dB re 1 µPa), with significant changes in the time the seals either held their head out of the water or hauled occurring above 160 dB re 1 µPa. The seals employed differing strategies to avoid the sound above a specific SPL; whilst the responses of both seals involved jumping, one seal held its head out of the water more frequently whereas the other hauled out more frequently. This could demonstrate the variability between individuals in how they choose to respond to averse sounds. The individual effect of each of the 16 sounds was not evaluated, so it is not known which of these induced a greater response. The mean SL of the signal was 182 dB re 1 µPa, and combining this with the behavioural thresholds and	Kastelein et al., 2017

			sound propagation modelling, the authors estimate the effective deterrent range for the device is between 500-1000 m.	
GenusWave 'Unknown'	Grey Seal	Captive Study	Captive exposure experiments with six grey seals to startling band-limited noise pulses 200 ms long with rise and fall times of 5 ms, a peak frequency of 950 Hz spanning approximately 2 octaves and a SL of 170 dB re 1 µPa (RMS) which exceeded the animal's hearing threshold by approximately 100 dB. Five of seven seals showed clear signs of a startle response (flinches) while two did not. In seals that startled, the sound pulse also prevented fish retrieval and increasingly caused an immediate rapid flight response which was followed by an erratic jump out of the pool indicating sensitisation to the ADD signal. An average startle response threshold of 159 dB re 1 µPa reflects a sensation level of approximately 93 dB above the hearing threshold. Once sensitised, seals even avoided a known food source that was close to the sound source. However when exposed to sounds of equal energy as the startle stimulus but with a longer rise time of 100 ms, the flight responses were either not initiated or waned, demonstrating habitation in contrast to the signals with shorter rise times (5 ms)	Götz & Janik, 2011
	Harbour Seal	Field Study (Aquaculture)	Field testing of an ADD at finfish farms on the west coast of Scotland. The sound exposure consisted of isolated 200 ms long, 2–3 third octave-band noise pulses with a peak frequency of 1 kHz and a SL of ~180 dB re 1 µPa (RMS). Significant reduction in the number of seal tracks recorded by land-based observers (91%) within 250 m of the device at a fish farm while the number of seal tracks at greater distances (250-1500 m and >1500 m) remained unaffected. The noise pulse is likely to elicit startle responses at RLs of approximately 145 dB re 1 µPa. Therefore startle responses would be expected to occur at distances of up to 82 m around the ADD. There was no evidence of habituation to the ADD signals over the 43 day study period and no significant effect on harbour porpoise distribution at distances within 250 m of the ADD, 250–1500 m and beyond 1500 m.	Götz & Janik, 2015
	Grey & Harbour Seal	Field Study (Aquaculture)	Long-term field trials with the GenusWave ADD (SL: 176–179 dB re 1 µPa @ 1 m) at a finfish farms in Scotland. The 1/3 octave band analysis at 20 m distance showed that the central band at 1 kHz exceeded the auditory threshold of a seal by 98 dB (sensation level). But visual monitoring showed that the number of seal surfacings within 100 m (modelled RL: 145 dB re 1 µPa) from the loudspeakers was only slightly lower during sound exposure. Modelling suggested a possible reduction in seal surfacings of ~57%, but this was not significant. Sound exposure resulted in a 91% reduction in lost fish when comparing predation levels within the test site and 97%	Götz & Janik, 2016

			when comparing the test site against both control sites. Similarly, sound exposure led to a 93% reduction in the number of fish lost due to seal damage at a short-term test site. The authors reported that predation occurred only in 2 months out of the 12.5 month study period, noting that these two months were early on in the study; concluding that this was therefore unlikely to be due to habituation.	
Lofitech **'Seal Scarer'**	Grey & Harbour Seal	Field Study (Salmon River)	Two Lofitech seal scarers (500 ms pulses at 15 kHz with a SL of ~ 189 dB re 1 µPa @ 1 m) were introduced to prevent seals swimming up a river on the northeast coast of Scotland. The use of the ADDs had no significant effect on the absolute abundance of seals in the survey area in either river tested, but it did reduce seal movement upstream significantly, by ~50% in both rivers (constant over the 4 month trial). Notably during 67% or more of surveys when seals were present and the ADD was operating, seals were observed in close proximity to the device (<200 m). Results suggest that the ADD was partially effective as a barrier to seal movements upstream. The authors note that the effective deterrent range stated by the manufacturer (~300 m) will be considerably less in the noisy environment and shallow topography found in a river.	Graham et al., 2009
	Grey & Harbour Seal	Field Study (Salmon Fishery)	Field trials of Lofitech ADD in a salmon bagnet fishery in Scotland. Grey seals were more persistent at this site than harbour seals, both when the ADD was off and on. The number of seal sightings and the time seals spent near a coastal salmon fishery were significantly reduced. Significantly fewer seals were observed when the device was active; in 2009, 19 seals were detected when the ADD was off compared to none when it was on, and in 2010 there were 19 seals detected when off and 6 detected when on. Approximately a third more fish were landed per hour (also significant) during periods where a Lofitech ADD was switched on. Results indicated that the higher fish landings when the ADD was operating were a direct result of the reduction in the number of seals in the vicinity of the net. Seal-damaged fish were only found within the bagnet during off treatments. Some potential habituation was found, with no seals sighted within 80 m of the device in the first year (2009) and 7 sightings the following year, however in both years the ADD significantly reduced the sightings of seals. Overall, the ADD was found to be an effective seal deterrent, however this study had relatively low sample sizes with very few depredating individuals. On 20 occasions when seals were seen with salmon prey, 15 of these occasions were attributed to one individual.	Harris et al., 2014
	Harbour Seal	Field Study	CEEs to wild seals on the west coast of Scotland using telemetry methods to monitor movement in response to signals from two models of ADD (the Lofitech device SL	Gordon et al., 2015

			was measured at 193 dB re 1 µPa @ 1 m (RMS). Typical behavioural changes during responses included restricted area movement, directed movement away from the sound source and diverting of existing movement around the sound source. The shortest range for a CEE that did not elicit a response was 998 m (predicted SL 132 dB re 1 µPa (RMS)). The greatest range at which a response was recorded was 3,122 m (predicted RL:120 dB re 1 µPa (RMS)). 100% of CEEs within ~1 km showed a response and the minimum approach distance was 473 m throughout the study. Tolerance ranges were between 225 m to over 2,000 m with the average tolerance range reported at 943 m. This study demonstrates that averse behavioural responses can occur at the scale of multiple kilometres for the Lofitech device.	
	Harbour Seal	Captive Study	Playback experiments with captive harbour seals estimated the audibility and behavioural response to signals from different types of ADD. The effect of different received broadband SPLs were measured; a level which just did not cause a behavioural change (128 dB re 1 µPa), a level which caused the seal to haul out very occasionally (133 dB re 1 µPa) and a level which caused the seal to haul out approximately 10% of the time (138 dB re 1 µPa). Depending on sea conditions and based on noise modelling, the Lofitech ADD was expected to be audible to seals between 19-99 km and likely to deter seals at ranges between 0.2-4.1 km based on harbour seal hearing thresholds (stimulus levels resulting in a 50% detection rate).	Kastelein et al., 2010
	Harbour Seal	Captive Study	Captive harbour seals were exposed to playback signals from two models of ADD. Effects on the seals' behaviour were quantified at three threshold SPLs: one which did not cause behavioural changes (128 dB re 1 µPa @ 1 m (RMS)), one which caused one of the seals to haul out occasionally (133 dB re 1 µPa @ 1 m (RMS)), and one which caused one of the seals to haul out more than 10% of the time (138 dB re 1 µPa @ 1 m (RMS)). The lack of response by the seals to the Lofitech AMD sound was unexpected, though the SL of the actual Lofitech is much higher than the maximum SL that was used in the present study. Small changes in behaviour were observed during the pre-tests, but these were not statistically significant in the main study. Thus at similar received levels under the conditions tested, the authors reported that the Ace Aquatec seems more effective than the Lofitech in deterring harbour seals.	Kastelein et al., 2015b

	Grey Seal	Field Study (Salmon & Whitefish Fishery)	ADDs were deployed during three consecutive fishing seasons. However, the ADDs were modified slightly; device usually operates at a duty cycle of between 9 to 10%; the authors partly used a modified version with a duty cycle of 4.5% by reducing the pulse length to 250 ms. Catches were significantly higher in traps with ADDs (25.5 kg d−1) than in controls (12.0 kg d−1), and catch damage was less (3.5 vs. 6.7 kg d−1). These results persisted over and between fishing seasons, but late in the season damage to the catches was common also in traps with ADDs.	Fjälling et al., 2006
	Grey & Harbour Seal	Captive Study & Field Study	Playback experiments with both grey and harbour seals were carried out in captivity and in the wild, with different sound sources including four types of ADD (but with lower SLs). In captivity, food motivation was introduced and mean RLs (RMS) for all sounds in the pool ranged from 142-147 dB re 1 µPa. Playback experiments in the wild used broadband SLs of 172 dB re 1 µPa (RMS). A single emission of sounds in the field experiment (10 s burst) would result in a SEL of 182 dB re. 1 $\mu Pa^2 s$ and a single emission (6 s) in the captive trials would amount to a SEL of 156 dB re 1 $\mu Pa^2 s$. In captivity with food motivation, seals did not respond differently to the different sound types and habituation in both grey and harbour seals occurred at RL of 146 dB re 1 µPa (RMS). In the wild, for signals resembling that of a Lofitech ADD (but with a lower SL), the deterrence range was 60 m with an avoidance threshold of 138 dB re 1 µPa (RMS).	Götz & Janik, 2010
Lofitech **'Simulated signals'**	Harbour Seal	Field Study	In Denmark, wild harbour seals were exposed to simulated ADD sounds that resemble a Lofitech ADD but with a reduced SL (165 dB re 1 µPa (p-p); compared with 189 dB re 1 µPa (RMS) of a real Lofitech) to allow closer exposure to visual tracking. There was an increase in seal observations within 100 m of device when active. Seals did not evade the sound source and were observed more often and closer to the ADD during sound exposures than in control periods. Some individuals approached the device within approximately 10 m at RLs exceeding 142 dB re 1 µPa. No deterrence thresholds could be generated due to the lack of an avoidance response. As significantly more seals were observed just after sound was played compared to just before, the reduced sound source appeared to attract the seals instead of deterring them.	Mikkelsen et al., 2017
Terecos **'Unknown'**	Grey Seal & Harbour Seal	Captive Study & Field Study	Playback experiments with both grey and harbour seals were carried out in captivity and in the wild, with different sound sources including four models of ADD (but with lower SLs). In captivity, food motivation was introduced and mean RLs (RMS) for all sounds in the pool ranged from 142-147 dB re 1 µPa. Playback experiments in the wild used broadband SLs of 172 dB re 1 µPa (RMS). A single emission of sounds in	Götz & Janik, 2010

			the field experiment (10 s burst) resulted in a SEL of 182 dB re. 1 μPa^{2}s and a single emission (6 s) in the captive trials corresponded to a SEL of 156 dB re 1Pa^{2}s. In captivity with food motivation, seals did not respond differently to the different sound types and habituation in both grey and harbour seals occurred at RL of 146 dB re 1 μPa (RMS). In the wild, for signals resembling that of a Terecos ADD no deterrence distance was found.	

Table A2-2: Summary of studies investigating and/or documenting efficacy of non-commercial ADDs. Studies are detailed by manufacturer and device type (based on the name provided in the study), the species assessed, and a definition of the study type (e.g. field study or noise modelling). A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Device	Species	Use	Study Summary	Reference(s)
Bespoke ADD signals (i.e. not from a specific manufacturer)	Harbour Seal	Field Study	In an experimental field study with harbour seals, high frequency test signal was designed using single frequency tonal bursts between 8 – 18 kHz, similar to signals produced by the Airmar, Lofitech and Ace Aquatec devices (the random frequency sequencing and the pulse width and duty cycle of the Ace Aquatec were also adopted). A low frequency test signal was also made up of pulsed continuous wave sinusoidal tonal bursts at one of 11 randomly switching fundamental frequencies between 1 – 2 kHz and frequency intervals at 100 Hz. This signal was designed to produce outputs comparable to those from the Ace Aquatec US3 low frequency variant ADD design. The source levels used were lower (approximately 170 dB re 1 μPa @ 1 m (RMS)) than manufactured devices. Although not the focus of the study, harbour seals were not noticeably deterred from the vicinity of the fish farm by experimental ADD signal emissions, with no obvious difference between high frequency or low frequency signals in terms of surface observations.	Benjamins et al., 2018

Table A2-3: Summary of industry responses to questionnaires on perceived efficacy of ADDs. A summary of the study is provided; these summaries are not presented as a critical review of the work, but are to provide a brief overview of the experimental design, findings and/or conclusions of the author(s) where relevant to the context of this report

Industry response	Reference(s)
A survey amongst Scottish aquaculture sites reported that out of 28 fish escape incidents that had been thought to be caused by predators, 9 occurred at sites using ADD and 12 at sites not using ADDs, while the availability of ADDs at the remaining 7 sites was unknown. However it is unknown if all the sites that had been using ADDs at the time had the devices switched on during escape incidents.	Thistle Environmental Partnership (TEP), 2010
A survey of 49 stakeholders with responsibility for over 136 different sites reported that ADDs were in use at 40 sites and not in use at 41 sites. At 16 of the 40 sites ADDs are used continuously; at 12 sites ADDs are only switched on when the fish become large enough to be considered at risk; at 4 sites ADDs are switched on when seals are seen close to the cages; while at 21 sites ADDs are only used when seal damage begins to be noted. The majority of stakeholders thought that the use of ADDs reduced seal attacks without eliminating them, and at 15/20 sites they were judged overall to have some preventative effect, and not at 5. Habituation to ADD signals was considered a problem for 41 sites, but not at a further 10.	Northridge et al., 2010
A questionnaire study of aquaculture sites in Scotland where a variety of ADDs were used reported that only 23% of fish farmers reported ADDs to be very effective, 50% reported moderate, 15% poor and 7% little efficiency.	Quick et al., 2004

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