JNCC Report 615

**Evidence base for application of Acoustic Deterrent Devices (ADDs)
as marine mammal mitigation
(Version 5)**

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Please note:
This report is a 'live' document, and the intent is for it to be updated periodically in line with additional information on the acoustic deterrents described herein, and on the basis of new technologies that become available.

Summary

Subsea noise produced by anthropogenic activities in coastal and offshore waters has the potential to cause injury or death to marine mammals. To reduce this risk, mitigation solutions have included the deployment of acoustic devices in proximity to the noise-producing activity, to deter animals from potential injury zones. There is also the potential to use acoustic devices for collision risk mitigation.

Acoustic devices have been applied as mitigation across various marine industries. The range of applications for these devices (i.e. different industries, intended purpose, or different target species), has led to a wide variety of available technologies on the market. Whilst most emit medium to high frequency sounds, the acoustic characteristics of each device differ in terms of the sound levels produced, frequency range, temporal pattern/duty cycle and harmonics. In addition, there are also differences in the method of deployment and operating functions.

Extensive reviews of devices are available; however, a single report, collating and summarising the evidence around their effectiveness was considered useful and enables the information to be processed readily by Statutory Nature Conservation Bodies (SNCBs) when advising regulators on the use of acoustic devices to deter marine mammals from areas where there is a risk of injury or death. This report reviews evidence on the effectiveness of acoustic devices at deterring a range of marine mammal species. A coarse assessment of the current understanding of potential risk of auditory injury from ADDs is included, with a general conclusion that the risk of injury is likely to be low for all devices, although this is context dependent. It is acknowledged ADDs themselves may introduce additional disturbance, and therefore deployment of devices as mitigation should be carefully considered with general principles for deployment included in this report.

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Glossary of Terms and Abbreviations

Term	Definition / Description
ADD	Acoustic Deterrent Device
AHD	Acoustic Harassment Device
Duty cycle	The cycle of operation of a device which operates intermittently rather than continuously
DAERA	Department of Agriculture, Environment and Rural Affairs
EPS	European Protected Species
EC	European Council
FCS	Favourable Conservation Status
Frequency	The number of times that a periodic function occurs or repeats itself in a specified time
Harmonics	A wave with a frequency that is a positive integer multiple of the frequency of the original wave, known as the fundamental frequency
HRA	Habitats Regulation Appraisal/Assessment
JNCC	Joint Nature Conservation Committee
MMO	Marine Management Organisation
MSFD	Marine Strategy Framework Directive
NRW	Natural Resources Wales
PTS	Permanent Threshold Shift
RMS	Root Mean Square – square root of the mean value of the square of the quantity taken over a given time interval
SAC	Special Area of Conservation
SEL	Sound Exposure Level - a measure of the total sound energy of an event normalised to one second. This allows the total acoustic energy contained in events lasting a different amount of time to be compared on a like-for-like basis
SELcum	Cumulative Sound Exposure Level – a measure of the total sound energy of a number of events (e.g. over the course of a day) normalised to one second
SNH	Formerly Scottish Natural Heritage, now NatureScot
SNCB	Statutory Nature Conservation Body
Source level	The sound pressure level (SPL) at a unitary distance assuming an infinitesimally small source dimension
SPL	Sound Pressure Level – a logarithmic measure of the pressure of a sound relative to a reference value
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance

1   Project purpose and approach

1.1   Introduction

1.1.1   Background

Subsea noise produced by anthropogenic activities in coastal and offshore waters has the potential to cause injury or death to marine mammals. In order to reduce this risk, mitigation solutions have included the deployment of acoustic devices in proximity to the noise- producing activity, in order to deter animals from potential injury zones. 'Acoustic Deterrent Device' (ADD) is a generic term applied to a variety of different devices which, although differing in their sound emitting characteristics, all have a similar purpose, which is to deter/alert marine mammals from a specific hazard/area. There is also the potential to use acoustic devices for collision risk mitigation (e.g. from underwater turbines).

Acoustic devices have been applied across various marine industries. Originally developed for the aquaculture industry to deter marine mammals, largely seals, from fish farms, the deterrents deployed were relatively low power. Problems of habituation by animals exposed to these sounds led to technological development with the production of devices (referred to as 'acoustic harassment devices (AHDs)', 'seal scrammers' or 'seal scarers') that could emit higher amplitude sounds that would be painful to seals, and potentially other species. Wider application of this technology across fisheries includes the use of devices known as 'pingers', on static fishing nets, to reduce bycatch of marine mammals. Other offshore industries have since adopted acoustic devices to be used as part of mitigation strategies. For example, ADDs have been widely applied to reduce the risk of injury to marine mammals during pile-driving at offshore wind farms, or for underwater explosive ordnance (UXO) clearance activities.

The range of applications of the devices (i.e. different industries, intended purpose, or different target species), has led to a wide variety of available devices on the market. Whilst most emit medium to high frequency sounds, the acoustic characteristic of each device differs in terms of the sound levels produced, frequency range, temporal pattern/duty cycle, and harmonics. In addition, there are differences in the method of deployment and operating functions.

Several reports have been published that provide extensive reviews of the devices available, their acoustic characteristics, and importantly their proven effectiveness on different species; however, a single report, collating and summarising that evidence was considered useful and would enable the information to be processed readily by Statutory Nature Conservation Bodies (SNCB) when advising regulators. In addition, there was no single report that provided information on all the devices available for use in fisheries and offshore industries.

Therefore an original version of this report was published in 2018 (Version 1) (which contained simple empirical modelling for available devices, see section 1.3), and has been subject to minor updates since 2018, resulting in the latest version of the report prior to this current update being published in 2022 (Version 4) (McGarry *et al.* 2022). ADD technologies are evolving and this report therefore provides an update to the original 2022 report (Version 4) (McGarry *et al.* 2022) and represents a review of the current information on available devices and the latest relevant literature. No updated empirical modelling has been undertaken for this report.

1.1.2   Purpose of report

The purpose of this report is to provide an updated reference for SNCBs in the UK when advising on mitigation requirements for marine mammals, and for industry when deciding what device to use on a particular project. The report reviews available ADDs and the evidence on the effectiveness of acoustic devices at deterring a range of marine mammal species. The report also explores the potential for ADDs to cause hearing damage to marine mammals.

Key issues considered by the SNCBs when providing advice in relation to acoustic devices include:

1. Is there a device available with a proven track record of deterring the species of concern at the distances required?
2. Can a device be feasibly employed as a mitigation measure?
3. Do devices pose a risk of injury to marine mammals?
4. What factors should be considered in establishing deployment protocols?

The report provides an easily accessible reference for the types of acoustic devices that are currently, or due to be, commercially available. For each device, the report highlights their purpose, proven effectiveness, limitations, gaps in knowledge, and where possible, any identified risk to marine mammals (i.e. potential risk of injury from deployment of the device itself). This report will help readers to assess whether proposed acoustic devices and operating methods in mitigation plans are the most appropriate for the purpose intended and may inform further discussions on the extent of disturbance likely to arise from devices. Finally, this report presents on overview of device deployment for mitigation and points of consideration for establishing deployment protocols appropriate to an activity.

It should be noted that this report represents a 'live' document which can be updated periodically if new or additional information is provided by ADD manufacturers, as new ADD technologies become commercially available or new evidence is published.

The original 2022 report (Version 4) (McGarry *et al.* 2022) provides a summary of the key legislation and regulations pertaining to the protection of marine mammals in relation to ADD deployment. Whilst this information is not included here it should be noted that an offence could be committed under UK legislation, in relation to protected species including marine mammals, basking shark *Cetorhinus maximus*, marine turtles and Atlantic sturgeon *Acipenser oxyrinchus*.

1.1.3   Structure of report

The acoustic devices reviewed for this report have been categorised in different ways to allow the reader to quickly navigate to the information of relevance. In Table 1-1 below, click on the section reference in the "Link" below, to navigate between sections of the report.

Table 1-1: Report navigation.

Section	Overview	Link
Section 1: Project purpose and approach		
1.1 Introduction	Background to the project and purpose of the report	1.1
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2.4 Acoustic device by species / species group	Categorisation of devices according to which species group they were developed for, available literature on species impacts, and their intended industry purpose	2.4
Part 3: Deployment of devices as mitigation		
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3.2 Operator requirements and Training	Training and/or experience required for the deployment of ADDs	3.2
3.3 General principles for deployment	Recommendations for deployment, testing and failsafe planning for mitigation including example ADD protocol and task plan	3.3

3.4 Considerations to minimise potential risk to marine mammals	Considerations to minimise potential risk to marine mammals when deploying ADDs, and during active ADD deployment.	3.4
4 Conclusion	Conclusions and summary of the report.	4
5 References	List of references used in the paper	5
6 Appendix A 6.1 to 6.34	Acoustic device technical information.	6

1.2   Methodology

1.2.1   Literature review

A search was undertaken to identify all the ADDs that have been used across the aquaculture, fisheries and offshore industries. A comprehensive literature review was then undertaken of all available reviews and field studies that included any of the ADDs identified on this list. The search included peer reviewed and published scientific studies, non-peer reviewed reports, and manufacturers' information. The following information was collated from each report:

- acoustic device name,

- author, year, journal/publication and title,

- receptor (species or species group studied),

- study type (e.g. field observations, field experiment, captive experiment, modelling, or review paper),

- response type (physiological, behavioural, neural, other),

- research objectives/stated hypothesis,

- noise source details (pulsed/continuous, source level, frequency, pulse length, marine mammal auditory thresholds),

- study site,

- method/approach,

- response (including type of response (avoidance or other), distance of effect, duration of response, proportion of animals responding),

- peer reviewed (Y/N); robustness and key limitations (including methods used or margins of error in data),

- additional reviewer comments, and

- hyperlink to journal/publication.

This literature review provided the evidence base with respect to the efficacy of specific devices to deter different species/species groups from a given area. Where this evidence has been presented for each of the reviewed devices, the key findings of the study have been summarised and the publication source acknowledged. An evidence score was also assigned to provide a level of confidence in the available information.

1.2.2   ADD technical specifications review

Technical specifications for each ADD were obtained through a web-based search, direct contact with manufacturers or from the literature review (section 1.2.1). In the first instance, a simple information request spreadsheet, listing the following characteristics, was sent to all of the manufacturers for their input:

- source level - typically measured as a sound pressure level (SPL) at a distance of 1 m from the device in dB re 1µPa re 1 m,

- frequency - given as range (in Hz) which, if designed with a particular species in mind, would likely overlap with the key hearing sensitivity of that species,

- continuous or intermittent - describes whether the output is delivered as a continuous sound or whether the sound is pulsed with delays between each pulse,

- duty cycle - description of the cycle of operation of a device,

- range –the range of effectiveness of a device for the intended use,

- battery – a description of the battery type / capacity / characteristics;

- training requirements – training recommend prior to use by the manufacturer,

- device testing – manufacturers suggested method of testing functionality prior to use,

- deployment – suggested method of deployment, and

- functionality – description of any additional functionality of interest.

The response rate from manufacturers was 61% with 11 respondents out of 18 manufacturers contacted. No contact details available for two further manufacturers. Therefore, the technical information gathered for this report relies on a combination of manufacturer-supplied information, information available on the internet and that in published papers that had discussed specific devices. Where no response was received from manufacturers, and no online evidence otherwise contradicted this, the authors have made the assumption that a device status has not changed since the original 2022 report (Version 4) (McGarry *et al.* 2022).

1.2.3   Categorisation of devices

Information obtained from the literature search and ADD technical specification review was used to categorise the devices into a format that was accessible by the user:

a)   Table of available devices (Table 2-1)

The devices were tabulated in alphabetical order by name and manufacturer (Table 2-1). Each device has been given a device identification number (ID) to facilitate cross referencing across the tables and within the associated database. Hyperlinks have been provided to the manufacturers' websites or to the individual device specification itself. Further information provided for each device includes their commercial availability, intended industry use and target species group/species. A cross reference has been provided to the relevant technical specification in Appendix A: Acoustic Device Technical Information.

b)   Table of devices by acoustic characteristics (Table 2-2)

The devices were tabulated, as before, in alphabetical order by name and manufacturer

(Table 2-2). Information was provided for each device relating to their key acoustic characteristics. This included their sound pressure level output, frequency range and whether the sound source was continuous or intermittent. As before, a cross reference has been provided to the relevant technical specification in Appendix A: Acoustic Device Technical Information.

    c)   Tables assigning devices to marine mammal species or species group (Table 2-3 to Table 2-6)

The devices were also grouped according to the species or species hearing group (as in Southall *et al.* 2019) for which information was available: Hearing groups are:

- very high frequency (VHF) cetaceans (e.g. harbour porpoise, *Phocoena phocoena*) (Table 2-3),

- high frequency (HF) cetaceans (e.g. bottlenose dolphin, *Tursiops truncatus*) (Table 2-4),

- low frequency (LF) cetaceans (e.g. minke whale, *Balaenoptera acutorostrata*) (Table 2-5), and

- pinnipeds (e.g. grey seal, *Halichoerus grypus*) (Table 2-6).

Where evidence relates to a particular species within the group, that species is listed. All available evidence is summarised (identification of the evidence that was available from the original 2022 report (Version 4) and evidence which is new in this report) and references are given.

1.2.3.1. Deterrence ranges

Table 2-3 to Table 2-6 provide deterrence ranges derived from the literature or manufacturer's information. Deterrence range is defined here as the distance over which an animal of a specific species/species group is observed or predicted (e.g. using noise modelling) to move away from the ADD in response to activation. This does not infer that all animals of that specific species/species group will be deterred at that distance. In addition, it is important that these deterrence ranges are interpreted with caution as for each device the literature shows a wide range of effect distances for a given species. One reason for this is that there are considerable differences in factors that influence the observed response, such as an animal's behaviour at the time of exposure, previous exposure history, sex and age of individual, background noise and the environmental conditions that affect local propagation. Another factor to account for is the differences between noise models and hearing thresholds used by the different studies to predict the deterrence ranges. Therefore, the deterrence ranges presented in the Table 2-3 to Table 2-6 below, should not be used as a definitive measure of the effectiveness of a device. Furthermore, there is no guarantee that an ADD will be 100% effective (i.e. animals may respond differently) out to the furthest deterrence range presented.

The deterrence ranges summarised in Table 2-3 to Table 2-6 were subsequently used to inform the categorisation of mitigation ranges provided in the searchable database, grouped into three bands, where deterrence occurred over ranges of: <500 m; 500 – 1,000 m; and >1,000 m.

1.2.3.2. Evidence Scoring System

For each device reviewed, an evidence score is assigned to provide a level of confidence in the information available on the effects of that ADD on a specified species or species

group.

The Evidence Scoring system was applied as follows:

1 = Low confidence (intended for use as stated by the manufacturer with limited published evidence to support conclusion)

2 = Medium confidence (backed by non-peer reviewed/grey literature)

3 = High confidence (backed by at least one peer reviewed study)

For example, for some devices peer-reviewed studies are available which provided a high level of confidence in the conclusions. The conclusions themselves might or might not support the effectiveness of the ADD but because the study has been published and peer-reviewed, the device can be assigned the highest evidence score of 3. For other devices the information available might be provided by the manufacturer but without a supporting scientific peer-reviewed study; in these instances, the evidence score is 1. This does not mean that those devices might be less effective or that the information supplied by the manufacturer is not robust but simply that the evidence is limited or not reported in more detail.

1.2.3.3. Device ID cross-references

For each device reviewed in Table 2-3 to Table 2-6, a cross-reference has been provided to the device ID so that the reader is able to locate the correct device listed in the two previous tables (Table 2-1 and Table 2-2).

1.2.4 Database development

The information gathered through the literature review and search of ADD technical specifications was used to populate a searchable database (available online at https://hub.jncc.gov.uk/assets/e2d08d7a-998b-4814-a0ae-4edf5d887a02#jncc-report-615-add-database-release-5-2025-02.xlsm). Table 1-2 below provides a summary of the information within the database.

Table 1-2: Structure of the searchable database linked to this report.

Field	Description
Device ID	Numerical identifier for each device.
Manufacturer	ADD Manufacturer.
Model	Most recent name that the device is known under.
Control	Manual or automatic.
Link to website	Hyperlink to manufacturer's website or to the specific device if available.
Current known uses	Industry application (e.g. offshore piling mitigation, aquaculture, bycatch mitigation).
Acoustic characteristics	Source level, frequency, intermittency, continuous/pulsed, pulse width.
Evidence Score	Level of confidence in the information available on the effects of the ADD on a certain species or species group. This is not a measure of effectiveness.
Mitigation range	Approximate range of effectiveness broadly grouped into three categories: <500 m; 500 – 1,000 m; and >1,000 m. Exact ranges are not given as it is important not to place too much emphasis on cited effect ranges studies due to difference in propagation between sites.

1.3   Exploring the potential for ADDs to cause hearing damage in marine mammals

1.3.1   Simple empirical model for the original 2022 report (Version 4)

There are concerns within SNCBs, academia and industry that some of the louder ADD devices may have the potential to result in hearing damage (auditory injury) in the form of onset of permanent threshold shift (PTS onset), particularly from accumulated exposure to the sound. To investigate the potential for auditory injury due to use of ADDs, a simple empirical model was developed as part of the original 2022 report (Version 4) (McGarry *et al.* 2022) to estimate the received cumulative Sound Exposure Level (SEL_{cum}) that marine mammals swimming away from a single active ADD could be exposed to.

The modelling undertaken as part of the original 2022 report (Version 4) assumed a generalised swim speed of 2.5 m s^{-1} (a single swim speed was applied to cover a range of assumptions and species) and utilised the source noise data, frequency and pulse rate specific to each ADD available at the time of modelling. The modelling assumed 30 minutes of activation and is based on a simplistic 15 log R propagation assumption.

It should be noted that the sound exposure calculations are based on a set of simplistic assumptions and that real-world sound propagation is more complex. Therefore, the modelling should be treated as an indicative, risk-based approach rather than a definitive statement or assessment as to whether there is potential for any ADD in any situation to cause injury.

The modelling found the NOAA (2018) Permanent Threshold Shift (PTS) onset threshold (i.e. hearing frequency weighted SEL_{cum}) for all mammals was not exceeded beyond a range of 100 m for any of the modelled devices except the SaveWave Orcasaver (noting OrcaSaver is no longer commercially available, with OrcaSaver 2 the latest device available) where, according to the model, it is theoretically possible that PTS could occur in VHF cetaceans (e.g. harbour porpoise) at a range of up to 130 m.

Although new devices have become commercially available since this modelling was undertaken, and specifications for some ADD devices have been updated, the operational parameters (e.g. source level, frequency and pulse rate) of all available devices is considered to be similar to those previously modelled. Further modelling was therefore not considered necessary as the risk of injury from ADDs, which are designed specifically to elicit a fleeing response only, is considered to be negligible. To support this conclusion, further evidence was collated from the literature to determine whether there were any published findings which suggested that ADDs themselves may lead to a risk of auditory injury (hearing damage) (see below).

1.3.2 Potential for ADDs to cause hearing damage in marine mammals – overview of current knowledge

To support the results of the empirical modelling undertaken for devices that were available at the time in the 2022 report (McGarry *et al.* 2022) (see section 1.3.1 above) and in light of concerns in academia and industry on the potential for ADDs to cause hearing damage in marine mammals, a comprehensive review of peer-reviewed literature was undertaken, including developer/manufacturer specifications and industry reports which investigated or discussed the potential for ADDs to cause auditory injury to marine mammals. An overview of the literature review and a selection of key sources are presented below, but to avoid repetition, where specific devices were investigated/discussed, the relevant sources of information were added to the evidence presented in full in Table 2-3 to Table 2-6.

Given the commercial and cultural value of fisheries and aquaculture and historical use of ADDs at fish farms, much of the focus within the literature and other reporting is on ADD use to reduce depredation of catch/farm stocks, either while fishing gear was deployed, or ongoing deployment at aquaculture sites (e.g. Carlén & Cosentino 2023; Ceciarini *et al.* 2023; Findlay *et al.* 2018; Omeyer *et al.* 2020). The focus species' in the context of fisheries/aquaculture depredation, are grey seal and harbour porpoise (e.g. Carlén & Cosentino 2023; Königson *et al.* 2022; Lehtonen *et al.* 2022; Veneranta *et al.* 2024), with the predominant target species being grey seal, and discussion around non-target impacts to harbour porpoise.

Lehtonen *et al.* (2022) used novel mobile ADDs in trap-net fisheries on the Finnish coast and found this reduced seal depredation, whilst Veneranta *et al.* (2024) created a sound barrier produced by a line of ADDs across a river which effectively prevented seals from passing the barrier line to the fishery. Carlén and Cosentino (2023) attached pingers to nets in the Baltic Proper (the part of the Baltic Sea between the Åland Sea and the Danish straits) and found that high-frequency pingers could be used to minimise bycatch of a Critically Endangered harbour porpoise population, without increasing seal depredation at static nets; harbour porpoise were still able to hear the sound at 50–120

kHz, whereas this is above or at the limit of seal hearing, and therefore the 'dinner bell' effect (when an underwater sound (or some other stimulant) acts like a dinner bell, alerting and attracting an animal to the presence of a food source) was avoided. Findlay *et al.* (2024), which investigated the responses of harbour porpoise to continous aquaculture ADD activation, found that high intensity ADD noise coincided with significantly fewer harbour porpoise detections, compared to areas with no active ADDs. Other species discussed less frequently in literature are harbour seal, bottlenose dolphin, minke whale and humpback whale.

Whilst the majority of the available literature focuses on disturbance effects (i.e. avoidance of habituation to ADDs and reduction of the dinner-bell effect were also key topics (e.g. see Todd *et al.* 2021; Voss *et al.* 2023)), there is less information available to date on the potential for auditory injury as a result of ADD activation. Evidence indicates that the use of some types of ADD has led to reduced detection rates of harbour porpoise at greater distances than are generally required to mitigate auditory injury (Thompson *et al.* 2020; Voss *et al.* 2023), therefore raising questions regarding whether some devices currently in use may be too powerful (i.e. operating at too high a source level) as a tool for mitigation to prevent potential hearing damage from offshore construction (Elmegaard *et al.* 2023). Furthermore, there is evidence to suggest that ADDs themselves have the capacity to directly cause hearing damage (Hiley *et al.* 2021). For instance, modelling based upon the parameters of several commercially available ADD devices at aquaculture sites indicated that, assuming continuous 24-hour operation, there is the potential for TTS, and PTS (at much smaller ranges than TTS), to be induced by ADD operation in harbour porpoise (and other cetacean and seal species) (Findlay *et al.* 2021). Findlay *et al.* (2021) showed that for a single device at each site, the predicted TTS radius ranged from 11 to 53 km (median: 28 km) whilst the predicted PTS radius ranged from 0.2 to 0.9 km (median of 0.5 km). The study showed that increasing the aggregate duty cycle (to either 75% or 100%, as a proxy for multiple overlapping devices) at sites increased median distances for both TTS and PTS, with 100% duty cycle predicting PTS distances of 0.4 to 2 km (median 1 km) (Findlay *et al.* (2021). Additionally, desk-based noise-propagation modelling of real and fictional ADDs presented in Todd *et al.* (2021) investigated the potential for auditory impacts to occur as a result of ADD systems used in aquaculture. Cumulative effects of 23 real ADDs were predicted to cause TTS to VHF cetaceans at ranges of 4 – 31 km, and a single fictional device operating at the highest outputs tested was predicted to cause TTS to VHF cetaceans at up to 32 km.

Whilst the overarching implication from peer-reviewed literature and industry reporting has been that ADDs do have the potential to induce auditory injury in marine mammals, the focus of these studies is on the continuous activation of devices (SEL$_{cum}$) over 24 hours, rather than in the context of SPLs. In view of the current information available, in the context of auditory injury as a result of continuous activation of ADDs, injury in marine mammals may be avoided by the judicious and proportionate use of ADDs (Boisseau *et al.* 2021; Schaffeld *et al.* 2019; Thompson *et al.* 2020). Whilst peak SPLs (SPL$_{pk}$) are not readily reported in the context of ADDs, given their non-impulsive nature, the need for discussion in this context may increase. Any SPL$_{pk}$ values which are currently reported in literature (noting that Todd *et al.* (2021) highlighted that reported ADD SPLs can be derived in several ways and are therefore not necessarily directly comparable) do have the potential to breach TTS and PTS thresholds (Southall *et al.* 2019) but more information is needed to understand to what extent the potential for instantaneous auditory injury will require consideration.

1.3.3   Proportionate use of ADDs

As discussed previously, ADDs themselves are likely to have disturbance effects in the far-field (Todd *et al.* 2021; Voss *et al.* 2023) but it remains unclear to what extent

observed responses to disturbance are associated with noise generated by ADDs, rather than other sources such as pile driving, construction vessels, geophysical and seismic surveys, and the cumulative effect of all sources (Graham *et al.* 2019). The source level and amount of noise introduced into the marine environment should therefore be selected to be the absolute minimum required to meet mitigation requirements in preventing hearing damage from offshore activities (e.g. construction pile driving). It is important, therefore, that the deployment of ADDs is carefully planned and the relative contribution of ADDs to the underwater sound field is given due consideration. This is especially true in regions where continuous operation of ADDs is routinely employed at aquaculture sites, where multiple sound sources may create a confusing sound field (Todd *et al.* 2019). Recommendations include a gradual increase (where possible) in the source level of ADDs to the desired deterrence efficacy (Schaffeld *et al.* 2019; Voss *et al.* 2023), optimising source signals and deployment schedules to minimise broad-scale disturbance (Thompson *et al.* 2020), and selection of ADDs that are appropriate to the target species (Voss *et al.* 2023).

1.4   Limitations of this report

The information provided in this report is subject to a number of limitations listed below:

- Only 60% of the manufacturers contacted responded and therefore the technical specifications provided in the Appendix have information gaps.

- Without contact from some manufacturers, and therefore with information based on published literature and web-based searches alone, it was occasionally difficult to determine whether a given device was still commercially available. Therefore, the literature review included all known devices, irrespective of their current commercial availability. In these cases, the report states 'unknown' for their commercial availability.

- The level of detail within each publication reviewed varied considerably. Few of the studies reviewed undertook field measurements on the devices themselves and quoted other studies or relied on the technical specifications provided by manufacturers instead. This can be problematic since often measured acoustic properties differ from those given by manufacturers. Additionally, there is known to be slight differences between different units of the same device.

- Several devices have been renamed and therefore it was often difficult to determine if a device reviewed in the literature was the same as the current device name given on a manufacturer's website. Where possible, this report identifies the most recent name given to a device and highlights where a device has been known by other names.

- Whilst some devices have been designed for a specific species or species group, studies often looked at effects on other species or species groups. The most common situation encountered was where devices had been designed for seals, but the study looked at disturbance effects on harbour porpoise.

- Many of the papers reviewed reported a change in behaviour in response to an ADD, but there was no statistical significance in the results. The summary of evidence provided refers to whether a result had been found to be statistically significant or not.

- Studies did not always provide clear information on the range over which animals were deterred.

- For some of the devices that had several associated research studies there was disparity in the reported range of effects. Therefore, Table 2-3 to Table 2-6 reports

the range across all the studies.

- For studies on pingers, the focus was more on whether device activation altered marine mammal predation on fish or whether device activation reduced marine mammal bycatch, rather than range of deterrence. These studies however often cited the closest approach distance of an animal.

2 Acoustic devices

2.1 Overview

Section 2 provides information on available devices (section 2.2, Table 2-1) and acoustic characteristics of available devices (section 2.3, Table 2-2). Devices are listed alphabetically in both tables for ease of reference. In the final section, the devices have been categorised according to the species group or species for which they are effective (section 2.4, Table 2-3).

Alphabetical listing is by the device name, but devices have also been grouped by manufacturer to facilitate searching. The report first provides information on the general use of each device (section 2.2) and then on the acoustic characteristics of the devices (section 2.3). Each device has been assigned a unique identifier (Device ID) which relates to the make and model of the device. In section 2.4 the devices are grouped according to the available evidence on their effectiveness across the different species/species group. The table in section 2.4 provides a cross reference to the Device ID to enable the user to go back to sections 2.2 and 2.3 to look up the general properties and acoustic characteristics of the device(s) of interest for a specific species/species group.

The accompanying database also provides a searchable tool that can be used to identify information on a particular device or to filter the list of devices by searching under a particular field. For example, the user can search for all devices by manufacturer name, acoustic characteristics, industry use, or species/species group. The database provides hyperlinks to evidence for each device.

2.2 Available devices

A full list of available devices is provided in Table 2-1 with details of name, manufacturer, commercial availability, and link to technical information (within the associated Appendix). The main industries the devices are designed for are provided, however there may be industries for which devices may be suitable that are not currently listed. In addition, the table lists the species or species group for which the device was designed, according to information from the manufacturer.

Table 2-1: List of acoustic deterrent devices.

* Not publicly available - can be made available upon request.

ǂ No longer publicly available but may still be in use.

1 It is understood that the Ace Aquatec US2 and US3 Universal Scrammers were formally Ferranti Thomson Mk2 and Mk3 Seal Scarers. The name of these ADDs changed following the acquisition of Ferranti Thomson by Ace Aquatec. Ferranti Thomson was also part of a series of mergers between various companies that became Thale Underwater Systems Limited (TUS). However, it is understood that the ADD element of the business was sold on, and as such the devices have been rebranded as above.

2 See Table Note 1. Previously Silent Scrammer.

3 Aquatec Group has informed the authors that the Aquamark 100, 200, 210 and 300 are not in production. However, it is highly likely that a large number of these units will still be in market circulation.

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
1	Ace Aquatec Marine Mammal Mitigation Device (A-MMD) Low - Pinnipeds	Ace Aquatec	https://www.aceaquatec.com/	Y	Pile-driving, oil spills, underwater explosives, protection of wild fish stocks in rivers, underwater turbines	Pinnipeds	**Appendix 6.1**
2	Ace Aquatec Marine Mammal Mitigation Device (A-MMD) (Ultra Low frequency) - Fish	Ace Aquatec	https://www.aceaquatec.com/	Y*	Pile-driving, oil spills, underwater explosives, protection of wild fish stocks in rivers, underwater turbines	Fish	**Appendix 6.2**
3	Ace Aquatec Marine Mammal Mitigation Device (A-MMD) Mid-frequency - Pinnipeds and Cetaceans	Ace Aquatec	https://www.aceaquatec.com/	Y	Pile-driving, oil spills, underwater explosives, protection of wild fish stocks in rivers, underwater turbines	Pinnipeds and high-frequency cetaceans	**Appendix 6.3**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
4	Ace Aquatec Marine Mammal Mitigation Device (MMD) High frequency - Pinnipeds and Odontocetes	Ace Aquatec	https://www.aceaquatec.com/	Y*	Pile-driving, oil spills, underwater explosives, protection of wild fish stocks in rivers, underwater turbines	Pinnipeds and VHF cetaceans	**Appendix 6.4**
5	Universal Scrammer US2[1]	Ace Aquatec[2]	https://www.aceaquatec.com	N[†]	Aquaculture	Seals	**Appendix 6.5**
6	Mid-frequency Acoustic Startle Response Device (US3)	Ace Aquatec	https://aceaquatec.com/products/predator-control/	Y	Aquaculture	Seals and sealions	**Appendix 6.6**
7	Ace Aquatec: Low-Frequency Acoustic Startle Response Device (RT1/FS1)	Ace Aquatec	https://aceaquatec.com/products/predator-control/	Y	Aquaculture	Seals	**Appendix 6.7**
8	Airmar dB plus II (now Mohn Aqua MAG seal deterrent)	Airmar	https://www.airmar.com	N[†]	Aquaculture	Seals	**Appendix 6.8**
9	Airmar: Gillnet Pinger	Airmar	https://www.airmar.com	Y	Gill net entanglement	Harbour porpoise	**Appendix 6.9**
10	Aquamark 848	Aquatec	http://www.aquatecgroup.com/11-products/25-aquamark-848	Y	Offshore construction, sea fishing	Marine mammals	**Appendix 6.10**
11a	Aquamark 100[3]	Aquatec	http://www.aquatecgroup.com	N[†]	Oil and gas industry and traditional trammel nets	Harbour porpoise	**Appendix 6.11**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
11b	Aquamark 200[3]	Aquatec	http://www.aquatecgroup.com	N[†]	Oil and gas industry but also offshore fisheries	Dolphins	**Appendix 6.11**
11c	Aquamark 210[3]	Aquatec	http://www.aquatecgroup.com	N[†]	Where predation is severe, 210 is recommended for nets	Dolphins	**Appendix 6.11**
11d	Aquamark 300[3]	Aquatec	http://www.aquatecgroup.com	N[†]	Oil and gas industry and commercial gill net fisheries	Harbour porpoise	**Appendix 6.11**
12	Cetasaver V.03	IFREMER/ IXTrawl	http://wwz.ifremer.fr/	Y	Gillnet fisheries	Harbour porpoise and dolphins	**Appendix 6.12**
13 (a, b, c, d, e)	Dolphin Deterrent Devices (DDD) and Dolphin Interactive Deterrent (DID)	STM Products	http://www.stm-products.com/en/products/fishing-technology/	Y	Fishing	Dolphins	**Appendix 6.13**
14	Dukane NetMark 1000	Dukane Corporation	http://www.dukane.com/	Y	Set net bycatch	Harbour porpoise	**Appendix 6.14**
15a	Future Oceans 10 kHz Porpoise and Dolphin Pinger	Future Oceans	https://www.futureoceans.com/our-pingers/	Y	Gill net fisheries	Harbour porpoise and dolphins	**Appendix 6.15**
15b	Future Oceans 60kHz - 120kHz Netguard Dolphin Pinger	Future Oceans	https://www.futureoceans.com/our-pingers/	Y	Gill net fisheries	Dolphins	**Appendix 6.15**
15c	Future Oceans 3kHz Netguard Whale Pinger	Future Oceans	https://www.futureoceans.com/our-pingers/	Y	Gill net fisheries	Whales	**Appendix 6.15**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
16a	Banana Pinger (50-120)	Fishtek Marine	www.fishtekmarine.com	Y	Fisheries, reduction of bycatch	Porpoise and dolphin species	**Appendix 6.16**
16b	Banana Pinger whale (3-20)	Fishtek Marine	www.fishtekmarine.com	Y	Fisheries, reduction of bycatch	Baleen and beaked whales	**Appendix 6.16**
16c	Banana Pinger US (10)	Fishtek Marine	www.fishtekmarine.com	Y	Fisheries, reduction of bycatch	Porpoise	**Appendix 6.16**
16d	Dolphin Anti-depredation Pinger	Fishtek Marine	www.fishtekmarine.com	Y	Mitigating fisheries depredation and bycatch, mitigation of marine mammal interactions with construction operations	Dolphin species and porpoise	**Appendix 6.16**
17a	F3: Porpoise – PAL (Programmable Alert System)	F3: Maritime Technology UG Ltd	https://www.f3mt.net/home.html	Y	Fisheries, reduction of bycatch	Porpoise species	**Appendix 6.18**
17b	F3: 10 kHz – PAL	F3: Maritime Technology UG Ltd	https://www.f3mt.net/home.html	Y	Fisheries, reduction of bycatch, Marine construction	Marine mammals	**Appendix 6.18**
17c	F3: Wideband PAL	F3: Maritime Technology UG Ltd	https://www.f3mt.net/home.html	Y	Fisheries, reduction of bycatch, Marine construction	Marine mammals	**Appendix 6.18**
17d	F3: Whale PAL (v3)	F3: Maritime Technology UG Ltd	https://www.f3mt.net/home.html	Y	Fisheries, reduction of bycatch, Marine construction	Whales	**Appendix 6.18**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
18	LU-1 prototype	Loughborough University	None listed	Unknown	Unknown	Unknown	**Appendix 6.19**
19	Lofitech Seal Scarer/FishGuard	Lofitech	http://www.lofitech.no/en/seal-scarer.html	Y	Fisheries, aquaculture, offshore piling mitigation, UXO removal	Seals and odontocetes	**Appendix 6.20**
20a	Acoustic Pinger V2.3	Marexi Marine Technology	https://marexi.com/en/pinger/	Y	Fisheries	Not given	**Appendix 6.21**
20b	Acoustic Pinger M2.1	Marexi Marine Technology	https://marexi.com/en/pinger/	Y	Fisheries	Not given	**Appendix 6.22**
20c	Acoustic Pinger H1.0	Marexi Marine Technology	https://marexi.com/en/pinger/	Y	Fisheries	Not given	**Appendix 6.23**
21a	GenusWave Ltd : Targeted acoustic startle technology (TAST) Acoustic Startle Device (ASD) 'SalmonSafe'	GenusWave Ltd	http://www.genuswave.com/	Y	Aquaculture	Pinnipeds	**Appendix 6.24**
21b	GenusWave Ltd: TAST ASD 'FisheriesSafe'	GenusWave Ltd	http://www.genuswave.com	Y	Fisheries	Pinnipeds bycatch reduction signal (porpoise and delphinids) can be included for fisheries application'	**Appendix 6.24**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
21c	GenusWave Ltd: TAST ASD 'Mitigation Device' 'TurbineSafe' 'ConstructionSafe'	GenusWave Ltd	http://www.genuswave.com	Y	Renewables (e.g. collision risk mitigation around tidal turbines), marine construction, pilling, drilling, blasting, dredging, offshore wind	Pinnipeds/ Odontocetes (porpoise, *delphinids* etc)	**Appendix 6.24**
21d	GenusWave Ltd: TAST ASD 'OdontoceteSafe', 'FisherySafe' 'OrcaSafe'	GenusWave Ltd	http://www.genuswave.com	Y	Aquaculture, fisheries, offshore wind mitigation	Odontocetes, (Killer whale)	**Appendix 6.24**
21e	GenusWave Ltd: TAST ASD 'Whale Safe'	GenusWave Ltd	http://www.genuswave.com	Y	Aquaculture, fisheries, offshore wind mitigation	Whales (humpback)	**Appendix 6.24**
22a	Seal Salmon Saver (High-impact)	SaveWave	https://www.savewave.net/	Y	Aquaculture, offshore wind mitigation	Dolphins, seals	**Appendix 6.25**
22b	Long Line Saver	SaveWave	https://www.savewave.net/	N	Unknown, but probably fisheries	Not given	**Appendix 6.25**
22c	Endurance Saver	SaveWave	https://www.savewave.net/	N	Unknown, but probably fisheries	Not given	**Appendix 6.25**
22d	OrcaSaver	SaveWave	https://www.savewave.net/	N	Long line fisheries	Killer whale *Orcinus orca*	**Appendix 6.25**
22e	OrcaSaver 2	SaveWave	https://www.savewave.net/	Y	Long line fisheries	Killer whale	**Appendix 6.25**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
23	SeaGuard Seal Deterrent	Gael Force	https://www.gaelforcegroup.com/	Y	Aquaculture	Seals	**Appendix 6.26**
24	FaunaGuard – Porpoise Module	Van Oord and Seamarco and Ace Aquatec	https://www.vanoord.com/	Y	Dredging and marine construction, including piling and drilling and blasting	Porpoise species	**Appendix 6.27**
25	Fauna Guard – Seal Module	Van Oord and Seamarco and Ace Aquatec	https://www.vanoord.com/	Y	Dredging and marine construction, including piling and drilling and blasting	Seals	**Appendix 6.28**
26	Fauna Guard – Turtle Module	Van Oord/ SEAMARCO and Ace Aquatec	https://www.vanoord.com/	Y	Dredging and marine construction, including piling and drilling and blasting	Turtles	**Appendix 6.29**
27	Fauna Guard – Fish Module	Van Oord/ SEAMARCO and Ace Aquatec	https://www.vanoord.com/	Y	Dredging and marine construction, including piling and drilling and blasting	Fish	**Appendix 6.30**
28	Fish Protector	Sea Master Enterprise Co. Ltd	http://www.seamaster.com.tw/sea-master-protector.htm	Y	Fisheries such as gill net and trawling	Dolphins, particularly bottlenose dolphin	**Appendix 6.32**
29	SealFence 3/SealFence 4	OTAQ	https://offshore.otaq.com/	Y	Aquaculture	Seals and sea lions	**Appendix 6.33**

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species/group	Technical specification in this Report
30 (a, b, c, d)	Terecos DSMS-4	Terecos Ltd	No website available	Y	Unknown	All species	**Appendix 6.34**
31	L2/L3	Lien	None listed	Unknown	Unknown	Unknown	**No details available**
32a	3 kHz -12 kHz Netshield Whale, Seal and Dolphin Anti-predation Pinger	Future Oceans	https://www.futureoceans.com/our-pingers/	Y	Fisheries depredation	Whale, seals, dolphins	**Appendix 6.16**
32b	60 kHz -120 kHz Netshield Dolphin Anti Depredation Pinger	Future Oceans	https://www.futureoceans.com/our-pingers/	Y	Fisheries depredation	Dolphins	**Appendix 6.16**
33	FaunaGuard Minke Whale Module	Van Oord/ SEAMARCO and Ace Aquatec	https://aceaquatec.com/marine-protection-solutions/faunaguard	Y	Fisheries depredation	Minke whale	**Appendix 6.31**

2.3   Acoustic characteristics of devices

Table 2-2 provides a summary of the key acoustic characteristics of the devices available and listed in Table 2-1. Devices are presented in alphabetical order. Please refer to Table 2-1 for manufacturer details and weblinks.

Note that a number of available devices used by UK fishing vessels have been authorised by the Department of Environment, Food and Rural Affairs (Defra) as meeting specific signal and implementation characteristics. There are many compliant devices and some of these are listed on the UK government webpage (https://www.gov.uk/guidance/reduce-dolphin-and-porpoise-by-catch-comply-with- regulations).

Table 2-2: Acoustic characterisation of devices.

[1] Where multiple devices are deployed the duration between pulses may appear to be reduced due to non-synchronicity between devices thereby effectively producing a more 'continuous' sound than if a single device was deployed. Some models may have settings to allow the duration of non-pulses to be increased.

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
1	Ace Aquatec: Marine Mammal Mitigation Device (A-MMD) Low (Pinnipeds)	Average within a transmission: 182 dB re 1 µPa at 1 m (RMS)	Flex (Setting 1): 0.9 kHz – 1.4 kHz Ring (Setting 2): 1.0 kHz – 2.0 kHz	Intermittent sound source	**Appendix 6.1**
2	Ace Aquatec: Marine Mammal Mitigation Device (MMD) (Ultra Low frequency) Fish	Average within transmission: 182 dB re 1 µPa at 1 m (RMS)	200 – 900 Hz	Intermittent sound source	**Appendix 6.2**
3	Ace Aquatec: Marine Mammal Mitigation Device (A-MMD) Mid-frequency - Pinnipeds and Cetaceans	Average within a transmission: 188 dB re 1 µPa at 1 m (RMS)	8 – 20 kHz	Intermittent sound source	**Appendix 6.3**
4	Ace Aquatec: Marine Mammal Mitigation Device (MMD) High Frequency - Pinnipeds and Odontocetes	Average within a transmission: 180 dB re 1 µPa at 1 m (RMS)	20 – 70 kHz	Intermittent sound source	**Appendix 6.4**
5	Ace Aquatec: Universal Scrammer US2[1] (obsolete)	Average within a transmission: 181 dB re 1 µPa at 1 m	8 – 30 kHz	Intermittent sound source	**Appendix 6.5**
6	Ace Aquatec: Mid-frequency Acoustic Startle Response Device (US3)	Average within a transmission: 181 dB re 1 µPa at 1 m	8 – 11 kHz with 8 – 20 kHz ability if required)	Intermittent sound source	**Appendix 6.6**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
7	Ace Aquatec: Low-Frequency Acoustic Startle Response Device (RT1/FS1)	Average within a transmission: 180 dB re 1 µPa at 1 m (Ring transducer) 182 dB re 1 µPa at 1 m (Flex transducer)	Flex (Setting 1): 0.8 kHz – 1.2 kHz Ring (Setting 2): 1.0 kHz – 2.0 kHz	Intermittent sound source	**Appendix 6.7**
8	Airmar: dB plus II (now Mohn Aqua MAG seal deterrent)	Nominal SPL output = 198 dB re 1 µPa at 1 m (RMS) Measured sound level = 192 dB re 1 µPa (RMS) at the fundamental frequency of 10.3 kHz (Lepper *et al.* 2014)	A broadband spectral response at the beginning of each pulse, with detectable energy levels between 1.5 kHz to 50 kHz (Lepper *et al.* 2014)	Continuous sound source	**Appendix 6.8**
9	Airmar: Gillnet Pinger	Nominal SPL output = 132 dB re 1 µPa at 1 m (RMS)	10 kHz	Continuous sound source	**Appendix 6.9**
10	Aquamark 848	Nominal SPL output = 165 dB re 1 µPa at 1 m	Primary bandwidth 5 kHz to 30 kHz	AQUAmark chirp repertoire for general deterrence	**Appendix 6.10**
11a	Aquatec Group: Aquamark 100	Nominal SPL output = 145 dB re 1 µPa at 1 m	20 – 160 kHz	Continuous sound source	**Appendix 6.11**
11b	Aquatec Group: Aquamark 200	Nominal SPL output = 145 dB re 1 µPa at 1 m	5 – 160 kHz	Continuous sound source	**Appendix 6.11**
11c	Aquatec Group: Aquamark 210	Nominal SPL output = 150 dB re 1 µPa at 1 m	5 – 160 kHz	Continuous sound source	**Appendix 6.11**
11d	Aquatec Group: Aquamark 300	Nominal SPL output = 132 dB re 1 µPa at 1 m	10 kHz	Continuous sound source	**Appendix 6.11**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
12	IFREMER/IX Trawl: Cetasaver V.03	Nominal SPL output = 165 dB re 1 µPa at 1 m	30 – 150 kHz	Continuous sound source	**Appendix 6.12**
13a, b, c, d, e	STM Products: Dolphin Deterrent Devices (03L, 03N, 03H, 03U) and Dolphin Interactive Deterrent (DiD01)	Nominal SPL output = 165 dB re 1 µPa at 1 m	5 – 500 kHz (Random)	Intermittent sound source	**Appendix 6.13**
14	Dukane: NetMark 1000	Nominal SPL output = 132 dB re 1 µPa at 1 m	10 kHz	Continuous sound source	**Appendix 6.14**
15a	Future Oceans: 10 kHz Porpoise and Dolphin Pinger	Nominal SPL output = 132 dB re 1 µPa at 1 m	10 kHz (includes multiple ultrasonic harmonics).	Intermittent sound source	**Appendix 6.15**
15b	Future Oceans: 60 kHz -120 kHz Netguard Dolphin Pinger	Nominal SPL output = 145 dB re 1 µPa at 1 m	60 kHz-120 kHz	Intermittent sound source	**Appendix 6.15**
15c	Future Oceans 3 kHz Netguard Whale Pinger	Nominal SPL output = 145 dB re 1 µPa at 1 m (±4 dB)	3 kHz (±5 kHz) (includes multiple ultrasonic harmonics)	Intermittent sound source	**Appendix 6.15**
16a	Fishtek Marine: Banana Pinger (50-120)	Nominal SPL output = 145 dB re 1 µPa at 1 m	50 kHz – 120 kHz. Intermittent sound source Ping duration of 300 ms, and ping interval 4 – 12 sec	Intermittent sound source	**Appendix 6.16**
16b	Fishtek Marine: Banana Pinger whale (3-20)	Nominal SPL output = 135 dB re 1 µPa at 1 m	3 kHz – 20 kHz	Intermittent sound source	**Appendix 6.16**
16c	Fishtek Marine: Banana Pinger porpoise (10)	Nominal SPL output = 132 dB re 1 µPa at 1 m	10 kHz	Intermittent sound source	**Appendix 6.16**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
16d	Fishtek Marine: Dolphin Anti-depredation pinger	Nominal SPL output = 175 dB re 1 µPa at 1 m	40 kHz	Intermittent sound source	**Appendix 6.16**
17a	F3: Maritime Technology UG Ltd: Porpoise PAL (Programmable Alert System)	Nominal SPL output = 145 dB re 1 µPa at 1 m	133 kHz	Intermittent	**Appendix 6.18**
17b	F3: Maritime Technology UG Ltd: 10 kHz – PAL	Nominal SPL output = 132 dB re 1 µPa at 1 m	10 kHz narrow band	Intermittent sound source	**Appendix 6.18**
17c	F3: Maritime Technology UG Ltd: Wideband PAL	Nominal SPL output = 145 dB re 1 µPa at 1 m	20 – 160 kHz wideband	Intermittent sound source	**Appendix 6.18**
17d	F3: Maritime Technology UG Ltd: Whale PAL (v3)	Nominal SPL output = 145 dB re 1 µPa at 1 m	10 kHz – 160 kHz	Intermittent sound source	**Appendix 6.18**
18	Loughborough University: LU-1 prototype	Nominal SPL output = 145 dB re 1 µPa at 1 m (Larsen & Eigaard 2014)	40 – 120 kHz	Intermittent sound source	**Appendix 6.19**
19	Lofitech: Seal Scarer/FishGuard	Nominal SPL output = 189 dB re 1 µPa at 1 m. Measured sound level = 204 dB re 1 µPa at 1 m (McGarry *et al.* *2017*)	13 – 15 kHz	Intermittent sound source	**Appendix 6.20**
20a	Marexi Marine Technology: Acoustic Pinger V2.3	Nominal SPL output = 145 dB re 1 µPa at 1 m (± 4 dB)	10 kHz (±2 kHz) tonal	Intermittent sound source	**Appendix 6.21**
20b	Marexi Marine Technology: Acoustic Pinger M2.1	Nominal SPL output = 165 dB re 1 µPa at 1 m (± 4 dB)	70 kHz (±2 kHz) tonal	Intermittent sound source	**Appendix 6.22**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
20c	Marexi Marine Technology: Acoustic Pinger H1.0	Nominal SPL output = 140 dB - 165 dB re 1 µPa at 1 m (± 4 dB)	3 – 600 kHz (sequence controlled by algorithms) (±5 kHz)	Intermittent sound source	**Appendix 6.22**
21a	GenusWave Ltd: TAST ASD 'SalmonSafe'	Measured SPL output = ~180 - re 1 µPa at 1 m (RMS) for signals centred at 1 kHz (Götz & Janik 2015, 2016) SPL can be set flexibly to any value at or below 182 dB re 1 µPa	Centroid frequency: ~1 kHz, bandwidth (- 10 dB): 700 Hz to 1.5 kHz (Götz & Janik 2015). Commercial version has almost no energy above 2 kHz Signal for deterring seals while not affecting odontocetes (Götz & Janik, 2015, 2016a, b). Signal is adjustable	Intermittent sound source	**Appendix 6.24**
21b	GenusWave Ltd: TAST ASD 'Fisheries Safe'	Pinniped signal = 180-182 dB re 1 µPa at 1 m (RMS) (Götz Janik 2015; MMO 2020) Odontocete bycatch reduction signal: 140- 175 dB re 1 µPa at 1 m (RMS)	Pinniped/Seal signal: see 'SalmonSafe' (Götz & Janik 2015, 2016a) Bycatch reduction signal for odontocetes: 5 – 20 kHz for low source level (concept described in Götz & Janik 2015) Signals are adjustable	Intermittent sound source	**Appendix 6.24**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
21c	GenusWave Ltd: TAST ASD 'Mitigation ASD' 'TurbineSafe' 'ConstructionSafe'	Measured SPL output = 180 – 182 dB re 1 µPa at 1 m (RMS) for signals centred at 1 kHz (Götz & Janik 2015, 2016a) Up to 185 dB for high-frequency signal SPL is fully adjustable	Pinniped signal: see 'SalmonSafe' (Götz & Janik 2015, 2016a) Odontocete signal: 50-20 kHz (general concept described in Götz & Janik 2015, 2016) Marine mammals signal: 700 Hz to 20 kHz (concept described in Götz & Janik 2015; Janik & Götz 2013) Signals are adjustable	Intermittent sound source	**Appendix 6.24**
21d	GenusWave Ltd: TAST ASD 'OdontoceteSafe', 'FisherySafe' 'OrcaSafe'	Typical broadband SPL: 180 dB re 1 µPa at 1 m (RMS) Broadband SEL: 173 dB re Pa²s Values are typical examples Source levels are fully adjustable to comply with any regulatory requirements	5 to 20 kHz band-limited signals	Intermittent sound source	**Appendix 6.24**
21e	GenusWave Ltd: TAST ASD 'Whale Safe'	Typical SPL: 180 dB re 1 µPa at 1 m (RMS) SEL: 173 dB re Pa²s Values are typical examples Source level is fully adjustable to comply with any regulatory requirements	0.4 kHz to 1.8 kHz (centred at 0.7 kHz) Band-limited signals	Intermittent. sound source	**Appendix 6.24**
22a	SaveWave: SealSalmon Saver (High-impact)	Nominal SPL output = 155 dB re 1 µPa at 1 m (Franse *et al.* 2005)	Double signal 5 – 3 0 kHz and 30 – 160 kHz wide band sweeps, harmonics up to 180 kHz (Franse *et al.* 2005)	Intermittent sound source	**Appendix 6.25**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
22b	SaveWave: Long Line Saver	Nominal SPL output = 155 dB re 1 μPa at 1 m (Franse *et al.* 2005)	Single signal 5 – 60 kHz wide band sweeps, harmonics up to 180 kHz (Franse *et al.* 2005)	Intermittent sound source	**Appendix 6.25**
22c	SaveWave: Endurance Saver	Nominal SPL output = 140 dB re 1 μPa at 1 m (Franse *et al.* 2005)	Single signal 5 – 90 kHz wide band sweeps, harmonics up to 180 kHz (Franse *et al.* 2005)	Intermittent sound source	**Appendix 6.25**
22d	SaveWave: OrcaSaver	Nominal SPL output = 196 (± 2) dB re 1 μPa at 1 m (SeaWave 2013)	6.5 kHz (SeaWave 2013)	Intermittent sound source	**Appendix 6.25**
22e	SaveWave: OrcaSaver 2	Nominal SPL output = 200 dB re 1 μPa at 1 m	10 kHz to 100 kHz	Continuous sound source	**Appendix 6.25**
23	Gael Force: SeaGuard Seal Deterrent	Nominal SPL output = 198 dB re 1 μPa at 1 m (RMS). Measured sound level = 192 dB re 1 μPa (RMS) at the fundamental frequency of 10.3 kHz (Lepper *et al.* 2014)	A broadband spectral response at the beginning of each pulse, with detectable energy levels between 1.5 kHz to 50 kHz (Lepper *et al.* 2014)	Continuous and intermittent sound source options	**Appendix 6.26**
24	Van Oord/SEAMARCO and Ace Aquatec: FaunaGuard – Porpoise Module	Nominal SPL output = 159.7 dB re 1 μPa at 1 m Average output 165.0 dB re 1 μPa at 1 m	60 – 150 kHz	Intermittent sound source	**Appendix 6.27**
25	Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard – Seal Module	Nominal SPL output = 174.1 dB re 1 μPa at 1 m	1 – 20 kHz	Intermittent sound source	**Appendix 6.28**
26	Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard – Turtle Module	Nominal SPL output = 172.2 dB re 1 μPa at 1 m Average output 177.7 dB re 1 μPa at 1 m	200 Hz – 1 kHz	Intermittent sound source	**Appendix 6.29**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
27	Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard – Fish Module	Nominal SPL output = 186.5 dB re 1 µPa at 1 m	200 Hz – 1.5 kHz	Intermittent sound source	**Appendix 6.30**
28	Seamaster: Fish Protector	Nominal SPL output = up to 165 dB re 1 µPa at 1 m	Frequency sweep tones and harmonics 10 – 90 kHz	Continuous sound source	**Appendix 6.32**
29	OTAQ: SealFence 3/SealFence 4	Source level = 165 dB re 1 µPa at 1 m (RMS) (patrol mode) or 189 dB re 1 µPa at 1 m (RMS) (protect mode)	10 kHz	Intermittent sound source	**Appendix 6.33**
30 (a,b,c,d)	Terecos Ltd: DSMS-4	Programme 1: Measured SPL output = 177 dB re 1 µPa at 1 m (RMS) (± 1 dB) at 6.6 kHz (Lepper *et al.* 2004) Programme 2: Measured SPL output = 179 dB re 1 µPa at 1 m (RMS) (±1 dB) and 178 dB re 1 µPa at 1 m (RMS) (±1 dB) at 4.7 kHz and 6.8 kHz respectively (Lepper *et al.* 2014)	Fundamental frequencies ranging from 1.8 kHz – 3.8 kHz. Multi-component continuous tones with observed peak level frequencies of 4.7 kHz and 6.8 kHz	Continuous sound source	**Appendix 6.34**
31	L2/L3	No details available			
32a	Future Oceans: 3 kHz –12 kHz Netshield Whale, Seal and Dolphin Anti-predation Pinger	Nominal SPL output = 150 dB re 1 µPa at 1 m	3 kHz – 12 kHz	Intermittent sound source	**Appendix 6.16**
32b	Future Oceans: 60 kHz – 120 kHz Netshield Dolphin Anti Depredation Pinger	Nominal SPL output = 175 dB re 1 µPa at 1 m	60 kHz – 120 kHz	Intermittent sound source	**Appendix 6.16**

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent[1]	Technical specification in this Report
33	Van Oord/SEAMARCO and Ace Aquatec: FaunaGuard Minke Whale Module	Peak SPL output = 186.5 dB re 1 µPa at 1 m	200 Hz – 1,500 Hz	Intermittent sound source	**Appendix 6.31**

2.4   Acoustic devices by species or species group

Table 2-3 to Table 2-6 organise devices by species/species group for which the device has been designed (as per the manufacturers specifications), and/or species/species group assessed in the literature. Devices for which no evidence is available for a particular species/species group have been omitted from the respective table/s.

Table 2-3 summarises those devices for VHF cetaceans such as harbour porpoise, Table 2-4 for HF cetaceans such as bottlenose dolphin and short-beaked common dolphin *Delphinus delphis*, Table 2-5 for LF cetaceans such as minke whale and humpback whale, and Table 2-6 for pinnipeds such as harbour seal.

Details of species impacts/range are provided in Table 2-3 to Table 2-6 based on the literature review and/or from technical details provided in Appendix A (Acoustic Device Technical Information). As described in section 1.2.3 each device has been rated according to the level of evidence available in the literature (Evidence Score: 1, 2 or 3). For each device described, the Device ID is given, which can be used to look up the general description of the device (Table 2-1) or the acoustic characteristics (Table 2-2).

Table 2-3: Categorisation of devices suited for deterrence of Very High Frequency (VHF) cetaceans based on published evidence[1].

[1] NB: Refer to Table 2-1 and Table 2-2 for more information on devices, using the Device ID given in column 2 of Table 2-3 below for the relevant device.

[2] Deterrence ranges reported in the literature and/or manufacturer's information are likely to be influenced by factors such as local propagation characteristics, as well as animal's motivation, previous exposures to device and background noise levels.

[3] Evidence Score is not a measure of the effectiveness of an ADD but is an assessment of confidence in the evidence for an ADD's effectiveness. 1 = Low confidence (intended for use as stated by the manufacturer with limited published evidence to support conclusion), 2 = Medium confidence (backed by non-peer reviewed/grey literature), 3 = High confidence (backed by at least one peer reviewed study).

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
Harbour porpoise	Lofitech: Seal Scarer [19]	300 – 1,200 m (potential for disturbance at 7 km (Elmegaard *et al.* 2023; Rosemeyer *et al.* 2021) out to >21 km. (Thompson *et al.* 2020).	Animals experimentally exposed to ADD use following incidental bycatch in pound nets reacted at 0.9 to 7 km by displaying a mixture of acoustic startle responses, fleeing, altered echolocation behaviour, and by demonstrating unusual tachycardia while diving. Source level may be too powerful for mitigation use to prevent hearing damage of porpoises from offshore construction (Elmegaard *et al.* 2023). Strong responses of porpoises to ADDs resulted in far-field disturbance beyond that required to mitigate injury (Thompson *et al.* 2020). Authors recommend that risks to marine mammals can be further minimized by: • optimizing ADD source signals and/or deployment schedules to minimize broad scale disturbance;	Harbour porpoises were deterred out to at least 12 km and possibly out to 18 km from pile driving (not statistically significant for the latter). Reaction to the ADD was equal to or greater than that predicted from pile driving (with a bubble curtain) (Dahne *et al.* 2017). Device found to provide consistent and effective deterrence for harbour porpoise with short range deterrence observed for seals, but habituation occurred in several studies with seals (Sparling *et al.* 2015). In a study using loudspeaker to transmit signals akin to Lofitech device, all porpoises deterred to 190 m from the single device, with mixed behavioural reactions between 350 to 525 m (Mikkelsen *et al.* 2017). No reports of marine mammal sightings during soft start at active ADD locations (Dudgeon Offshore Wind Farm Ltd, 2016). Significant deterrence effect from one device on harbour porpoise out to 7.5 km (Brandt *et al.* 2012).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
			• minimizing initial hammer energies when received noise levels were highest; and • extending the initial phase of soft start with minimum hammer energies and low blow rates.	Clear deterrence effect (100% displacement) up to 1.9 km, with deterrence 50% of the time between 2.1 to 2.4 km. Closest observed porpoise to single device was 798 m (Brandt *et al.* 2013). Up to 75% reduction in harbour porpoise during use at measured distances of 750 and 1,500 m (Horschle *et al.* 2015). Increased swim speed, surfacing and jumps during device use on a captive harbour porpoise (Kastelein *et al.* 2015).	
Harbour porpoise	SaveWave: SealSalmon Saver [22a] (termed 'Black Saver' in Kyhn *et al.* 2015)	Not measured.	No new evidence.	Reduction by 65% in harbour porpoise encounters when devices placed at 200 m apart were periodically activated. During continuous exposure for 28 days there was no suggestion of habituation (Kyhn *et al.* 2015).	3 [3]
Harbour porpoise	Ace Aquatec: Mid-frequency Acoustic Startle Response Device (formerly the Universal Scrammer: device name updated since original 2022 report; see 6.6) (US3) [6]	Likely avoidance between 200 m and 1.2 km. Potential exclusion up to 6 km. Modelling suggests potential for audibility up to 68 km in Sea State 0, 33.5 km in Sea State 6 (Todd *et al.* 2019).	Acoustic propagation models of deployment at fish farms predict SEL_{24} at levels sufficient to induce TTS in single devices, and the potential to induce PTS, assuming multiple, continuously running devices with an aggregate duty cycle of 100% (Findlay *et al.* 2021). Predicted to cause TTS in VHF cetaceans (which includes harbour porpoise) at a range of 18 km, if operated for 24 hours (Todd *et al.* 2021).	Kastelein *et al.* (2010) found animals did not react to lowest sound levels. As the mean received level increased, significant displacement occurred alongside significantly higher numbers of surfacing's, swimming speed and respiration compared to baseline. Likely to deter porpoises at ranges between 0.2 and 1.2 km based on noise modelling (Kastelein *et al.* 2010).	3 [2]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
				As the mean received SPL increased, significant displacement occurred during test periods, and significantly higher numbers of surfacings, swimming speed and jumps occurred in test periods than in associated baseline periods (Kastelein *et al.* 2015). Using the Southall *et al.* (2007) criteria TTS was found to 4 m (ABPmer 2014), with potential to cause exclusion up to 6 km and potential to cause injury or mortality in very close proximity (1–3 m) (ABPmer 2014, based on noise modelling from Nedwell *et al.* 2007). Suitable for use during offshore wind farm construction (Sparling *et al.* 2015). Note: These papers use the maximum output not the average energy levels of the signal.	
Harbour porpoise	Terecos Ltd: DSMS-4 [30a – 30d]	301 m – 1.2 km. Modelling suggests potential for audibility up to 99 km in Sea State 0, 37 km in Sea State 6 (Todd *et al.* 2019).	Device no longer commercially available. Acoustic propagation models predict SEL over 24 hours at levels sufficient to induce TTS in single devices, and the potential to induce PTS, assuming multiple, continuously running devices with an aggregate duty cycle of 100% (Findlay *et al.* 2021).	Porpoise detections measured at nine stations between 301 m and 4.5 km. Only weak or minimal response in harbour porpoise; significant decline at 301 m with proportional displacement to 1.2 km (Northridge *et al.* 2013). Injury threshold (set at 186 dB for harbour porpoise) would be exceeded if animal was within 100 m of device for 2.5 hours, or over 24 hours at 500 m based on a 6.7% duty cycle (Lepper *et al.* 2014).	2 [2]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
			Habitat displacement may be a cause for concern if multiple devices are deployed simultaneously, as this could create a confusing sound field with the potential to deter harbour porpoises from sections of their habitat (Todd *et al.* 2019).		
Harbour porpoise	Van Oord/ SEAMARCO and Ace Aquatec Fauna Guard: Porpoise Module [24]	Observed efficacy of at least 1,000 m.	Disturbance to harbour porpoises is lower when using a deterrent compared to a seal scarer: use of an acoustic porpoise deterrent is an improvement to mitigation strategies for less harmful piling (Voss *et al.* 2023). FaunaGuard system is technically suitable for offshore applications and has a clear scaring effect on harbour porpoises up to a distance of >1,000 m (Rosemeyer *et al.* 2021; Voss *et al.* 2021).	Captive response showed increased distance from device (Van der Meij *et al.* 2015). Deterrence of harbour porpoise out to 1 km. Nearest surfacing was at 1,006 m (Geelhoed *et al.* 2017). Captive animal's respiration rate increased and distance from device significantly increased. Operational efficacy is sufficient to prevent PTS due to the first strike of offshore pile driving in wild harbour porpoises (Kastelein *et al.* 2017). Device concluded to be useful (Sparling *et al.* 2015).	3 [2]
Harbour porpoise	Gael Force: SeaGuard seal deterrent [23] (formerly Airmar dB plus II [8]: device name and device ID updated since original 2022 report; see Appendix 6.26)	200 m – 3,500 m Modelling suggests potential for audibility up to 63.5 km in Sea State 0, 32 km in Sea State 6 (Todd *et al.* 2019).	Acoustic propagation modelling predicts onset of TTS at a range of 31 km, assuming 24-hour operation (Todd *et al.* 2021).	No porpoise recorded within 200 m of the ADD. Deterrence recorded beyond 3.5 km. Porpoise appeared to return to normal levels soon after the AHD was deactivated. No evidence for habituation but study only over three weeks (Olesiuk *et al.* 2002).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
			Habitat displacement may be a cause for concern if multiple devices are deployed simultaneously, as this could create a confusing sound field with the potential to deter harbour porpoises from sections of their habitat. Source levels, propagation and transmission loss measurements were highly variable in modelling, and should be considered as site specific, meaning new estimates should be made for each situation (Todd *et al.* 2019).	Porpoises left the site soon after the ADD was activated and the mean distance of approach was 991 m when the ADD was active. Significantly fewer sightings of porpoises within 1,500 m when ADD was active. No porpoises were observed within 645 m of the device (Johnston 2002). 40–75% reported reduction in porpoise detection rate when the device was active. During the continuous-exposure scenario, detection rate was reduced by 65% throughout the 28-day trial; effective to 2.5 km but no effect between 2.5 and 5 km (Kyhn *et al.* 2015). Evidence of porpoise feeding within 200 m of 10 active ADDs; porpoises returned to areas almost immediately after ADDs are switched off (Northridge *et al.* 2010).	
Harbour porpoise	Aquatec Group: Aquamark 848 [10]	Up to 1,500 m depending on species.	No new evidence.	Potential to deter porpoise up to 200 m based on modelled ranges using dBht criteria from Nedwell *et al.* (2007) (ABPmer 2014).	2 [2]
Harbour porpoise	Aquatec Group: Aquamark 100 [11a]	100 m.	No new evidence.	100% (significant) reduction in bycatch at a pinger spacing of 455 m; 78% (significant) reduction in bycatch at a pinger spacing of 585 m (Larsen *et al.* 2007). No significant reduction in bycatch of harbour porpoise by four Aquamark100 pingers spaced every 400 m along headline of nets (Morizur *et al.* 2009).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
				Significant decrease in click detections and observations of harbour porpoise around nets with active devices (five devices spaced 200 m apart on 1 km of monk net). Observed that porpoises take ~7 hours to recolonize area (Hardy & Tregenza 2010). Approximate 48% reduction in porpoises at nets with pingers and evidence that period of exclusion following pinger use could exceed seven hours, with no evidence of habituation (Hardy *et al.* 2012). Potential to deter up to 100 m (ABPmer 2014). No evidence of displacement of porpoises using moored pingers on a simulated gillnet (Desportes *et al.* 2006).	
Harbour porpoise	Aquatec Group: Aquamark 200 [11b]	Approximately 130 m.	No new evidence.	A net equipped with an acoustic alarm was avoided within audible range. A single pinger created a total exclusion zone of 130 m, with a mean closest approach distance of tracked harbour porpoise groups to the pinger of 414 m. The porpoises were thus effectively excluded from the ensonified area (Culik *et al.* 2001).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
Harbour porpoise	Future Oceans: 60 kHz – 120 kHz Netguard Dolphin Pinger (formerly 70kHz Dolphin Pinger) [15b]	Not available.	Data collected from 110 deployments at active commercial static net fisheries in the Baltic suggest that the pinger is suitable for deterrence of harbour porpoise, without increasing seal depredation (no 'dinner bell' effect) (Carlén & Cosentino 2023). Pingers deployed every 200 m according to manufacturer's instructions.	No evidence presented in original report.	3 [N/A]
Harbour porpoise	Fishtek Marine: Banana Pinger (50-120) [16a]	Approximately 100 m.	Data collected from 532 deployments at active commercial static net fisheries in the Baltic suggest that the pinger is suitable for deterrence of harbour porpoise, without increasing seal depredation (no 'dinner bell' effect) (Carlén & Cosentino 2023). Pingers deployed every 100 m according to manufacturer's instructions.	82% reduction in potential bycatch when device in use. Cycling-pinger trial: the number of porpoise and dolphin click detections were reduced when the pinger was active, but this varied over time (Crosby *et al.* 2013). Potential to deter harbour porpoise up to 100 m (ABPmer 2014). No porpoises were observed in very close proximity to the nets fitted with pingers (<100 m) despite being seen in the vicinity (Woolmer 2015). Fewer porpoises detected moving from 400 m to 0 m from the pinger when activated (Friis 2017).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
Harbour porpoise	Fishtek Marine: Banana Pinger (10) [16c]	Approximately 50 m.	Data collected from 536 deployments at active commercial static net fisheries in the Baltic suggest that the pinger is suitable for deterrence of harbour porpoise, without increasing seal depredation (no 'dinner bell' effect) (Carlén & Cosentino 2023). Pingers deployed every 100 m according to manufacturer's instructions. Pinger had a significant negative effect on the porpoise click activity logged at 0 m and 100 m distance but not at 400 m from the pinger (Königson *et al.* 2022).	Meets acoustic characteristics as set out under US Federal Register/vol. 64, 1999 for use of pingers in US fisheries. Has demonstrated efficacy in mitigating cetacean bycatch in both USA Harbour Porpoise Take Reduction Plan (HPTRP) and the Pacific Offshore Cetacean Take Reduction Plan (POCTRP).	3 [3]
Harbour porpoise	F3 Maritime Technology UG Ltd (Life Systems): Porpoise PAL [17a]	Up to 250 m in 'good' weather.	No new evidence.	Reduction in harbour porpoise bycatch along gill nets in the Western Baltic Sea by over 70% (independently tested by Thünen Institute of Baltic Sea Fisheries; Culik & Dorrien 2017; Culik *et al.* 2017).	3 [3]
Harbour porpoise	Dukane: NetMark 1000 Pinger [14]	208 m to 375 m.	Results of three months of field testing indicated that porpoises habituated to the pinger and were not alerted to echolocate in the presence of nets (Cox *et al.* 2023).	87 to 98% reduction in bycatch at nets with pingers compared to net without pingers (Kraus *et al.* 1997). Estimated displacement of 208 m, diminishing by 50% in four days, therefore evidence that harbour porpoise habituate to pinger (Cox *et al.* 2001).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
				Demersal gill nets equipped with acoustic alarms reduced harbour porpoise by-catch rates by 77% over those without alarms (Trippel *et al.* 1999). Reduced sighting rate of harbour porpoise up to 375 m from pinger (Carlström *et al.* 2009). Controlled Exposure Experiments (CEE) found a significant reduction in entanglement with gill nets (Gönener & Bilgin 2009; Bordino *et al.* 2002). In a review of tidal-stream devices by Wilson and Carter (2013), in a tidal stream setting (where there is potentially higher ambient noise) sound will not propagate far (< 20 m) before dropping below ambient noise levels and therefore hearing damage is not a risk (Wilson & Carter 2013). Reduction in entanglement rates of 1/3rd for cetaceans (Barlow *et al.* 2003) for pingers (spaced one each end of float line and at 91 m intervals) with same acoustic characteristics.	
Harbour porpoise	GenusWave Ltd: TAST ASD 'SalmonSafe' [21a]	No measurable effect.	Desk-based noise-propagation modelling in the context of the Southall *et al.* (2019) criteria suggests that TTS may be induced out to 4,336 m, and PTS out to 760 m, for VHF cetaceans, assuming continuous operation for 24 hours (Todd *et al.* 2021).	During field tests on a fish farm in Scotland, a single device had no effect on harbour porpoise (Götz & Janik 2015, 2016a; Janik & Götz 2013). Therefore, aquaculture and most fisheries applications harbour porpoise is a non-target species that should not be adversely impacted (i.e. excluded from their habitat). No risk of hearing damage (Götz & Janik 2015).	3 [3]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
Harbour porpoise	GenusWave Ltd: TAST ASD 'Fisheries Safe' [21b]	No measurable effect (if none is intended). A few hundred metres for bycatch reduction.	No new evidence.	During field tests on a fish farm in Scotland, a single device had no effect on harbour porpoise (Götz & Janik 2015, 2016a; Janik & Götz 2013). In aquaculture, and most fisheries applications, the harbour porpoise is a non-target species that should not be adversely impacted (i.e. excluded from their habitat). No risk of hearing damage (Götz & Janik 2015). However, gillnet pinger capability for porpoise bycatch reduction can be provided in 'FisheriesSafe' by emitting a low-source level 'odontocete signal' (Hiley *et al.* 2021).	3 [3]
Harbour porpoise	GenusWave Ltd: TAST ASD 'Mitigation device' 'TurbineSafe', 'ConstructionSafe' [21c]	Adjustable from a few hundred metres up to several km.	Deterrence ranges from a few hundred metres to several kilometres. Device elicits a startle reflex, which the authors suggest is the underlying physiological mechanism mediating these responses and could be a suitable alternative to conventional ADDs to mitigate the risk of hearing damage during MRE construction (Hiley *et al.* 2021).	Götz and Janik (2015) carried out field tests on Scottish fish farms and found no risk of hearing damage at close ranges to a device. The deterrence range can be adjusted based on the requirements of the specific application. This is achieved by adjusting the source level of the 'odontocete signal' independently of the 'seal/pinniped signal' (see Götz & Janik 2015, 2016 for general concept).	3 [2-3]
Harbour porpoise	STM Products: DDD (03L, 03N, 03H, 03U), DID 01 [13a to 13e]	1.2 to 3 km.	No new evidence.	Nets with DDDs caught significantly fewer porpoise. Bycatch was reduced by 95% in nets less than 4 km length. Porpoise excluded to at least 1.2 km. Partial exclusion may extend to 3 km (Northridge *et al.* 2011). No significant reduction in bycatch of harbour porpoise (Morizur *et al.* 2009).	2 [2]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
				Originally designed to deter dolphins from fishing gear/aquaculture, and not currently useful for mitigation for offshore wind farms (Sparling *et al.* 2015).	
Harbour porpoise	Marexi Marine Technology: Pinger (V2.3, M2.1, H1.0) [20a, 20b, 20c]	Not available.	No new evidence.	No significant reduction in bycatch of harbour porpoise (Morizur *et al.* 2009).	2 [2]
Harbour porpoise	Lien: L2/L3 [31]	Not available.	No new evidence.	Harbour porpoise displaced to at least 125 m (Laake *et al.* 1998). Significant reduction in bycatch of harbour porpoise in nets with pingers in use (Gearin *et al.* 2000). 92.4% of harbour porpoise groups avoided floatline with pinger in use. Closest observed approach distance was 133 m. No long-term displacement recorded (Koschinski *et al.* 1997).	3 [3]
Harbour porpoise	OTAQ: SealFence [29]	Not available.	Assuming a single device is deployed, noise was predicted to be sufficient to induce TTS, and under the worst-case scenario (multiple, continuously running devices per site with an aggregate duty cycle of 100%), levels were predicted to exceed the PTS threshold (Findlay *et al.* 2021).	No evidence presented in original report.	3 [N/A]

VHF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence score[3] [2022 score]
			Desk-based noise-propagation modelling indicates that for harbour porpoises, TTS may be induced out to 20 km in standard mode and out to 5 km in patrol mode, assuming continuous 24-hour operation (Todd *et al.* 2021).		
Harbour porpoise	Loughborough University: LU-1 prototype [18]	Not available.	No new evidence.	Kastelein *et al.* (1997) found harbour porpoise reacted by moving away from the sensor during the 15 minute test period, swimming an average distance of 22.8 m from the alarm; swimming and diving pattern and breathing rate recovered to normal immediately after the sounds were switched off. No habituation was recorded (Kastelein *et al.* 1997). CEEs with pingers placed on gill nets found a 94% reduction in by- catch (significant difference) (Larsen *et al.* 2014).	3 [3]
VHF cetaceans	Ace Aquatec: MMD High Frequency) [4]	50 – 6,000 m.	No new evidence.	Using the Southall *et al.* (2007) criteria TTS was found to 4 m (ABPmer 2014). Modelled exclusion up to 6 km, however potential to cause injury or mortality in close proximity (1 m – 3 m) (ABPmer 2014, based on noise modelling using Nedwell *et al.* (2007) criteria).	2 [2]

Table 2-4: Categorisation of devices suited for deterrence of High Frequency (HF) cetaceans based on published evidence[1].

[1] NB: Refer to Table 2-1 and Table 2-2 for more information about the devices, using the Device ID given in brackets in column 2 of Table 2-4 below for the relevant device.

[2] Deterrence ranges reported in the literature and/or manufacturer's information are likely to be influenced by factors such as local propagation characteristics, as well as animal's motivation, previous exposures to device and background noise levels.

[2] Evidence Score is not a measure of the effectiveness of an ADD but is an assessment of confidence in the evidence for an ADD's effectiveness. 1 = Low confidence (intended for use as stated by the manufacturer with limited published evidence to support conclusion), 2 = Medium confidence (backed by non-peer reviewed/grey literature), 3 = High confidence (backed by at least one peer reviewed study).

HF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Bottlenose dolphin	SaveWave: SealSalmon Saver (High-impact) [22a]	Not available.	No new evidence.	Reduction in bycatch in the active condition compared to the no-pinger control but this was not significant (Brotons *et al.* 2008). Dolphins were significantly less likely to encounter (approach within 500 m), interact and engage with gillnets when the device was active, although it did not completely deter all animals from interacting with the nets. The study also found that dolphins increased their echolocation rates around active devices (Waples *et al.* 2013). Significant decrease in predation and number of holes in active nets (Northridge *et al.* 2003).	3 [3]
Bottlenose dolphin	Aquamark 210 [11c]	Not available.	No new evidence.	Significant reduction in bycatch when active compared to the no-pinger control. These pingers reduced the net interaction rate by 70% in active nets (Brotons *et al.* 2008).	3 [3]

HF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Bottlenose dolphin	Future Oceans: 60 kHz – 120 kHz Netguard Dolphin Pinger (formerly 70 kHz Dolphin Pinger) [15b]	Not available.	No new evidence.	No significant difference in behaviour of bottlenose dolphin around active versus control nets in Spanish mackerel gillnet fishery (Read *et al.* 2010).	2 [2]
Bottlenose dolphin	Seamaster: Fish Protector [25]	Up to 1 km.	No new evidence.	Predicted range of effect provided by manufacturer.	1 [1]
Bottlenose dolphin	Marexi Marine Technology: Pinger [20a, 20b, 20c]	Not available.	No new evidence.	Less damage to gillnets when device was present and active, than when it was not (Troncone *et al.* 2008).	2 [2]
Bottlenose dolphin	Aquatec Group: Aquamark 100 [11a]	Not available.	No new evidence.	Pingers did not stop dolphins from approaching the fishing nets, but the nets equipped with functional pingers received less damage (87% fewer holes) than nets with non-functional devices or without pingers (Gazo *et al.* 2008).	3 [3]

HF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Bottlenose dolphin	GenusWave Ltd: TAST ASD 'OdontoceteSafe', 'FisherySafe' 'OrcaSafe'	500 – 800 m.	13 groups of wild bottlenose dolphins tested in sound exposure studies, with another 13 as controls. 5 signals of 200 ms each were played within 1 min at a source level of 180 dB re 1µPa SPL$_{rms}$. Received levels were estimated to be 145–147 dB re 1 µPa SPL$_{rms}$. Dolphins moved quickly away from the sound source by changing their heading and increasing their swim speed. This avoidance lasted up to four minutes (Janik *et al.* 2023).	No evidence presented in original report.	2 [N/A]
Short-beaked common dolphin	Cetasaver V.03 [12]	Not available.	No new evidence.	Six acoustic devices were tested over 45 at-sea trials, with devices attached to vessel at mid-ship with devices at depth of 2–3 m. No major changes in dolphin behaviour were observed (Berrow *et al.* 2008). A reduction in common dolphin bycatch of around 70% during the year-long trial which deployed pingers every 200 m on French trammel nets (Morizur 2008).	3 [3]
Hector's dolphin *Cephalorhynchus hectori*	Aquatec Group: Aquamark 200 [11b]	Not available.	No new evidence.	No avoidance reaction or measurable effect on Hector's dolphins to pingers deployed from boat (Stone *et al.* 2000).	2 [2]

HF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Australian humpback dolphin *Sousa sahulensis* **and snubfin dolphin** *Orcaella heinsohni*	Future Oceans: 60 kHz – 120 kHz Netguard Dolphin Pinger (formerly 70 kHz Dolphin Pinger) [15b]	Not available.	No new evidence.	'At risk' interactions decreased from 81% to 50% in active nets (Read & Waples 2010). In vessel transects which deployed ADD for 10 minute trial periods for Australian humpback dolphins/5 minutes for snubfin dolphins, the likelihood of the animals leaving an area was not significantly different from the controls (i.e. when the device was not in the water) (humpback dolphin and Australian snubfin) (Soto *et al.* 2013). Suggested audibility to humpback dolphin and snubfin dolphin is 100 m. Only subtle responses from dolphins and no movement away from an area when pinger active therefore not considered effective for use in mitigation at offshore wind farms for dolphins (Soto *et al.* 2013).	3 [2]
Dolphins	Aquatec Group: Aquamark 200 [11b]	Not available.	No new evidence.	No avoidance reaction or measurable effect on Hector's dolphins to pingers deployed from boat (Stone *et al.* 2000). Significant reduction in by-catch of striped dolphin (*Stenella coeruleoalba*) of 81% (Imbert *et al.* 2007).	2 [2]

HF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Dolphins	Fishtek Marine: Banana Pinger (50–120) [16a]	Approx. 100 m.	No new evidence.	Studies were able to demonstrate a strong and sustained effect of the Fishtek 50 – 120 kHz pinger at reducing dolphin interactions with set fisherman (Vella 2016). Results indicate that trammel net damage and catch depredation by dolphins were reduced to 2% and 6% respectively when compared with the original records of damage and depredation before starting the pilot project.	2 [2]
Dolphins	Fishtek Marine: Dolphin Anti-depredation Pinger (DDD) [16d]	Approx. 50 m.	No new evidence.	Trials conducted in waters off Italy showed the Fishtek anti-depredation pinger to have a significant and strong effect at reducing the interactions of dolphins with set net fishing gear (Ferraro *et al*. 2018) Results showed a 100% increase in catch value and no net damage was recorded on nets equipped with pingers.	2 [2]
Dolphins	GenusWave Ltd: TAST ASD Mitigation Device 'TurbineSafe' 'Construction Safe' [21c]	Adjustable.	No new evidence.	General concept described in Janik and Götz (2013) and Götz and Janik (2015).	3 [2]

HF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Dolphins	Dukane: Netmark 1000 [14]	Not available.	No new evidence.	Reduction in entanglement rates of one third for cetaceans in California drift nets (Barlow *et al.* 2003) for pingers (spaced one each end of float line and at 91 m intervals) with same acoustic characteristics. No significant reduction in bycatch or encounters between gillnets in Fort Mason, USA with active and non-active (control group) pingers (Cox *et al.* 2004). Significant (73%) reduction in by-catch in nets with active pingers in Peru (Alfaro Shigueto 2010).	3 [3]
HF cetaceans	Ace Aquatec: MMD Mid Frequency [3]	50 – 1,000 m from source.	No new evidence.	Predicted range of effect provided by manufacturer.	1 [1]

Table 2-5: Categorisation of devices suited for deterrence of Low Frequency (LF) cetaceans based on published evidence[1].

[1] NB: Refer to Table 2-1 and Table 2-2 for more information on devices, using the Device ID given in brackets in column 2 of Table 2-5 below for the relevant device.

[2] Deterrence ranges reported in the literature and/or manufacturer's information are likely to be influenced by factors such as local propagation characteristics, as well as animal's motivation, previous exposures to device and background noise levels.

[3] Evidence Score is not a measure of the effectiveness of an ADD but is an assessment of confidence in the evidence for an ADD's effectiveness. 1 = Low confidence (intended for use as stated by the manufacturer with limited published evidence to support conclusion), 2 = Medium confidence (backed by non-peer reviewed/grey literature), 3 = High confidence (backed by at least one peer reviewed study).

LF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Minke whale	Ace Aquatec: Mid-frequency Acoustic Startle Response Device (US3) (device name updated from "Universal Scrammer" since original 2022 report: see Appendix 6.6) [6]	Not available.	Modelling predicts potential to induce TTS at 6 km and PTS at 1.4 km, assuming a continuous 24-hour operation (Todd *et al.* 2021).	No evidence presented in original report.	3 [N/A]
Minke whale	Ace Aquatec: Low-Frequency Acoustic Startle Response Device (RT1/FS1) (device name updated from "RT1" since original 2022 report: see Appendix 6.7) [7]	Not available.	Modelling predicts potential to induce TTS at 17 km and PTS at 2.7 km assuming a continuous 24-hour operation (Todd *et al.* 2021).	No evidence presented in original report.	3 [N/A]

LF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Minke whale	Lofitech: seal scarer [19]	1,000 m.	Caused focal animals to move away immediately, typically increasing horizontal speed and directness away from the source and extending dives. Unlikely that this device could cause instantaneous injury due to peak pressure (SPL$_{pk}$) alone, and at 25 m neither the PTS or TTS thresholds for LF cetaceans (over 24 h) were exceeded. Some evidence that changes in behaviour (e.g. dive duration/swim speed) were caused by the ADD signal itself, rather than its magnitude (Boisseau *et al.* 2021).	Measured response from exposure at 1 km range. Increase in speed and directionality during deployment. Animals fled beyond this distance. No injury predicted from model (McGarry *et al.* 2017). The initial ADD deployment protocol of activating the device at 500 m resulted in strong reactions, moving away quickly, making it difficult to undertake post-deployment tracking in some instances and therefore the protocol was modified to activation at 1000 m.	3 [2]
Minke whale	GenusWave Ltd: TAST ASD 'SalmonSafe' and 'FisherySafe' [21a, 21b]	Not available.	No new evidence.	No effect at ~1 km distance (Götz & Janik 2015).	3 [3]
Minke whale	GenusWave Ltd: TAST ASD 'MitigationDevice' 'TurbineSafe' 'ConstructionSafe' [21c]	Not measured.	Modelling predicts potential to induce TTS at 11 km and PTS at 2.7 km assuming a continuous 24-hour operation (Todd *et al.* 2021) Use of broadband marine mammal signal.	No evidence presented in original report.	3 [N/A]

LF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Minke whale	Gael Force: SeaGuard Seal deterrent [23] (device name updated from "Airmar dB plus II" [8] since original 2022 report: see Appendix 6.26)	Not available.	Modelling predicts potential to induce TTS at 3 km and PTS at 3.8 km assuming a continuous 24-hour operation (Todd *et al.* 2021).	No evidence presented in original report.	3 [N/A]
Minke whale	OTAQ: SealFence – standard mode ([29]	Not available.	Modelling predicts potential to induce TTS at 6 km and PTS at 1.4 km assuming a continuous 24-hour operation (Todd *et al.* 2021).	No evidence presented in original report.	3 [N/A]
Minke whale	OTAQ: SealFence – patrol mode ([29]	Not available.	Modelling predicts potential to induce TTS at 0.7 km, assuming a continuous 24-hour operation. PTS threshold not exceeded (Todd *et al.* 2021).	No evidence presented in original report.	3 [N/A]
Humpback whale *Balaenoptera novaeangliae*	Future Oceans: 3kHz Netguard Whale Pinger [15c]	Approx. 50 m (manufacturer).	No new evidence.	No effect of the pinger on the humpback whales; they neither changed direction, changed speed or altered their surfacing behaviour in response to the pinger (Harcourt *et al.* 2014).	3 [3]
Baleen whales	Fishtek Marine: Banana Pinger Whale (3-20) [16b]	Approx. 100 m.	No new evidence.	Predicted range of effect provided by manufacturer.	1 [1]
LF cetaceans	Ace Aquatec: MMD Low Frequency [1]	50 – 1,000 m from source.	No new evidence.	Measured displacement over ranges of >1 km depending on species. Sound detectable at 7 km (ABPmer 2014).	2 [2]

LF cetacean species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
LF cetaceans	Aquamark 848 [10]	Up to 1,500 m depending on species.	No new evidence.	Predicted range of effect provided by manufacturer.	1 [1]

Table 2-6: Categorisation of devices suited for deterrence of pinnipeds (seals) based on published evidence[1].

[1] NB: Refer to Table 2-1 and Table 2-2 for more information on devices, using the Device ID given in brackets in column 2 of Table 2-5 below for the relevant device.

[2] Deterrence ranges reported in the literature and/or manufacturer's information are likely to be influenced by factors such as local propagation characteristics, as well as animal's motivation, previous exposures to device and background noise levels.

[3] Evidence Score is not a measure of the effectiveness of an ADD but is an assessment of confidence in the evidence for an ADD's effectiveness. 1 = Low confidence (intended for use as stated by the manufacturer with limited published evidence to support conclusion), 2 = Medium confidence (backed by non-peer reviewed/grey literature), 3 = High confidence (backed by at least one peer reviewed study).

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Grey seal	Aquamark 848 [10]	Up to 1,500 m depending on species (from manufacturer).	No new evidence.	Very strong avoidance reactions in grey seal within 28 m (based on noise modelling using Nedwell *et al.* 2007 criteria) (ABPmer 2014).	2 [2]
Grey seal	Aquamark 100 [11a]	Up to 3 m.	No new evidence.	Very strong avoidance reaction within 3 m (based on noise modelling using Nedwell *et al.* (2007) criteria) (ABPmer 2014).	2 [2]
Grey seal, Harbour seal	Ace Aquatec: Mid-frequency Acoustic Startle Response Device (US3) (formerly Universal Scrammer) [6]	Between 200 m and 1.4 km.	No new evidence.	Captive animal behavioural experiments found that during sessions with the lowest level sounds, the seals' behaviour was similar during test and baseline periods. Noise modelling showed that device was likely to deter harbour seal at ranges between 0.2 km and 1.4 km (Kastelein *et al.* 2010). Significant decrease in the number of animals in at least one of the distance ranges tested. Deterrence range of 60 m in grey seals. Rapid habituation in both grey and harbour seals in context where food motivation is involved at RL of 146 dB re 1 µPa (Götz 2008; Götz & Janik 2010). Harbour seals in captivity hauled out more and spent more time with their heads above water as sound source levels increased (Kastelein *et al.* 2015).	3 [3]

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
				Fish mortalities (fish farms) reduced by 70% with use (Whyte *et al.* 2015).	
				PTS to 3 m, TTS to 15 m from source (based upon Southall *et al.* 2007 criteria). Strong avoidance reaction up to. 800 m, based on noise modelling (Nedwell *et al.* (2007) criteria) (ABPmer 2014).	
				Injury threshold for seal at 100 m would be exceeded after 3 hours, and 24-hour exposure would be 350 m (Lepper *et al.* 2014).	
				Suitable for use in offshore wind farm construction (Sparling *et al.* 2015).	
Grey seal, Harbour seal	Ace Aquatec: Low-Frequency Acoustic Startle Response Device (RT1/FS1) (device name updated from "RT1" since original 2022 report: see Appendix 6.7) [7]	>1,000 m.	Modelling predicts potential to induce TTS at 0.7 km, assuming a continuous 24-hour operation. PTS threshold not exceeded (Todd *et al.* 2021).	No evidence presented in original report.	3 [N/A]
Grey seal	Future Oceans: 60 kHz -120 kHz Netguard Dolphin Pinger (formerly 70 kHz Dolphin Pinger) [15b]	N/A.	No effect on grey seal as outside range of audible frequencies (Carlén & Cosentino 2023).	No evidence presented in original report.	3 [N/A]

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
Grey seal	Fishtek Marine: Banana Pinger (50 – 120) [16a]	N/A.	No effect on grey seal as outside range of audible frequencies (Carlén & Cosentino 2023).	No evidence presented in original report.	3 [N/A]
Grey seal, Harbour seal	OTAQ: SealFence [29]	Up to 45 m.	Desk-based noise-propagation modelling indicates that for pinnipeds, TTS may be induced out to 6 km in standard mode and out to 0.8 km in patrol mode, assuming continuous 24-hour operation (Todd *et al.* 2021).	Predicted range of effect provided by manufacturer. SealFence 3 and SealFence 4 have the same acoustic characteristics (see Appendix 6.33).	3 [1]
Seals	Lofitech: Seal Scarer [19]	60 – 473 m.	No new evidence.	Increase in seal observations within 100 m of device (Mikkelsen *et al.* 2017). No reports of marine mammal sightings during soft start at active ADD locations (Dudgeon Offshore Wind Farm Ltd). Significant reduction in predation by seal (fish) during use at fish traps at a Baltic salmon net fishery (Fjalling *et al.* 2006). Number of sightings and amount of time seals spent near nets significantly reduced, although some evidence of habituation in second year of trials (Harris *et al.* 2011).	3 [3]

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
				ADD sounds played back at 172 dB re 1 µPa at 1 m from anchored boat found significant decrease in seals over a distance of up to 60m with no evidence of habituation over 10 exposure days (Götz 2008; Götz & Janik 2010). Evidence for rapid habituation in captive experiment that simulated food motivation creating comparable received levels (Götz & Janik 2010). Fewer seals observed at a salmon net fishery with Lofitech device operating than without deterrent (Harris *et al*. 2014). Behavioural response when seals within 1 km of sound source. Animals involved in direct movement away and minimum approach distance was 473 m (Gordon *et al*. 2015). No significant effect on absolute abundance but significantly reduced seal movements upstream (Graham *et al*. 2009). Playback to captive seals found not significant response during exposure trials although a recording of the Lofitech was used rather than the device itself (Kastelein *et al*. 2015).	
Seals	Ace Aquatec: MMD Low Frequency [1]	50 – 1,000 m from source.	No new evidence.	Measured displacement over ranges of >1 km depending on species. Sound detectable at 7 km (ABPmer, 2014).	2 [2]
Seals	Ace Aquatec: MMD High Frequency [4]	50 – 2,000 m from source (from manufacturer).	No new evidence.	Permanent Threshold Shift (PTS) to 3 m and Temporary Threshold Shift (TTS) to 15 m (based on Southall *et al*. (2007) criteria). Strong avoidance reaction up to 800 m (based on noise modelling, Nedwell *et al*. 2007) (ABPmer 2014).	2 [2]

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
				Rapid habituation in both grey and harbour seals at received levels of 146 dB re 1 µPa (Götz & Janik 2010).	
Seals	Gael Force: SeaGuard Seal deterrent [23] (formerly Airmar: dB Plus II [8]: see Appendix 6.26)	<50 m Modelling suggests potential for audibility in harbour seal up to 55.6 km in Sea State 0, 32 km in Sea State 6. In grey seal this was 42 km and 21 km, respectively (Todd *et al.* 2019).	Modelling predicts potential to induce TTS at 13 km and PTS at 3.8 km, assuming a continuous 24-hour operation (Todd *et al.* 2021). Source levels, propagation and transmission loss measurements were highly variable in modelling, and should be considered as site specific, meaning new estimates should be made for each situation (Todd *et al.* 2019).	Responses observed at ranges up to 1,037 m. Shortest range at which no response was observed was 653 m (Gordon *et al.* 2015). Device considered unsuitable for use in offshore wind farms due to limited distance of effect (Sparling *et al.* 2015). Device effective out to 100 m (from salmon farm) with up to 50% reduction in fish mortalities (Mate & Harvey 1986). No effect was observed with seals were observed as close as 44 m from the sound source (Jacobs & Terhune 2002). Deterrence effect observed between 40 m and 50 m. Evidence for habituation in context where food motivation is involved at RL of 146 dB re 1 µPa. (Götz 2008; Götz & Janik 2010). Evidence for habituation in context where food motivation is involved at RL of 146 dB re 1 µPa. (Götz 2008; Götz & Janik 2010). Significantly fewer seals fed within a river when ADD was deployed compared to no ADD; deterrence range was 50 m (Yurk & Trites 2000). Average fish mortality due to seal predation reduced by 50% using Airmar devices at Scottish fish farms compared to sites without ADD (Whyte 2015).	3 [3]

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
				A seal at 100 m would exceed the injury threshold (each the injury threshold of 186 dB re 1 $\mu Pa^2 s$ for pinnipeds) after about 3.3 hours for a single device. With single device animals remaining at 400 m for 24 hours would reach the threshold for injury (Lepper *et al.* 2014). Noise modelling suggests signal may be audible to 1.4 km before nearing ambient noise levels (Wilson & Carter 2013).	
Seals	Terecos Ltd: DSMS-4 [30a – 30d]	Not Available. Modelling suggests potential for audibility in harbour seal up to 88 km in Sea State 0, 34 km in Sea State 6. In grey seal this was 69 km and 21.5 km, respectively (Todd *et al.* 2019).	Device no longer commercially available.	No reduction in fish mortalities from use of Terecos device (Whyte 2015). Seal injury threshold (186 dB re 1 $\mu Pa^2 s$) would be exceeded if seal remained within 100 m of device for 9 hours, or 24 hours within 200 m (Lepper *et al.* 2014). No significant change in seal numbers at any measured distance from the device (Götz 2008). Evidence for habituation in context where food motivation is involved at RL of 146 dB re 1 μPa. (Götz 2008; Götz & Janik 2010).	3 [3]
Seals	Van Oord/ SEAMARCO and Ace Aquatec: Fauna Guard: Seal Module [25]	Predicted efficacy of at least 100 – 500 m.	No new evidence.	Behavioural responses ranged from no reaction to increased time with head above the water. Deterrence range estimated from noise modelling at 100 – 500 m (Kastelein *et al.* 2017).	3 [3]
Seals	GenusWave Ltd: TAST ASD 'SalmonSafe' [21a]	60 – 250 m.	No new evidence.	Significant reduction in the number of seal tracks within 250 m of the device at a fish farm while not adversely impacting harbour porpoise (Götz & Janik 2015). Smaller deterrence ranges (~60 m) around haul out sites (Götz 2008).	3 [3]

Pinniped species	Device or group of devices and [Device ID]	Deterrence ranges[2]	Summary of new evidence in this report	Evidence from original 2022 report (Version 4)	Evidence Score[3] [2022 score]
				Significant effectiveness on seal predation at salmon farms over 19 months (i.e. 91–97% reduction in predated fish compared at test sites compared to control sites (Götz & Janik 2016a; 2016b).	
Seals	GenusWave Ltd: TAST ASD 'FisherySafe' [21b]	60 – 250 m.	No new evidence.	Significant reduction of seal predation on salmon (i.e. 91–97% reduction in predated fish (Götz & Janik 2016a, b). 74% increase of catch of on protected test net (MMO 2020) Reduction in predated fish in jigging and shallow water gillnet fisheries (Gosch *et al*. 2017, 2018).	3 [3]
Seals	GenusWave Ltd: TAST Acoustic Startle Device (ASD) 'Mitigation device' 'TurbineSafe' 'ConstructionSafe' [21c]	60 – 250 m	No new evidence.	Significant reduction in the number of seal tracks within 250 m of the device (Götz & Janik 2015). Can be extended by using multiple units. Up to 500 m in more offshore scenario.	3 [1]

3   Deployment of devices as mitigation

3.1   Overview

The purpose of deploying an ADD is to mitigate the negative impacts of a specified activity by deterring an animal from an area of impact. ADDs use a low-level disturbance effect, for example, to reduce auditory injury during impact piling or clearance of unexploded ordnance, to reduce bycatch in fishing nets or to reduce predation around fish farms. Different activities have different licensing requirements, however, for many, a detailed plan of what specific mitigation will be required is necessary, including how ADDs will be used, and for how long.

Manufacturers do not usually provide guidelines on deployment of ADDs, as these devices are designed with simple functionality and therefore do not require detailed device-specific guidelines. In addition, the specifics of how an ADD may be deployed will vary depending on the requirement of individual projects.

The approach for deployment of ADDs must be determined on a case-by-case basis. If detailed information is required by the Licensing Authority or advisory body, an ADD deployment plan can be produced by the applicant or the information could be included as part of a wider mitigation plan. As an example, the ADD deployment plan could set out the following information:

- details on the ADD device with technical specifications;

- role of ADD operator, including training requirements and experience;

- location of deployment and deployment depth;

- failsafe procedures in place including spares required and method of testing to ensure that the ADD is functioning effectively; and

- task plan to illustrate how mitigation will be carried out through communication with the offshore Operations/Fisheries Manager.

This section sets out the general considerations for deployment of ADD devices, as listed above.

3.2   Operator requirements and training

No training requirements were specified as being required before deploying an ADD at sea by any of the suppliers of the devices reviewed for this report, though many offered training if required.

All devices are operated by either an on/off switch for manual operation or an immersive switch which triggers the device once deployed. For many industry applications, deployment and operation of ADDs can therefore be undertaken by a member of staff/crew, and not necessarily a trained marine mammal field biologist (although this may sometimes be the case). If, however, monitoring of marine mammal presence (i.e. to check if the ADD has cleared the mitigation zone) is required via a hydrophone and computer interface (see section 3.3.3), it may be necessary to employ personnel experienced in the use of Passive Acoustic Monitoring (PAM) systems.

3.3   General principles for deployment

3.3.1   Deployment depth and location

Manufacturers do not give specific deployment requirements for ADDs. Devices are deployed from a platform or vessel to an appropriate depth (specified by a mitigation plan if applicable) and activation is either manual or automatic, depending on the device being used.

When considering the appropriate deployment depth, an ADD should be below the water's surface, the operator should aim to locate the transducer (i.e. the part of the ADD device that converts electrical energy into acoustic energy (Zhang *et al.* 2021)) below the maximum draft of the boat to ensure 360° coverage. The ADD should be lowered to a sufficient depth to avoid interference by surface water noise (surface thermocline) (Lepper *et al.* 2014), but to target the mitigation zone. For example, Götz and Janik (2015) stated they deployed a transducer ~ 2 m below the deepest part of the salmon farm cage. Depth of deployment will highly depend upon the particular activity, ADD platform and the surrounding marine environment (particularly water depth). Findlay *et al.* (2021) suggested 10 m depth was a typical deployment depth in Scottish aquaculture. Similarly, Todd *et al.* (2021) reported typical ADD deployment depths of 15 m depth at Scottish finfish farms. Reported deployment depths vary in published literature. For example Ace Aquatec *et al.* (2022) and Brandt *et al.* (2013a) suspended ADDs 10 m below the surface to investigate responses by harbour porpoise to an ADD device. Boisseau *et al.* (2021) activated a Lofitech ADD at 20 m depth from a Zodiac vessel to test minke whale responses in a control exposure experiment (CEE). In feasibility testing of raft-mounted ADDs, Lehtonen *et al.* (2022) stated the depth of the ADD depended on the depth of water at the site, with the ADD lowered to depths between 3 to 8 m. In CEEs on harbour porpoise, Brennecke *et al.* (2022) deployed pingers at 5 to 10 m depth. Some devices give minimum operating depths, such as 10 to 20 m for DiD01 device (Ceciarini *et al.* 2023), 1.5 m for Targeted Acoustic Startle Technology (TAST) (McKeegan *et al.* 2024, Williams *et al.* 2021) and 10 to 200 m for DDD 03H (De Carlo *et al.* 2012). Devices generally come with a set cable length, but manufacturers may be able to adjust this to specified requirements. The logistics of deploying the ADD should be considered as part of the deployment plan, such as:

(1)   platform for deployment (e.g. vessel, smaller rib, piling platform, on a net);

(2)   where the ADD will be deployed from on a vessel (or multiple vessels);

(3)   the length of cable required for deployment of device to a required depth; and

(4)   deployment location best suited to the ADD in relation to the activity.

The location of deployment is important to consider, particularly in coastal areas where water depth is shallower, channels where access routes could be limited or where multiple devices are required (Todd *et al.* 2019). Factors such as the environment (coastal or pelagic) and ambient noise level must be considered to determine the most appropriate ADD to use. It is the responsibility of the project/developer to select the most appropriate ADD that is (i) compliant (e.g. with any licence conditions/requirements) and (ii) characteristically/practically appropriate to mitigate of the concerned activity.

3.3.2   Spares

To ensure reliability of the deployment plan, it is recommended that as a minimum a spare battery should be included as part of the ADD equipment. Further to this would be to also include one or more back-up devices in the equipment. The need for this however depends on the logistical feasibility of replacing a device, should it malfunction. In practice, it is the

responsibility of the ADD user to ensure ADD use is successful and meets any given requirements.

3.3.3 Testing

It is recommended that both the main ADD unit and back up unit are tested prior to deployment to see if they are working (e.g. using a hydrophone and monitoring via computer interface with suitable software; such as PAMGuard). This would require suitably trained personnel (e.g. PAM operators). In addition to listening in real time, the computer interface shows a spectrogram (frequency over time) plot of the sound. This provides an indication of amplitude, but it is usually uncalibrated and therefore would not yield precise readings. This is not an issue if the device is just being tested for functionality.

Testing should be undertaken before a vessel leaves port (e.g. through an initial deploy and test whilst the vessel is docked).

Detailed information on required equipment, device durability and testing should be provided as part of procurement of an ADD and ultimate responsibility lies with the project/developer and ADD supplier to ensure the device is appropriate.

3.3.4 Length of ADD deployment

It is important to limit length of active ADD deployment due to the risk associated with increased and/or unnecessary disturbance. Whilst the ADD method actively encourages animals to leave an area by generating a sound that will cause a low level disturbance response, the length of deployment must be tailored to each individual situation, such that it is sufficient to flee the injury zone / mitigation zone but minimises any unnecessary additional disturbance from the ADD itself (see section 3.4). The duration of ADD should be tailored to the activity for which mitigation is required (e.g. piling, UXO clearance, preventing bycatch in fishing nets, preventing damage to fish farms) and the target species.

An example ADD deployment protocol for piling is presented in Figure 3-1. It assumes a standard 30 minutes of ADD deployment at the start of an example activity (piling), to account for an animal fleeing based upon a conservative swim speed. In this example, a piling soft start would follow ADD activation, commencing with hammer blows at low frequency and low hammer energy, allowing the animal to flee further. Ramp up (where the hammer energy and strike rate is increased) then commences, allowing further time for the animal to move away. By the end of the ramp up to maximum energy and at full strike rate, the animal is assumed to have left the zone of potential injury.

The protocol for breaks in piling is also included in Figure 3-1 and gives indicative procedures for breaks in piling of less than or more than 10 minutes, and the subsequent protocol for breaks less than 2.5 hours and those over 2.5 hours or in the case of incomplete soft start.

Protocol for piling mitigation at start of piling activity

a. Deploy ADD for a defined period based upon mitigation zone

e.g. 30 minutes

Animal flees up to 2,700 m based on 1.5 m/s swim speed

↓

b. Soft start commences with hammer blows at a low frequency and at as low hammer energy as practically possible

e.g. 5 blows at 1 blow per 10 seconds at <300 kJ

Animal continues to flee 90 m

↓

c. Soft start continues with an increased frequency over a period of no less than 20 minutes

e.g. ~1 blow per 2 seconds, starting at ≤300 kJ and not exceeding 500 kJ in the second half of soft start

Animal continues to flee 1,800 m

↓

d) Piling sequence ramps up (as required) at each location to maximum energy required to drive pile up to necessary target depth

Protocol to be used in planned or unplanned breaks

Break in piling <10 minutes, piling continues at the last used hammer energy and frequency.

Break in piling > 10 minutes the following options will be followed:

↓ ↓

b i) For break < 2.5 hours ADD is deployed for 15 minutes immediately prior to piling

c. For break > 2.5 hours or after incomplete soft start, the mitigation procedure recommences as described in Protocol for mitigation at start of piling activity

↓

b ii) Soft start initiated with single flows at a low frequency and at as low energy as practically possible

e.g. 5 blows at 1 blow per 10 seconds at <300 kJ

↓

b iii) Piling sequence ramps up (as required) at each location to maximum energy required to drive pile up to necessary target depth

Figure 3-1: Example ADD deployment protocol for piling. Note that the fleeing distance has been estimated at each stage of the protocol to demonstrate that the distance cleared is sufficiently greater than the injury range. Reproduced with permission from Beatrice Offshore Wind Farm Ltd (2017).

3.3.5   Task plan

As part of the mitigation plan, and for projects that require careful timing of ADD deployment to coincide with specific activities (e.g. offshore piling operations), it is recommended that the applicant produces a task plan to show the lines of communication between the ADD operator and the operations manager. An example of such a task plan has been shown below in Figure 3-2. It must be noted that task plans will be highly project specific and tailored to the activity for which mitigation is being used, with ADD deployment length tailored to the required mitigation zone. The use of ADD should be incorporated into any other mitigation measures (such as PAM, MMO, noise abatement, soft start, prioritising methods that result in less noise) and align with guidelines on a project level.

Figure 3-2: Example ADD task plan for deployment of an ADD as a mitigation measure during pile-driving activity (reproduced with permission from BOWL (2017)).

3.4   Considerations to minimise potential risk to marine mammals

ADDs have widely been used in aquaculture regularly to address fish depredation and mitigate bycatch. However, with increasing development in the marine environment, the likelihood for increased ADD requirement for construction and operational activities (e.g. underwater tidal turbines) is high. When assessing potential impacts from a specific activity and the need for an ADD, consideration should always be first given to alternative methods which may reduce the impact (e.g. low order clearance of UXO), or alternative mitigation solutions that do not release additional noise into the marine environment (e.g. noise abatement when piling). These may not always remove the need for an ADD but as a minimum they may reduce the duration for which it is deployed.

With each additional operational ADD, the potential contribution to increased anthropogenic noise above the ambient baseline also increases, which itself could cause a negative effect. Therefore, consideration should be given to minimising the noise introduced into the environment. Pertinent considerations include (but are not limited to):

- active deployment time (and source level) of an ADD relevant to risk (section 3.4.1);

- the requirement (if any) for deploying multiple ADDs (section 3.4.2); and

- active ADDs and marine mammal sightings (section 3.4.3).

The design of mitigation protocols for ADD deployment and operation should take into account any noise guidelines for ADDs, where they exist. Other guidelines such as those which focus on minimising the risk of injury from construction activities such as piling noise (JNCC 2010a) and UXO clearance (JNCC, 2017) have been considered in the absence of specific ADD deployment guidance.

3.4.1 Active deployment time (and source level) of an ADD relevant to risk

As discussed in section 1.3, ADDs have the potential to induce auditory injury in marine mammals, predominantly through of the continuous activation of devices, and therefore have the potential to themselves cause a negative effect in marine mammals. Consideration should therefore be given to designing a mitigation protocol which focusses on operating the device for the shortest possible time, and at the lowest source level that still achieves the required disturbance ranges. Operational parameters should be established on a case-by-case basis rather than a standard set of guidelines, as context-specific conditions (such as water depth, bathymetry, sea state, salinity) will affect parameters such as sound propagation and transmission loss (Todd *et al.* 2019). Furthermore, operational parameters should be appropriate to the target activity for which ADDs are being used (e.g. ADD use will be different for mitigating offshore construction activities such as piling or UXO clearance compared to those used for fisheries depredation or aquaculture).

When designing a mitigation protocol (e.g. a MMMP), factors to consider in determining the duration (and source level) of ADD activation include (but are not limited to):

- the size of the risk zone (i.e. auditory injury zone or collision risk zone, such as in the case of construction/operational activities) or the duration of the activity (e.g. in the case of depredation at fish farms);

- swim speeds used in determining how fast an animal will likely move out of the risk zone; and

- likely return time of an animal to the risk zone (either once the primary activity has stopped or between breaks in activity).

Determining the duration of deployment could employ a simple calculation to estimate the time required for an individual to exit a given radius (the risk zone), by dividing that radius distance by a species-specific swim speed. Species-specific swim speeds are often derived from published literature or provided in guidance documents (e.g. Scottish Natural Heritage (2016), or Natural England (2022)), however, this assumes that every animal would swim in a straight horizontal line and at a constant speed. It has been shown that marine mammals change their behaviour in the presence of anthropogenic underwater noise (Weilgart 2007). For example, individuals may respond by spending more time at the surface where received sound levels are generally lower (Richardson *et al.* 1995), extending dive time (Boisseau *et al.* 2021) or increasing swimming speed (Stone & Tasker 2023). As such, animals which swim directly away from a sound source will likely be able to exceed agreed conservative swim speeds. For example, Otani *et al.* (2000) reported harbour porpoise horizontal speed can be significantly faster than vertical speed and cited a maximum speed of 4.3 m/s compared to the median of 0.8 m/s (Otani *et al.* 2000). Boisseau *et al.* (2021) reported swim speeds of minke whale up to 2.3 m/s and stated in all deployments ADD caused focal animals to move away immediately and typically increased horizontal speed and directness, extending dive duration (surfacing for air less). Using a precautionary swim speed allows

contingency for animals that do not swim in a straight line or have resting periods, but swim speed should be carefully considered and following guidance where possible (e.g. Natural England 2022), as if swim speed is overly-cautious ADDs may inadvertently be deployed for longer than is necessary to deter the animal from the risk zone.

There is also a need to balance proportionate deployment time with ensuring an animal does not return to the risk zone prematurely (for example if there is a break in the activity). Consideration should be given to the likely time it will take for an animal to return to a risk zone on cessation of ADD operation. Although it should be noted that whilst there is growing evidence on the extent to which marine mammals directly respond to ADD activation, Thompson *et al.* (2020) highlights more data on the time it takes animals to return to affected areas is required.

Recent investigations found that harbour porpoises could be excluded from a 1 km radius for over two hours, following deployment of a specified Lofitech ADD at a piling site at Beatrice Windfarm for 15 minutes (Thompson *et al.* 2020). Similar deterrence responses using different ADDs (e.g. seal scarers; Lofitech ADD) were observed in field trials over test durations of 30 minutes (Brandt *et al.* 2013b) and 15 minutes for harbour porpoise (Graham *et al.* 2019; Mikkelsen *et al.* 2017) 15 minutes for minke whale (McGarry *et al.* 2017), and 20 minutes for harbour seal and grey seal (Mikkelsen *et al.* 2017). Hardy *et al.* (2012) showed long periods of exclusion following ADD operation (pingers) on monk fishing nets for harbour porpoise, with a significant reduction in clicks (probability of no detection in 7-hour period was 0.9388) throughout the seven hour down period following the period of normal pinger use. In contrast, it has been shown that porpoise click detections recovered almost immediately after ADDs were switched off at two Scottish salmon farm sites (Sound of Mull and Loch Sunart) (Northridge *et al.* 2010), and therefore the possibility that animals will return to the risk zone directly after an ADD is switched off must be considered. Behavioural responses will likely vary due to a range of factors, such as the ADD chosen and its acoustic characteristics (see Table 2-2) (e.g. the source level, the setting of the device, duty cycle), the duration of ADD activation or repeated activations, the target species, any noise-producing activity (e.g. piling, UXO clearance) prior or post ADD activation, ambient noise levels and prior exposure of animals to ADDs.

Ultimately, a balance must be struck between ensuring the animal is deterred from the risk zone and minimising the ADD duration required to avoid unnecessary additional anthropogenic underwater noise. Robust scientific literature should be used in combination with relevant contextual information on a case-by-case basis to establish the most appropriate protocol for ADD deployment. Further research on movements of animals in response to ADDs will aid in establishing an appropriate balance.

3.4.2   The requirement (if any) for deploying multiple ADDs

Deploying multiple ADD devices is common place in aquaculture and for depredation of fisheries (Northridge *et al.* 2010; Todd *et al.* 2019), but it is possible that during construction activities multiple ADD device deployments could be required (albeit over shorter periods of time compared to use on finfish farms, at which ADDs are deployed for long periods of time). However, it is important to consider whether similar or the same disturbance effects can be achieved with a single device, to reduce unnecessary additional anthropogenic underwater noise. For example, Rosemeyer *et al.* (2021) detailed how, until 2016, multiple ADDs (one seal scarer and two or three pingers) were deployed in a stepwise manner to provide a soft-start deterrence measure for German offshore construction projects. Lower-source-level devices would be operated first to exclude animals in the first few hundred metres, before higher-source-level devices are engaged to operate over greater distances. This effect could also have been achieved through gradual increase of a device source level, as recommended by Schaffeld *et al.* (2019).

Furthermore, spacing between devices is pivotal and must consider the emission radius of a single device, which is evidenced by the importance of spacing of ADDs on fishing nets; if ADDs are not spaced appropriately, this can lead to increased risk of cumulative effects. For example, in a study on interactive ADDs on trammel nets to reduce dolphin–fishery interactions Ceciarini *et al.* (2023) specified that the horizontal spacing between two DiD01 devices must be 600–800 m, as recommended in the device manual. Spacing varies by device and by target species and should follow manufacturer specifications where possible. For example, manufacture guidance states that the Future Oceans Dolphin pinger should be spaced every 200 m whilst the Future Oceans Whale Pinger and Future Oceans Porpoise and Dolphin Pinger should be spaced every 100 m.

As discussed in section 3, the simultaneous deployment of multiple ADDs may create a confusing sound field (Todd *et al.* 2019), with the potential to deter marine mammals from multiple sections of key habitat (rather than just one area) (based upon modelling of ADDs at a fish farm in Sound of Mull, Scotland in Todd *et al.* 2019), or in extreme cases has the potential to increase the area in which PTS threshold levels are exceeded. For example, Findlay *et al.* (2021) modelled the spatial extent of ADD noise at known aquaculture sites on the Scottish west coast, and reported that in a single ADD scenario, harbour porpoise PTS thresholds were exceeded over 0.2% of the Inner Hebrides and Minches Special Area of Conservation (SAC) compared to a multiple-ADD device scenario where PTS thresholds were exceeded over 0.9% of the SAC. Findlay *et al.* (2021) generated noise field maps to determine the risk of auditory impairment for harbour porpoises for both single and multiple ADDs (the authors stated there is a lack of information on aggregate duty cycles of sites with multiple devices and therefore as a proxy for aggregate duty cycles of multiple overlapping devices used either 75% or 100%) and simultaneous use across all sites. The study determined that for scenarios of multiple devices, areas exceeding ambient sound levels by more than 10 dB were larger than for the single-device scenario, with increased median distances for onset of TTS and PTS for multiple devices. Whilst this study relates to ADD deployment at fish farms and therefore not directly comparable to shorter periods of ADD deployment at noise-producing construction activities, it provides useful insight into potential cumulative effects of ADDs, where information is otherwise lacking.

Operation of up to 20 devices per site has been common practice on fish farms (Northridge *et al.* 2010). Findlay *et al.* (2018) highlighted overlapping signals, even of the same device, may alter the original duty cycle of ADDs and reduce silent periods between pulses, ultimately increasing the length of time of exposure to ADD noise (Götz & Janik 2013; Harris *et al.* 2014). It has further been suggested the effects of multiple ADDs in an area may be heightened where different ADD devices are deployed sufficiently close for noise sound fields to overlap spatially, potentially resulting in increased and more complicated ambient noise fields (Götz & Janik 2013). Findlay *et al.* (2024) used nine years of boat-based acoustic line-transect data for harbour porpoise along the west coast of Scotland alongside ADD presence and perceived loudness by volunteers at listening stations to assess if harbour porpoise respond to chronic ADD noise from aquaculture (using energy source levels for the Ace Aquatec US2, Airmar db Plus II and Terecos Type DSMS-4). The study suggested harbour porpoise are either displaced from habitats degraded by intense ADD noise, or echolocated less, with the most intense ADD noise coinciding with significantly fewer harbour porpoise detections than those with no ADD noise (Findlay *et al.* 2024). Findlay *et al.* (2024) did however highlight individual differences in tolerance during exposure to ADD noise were evident.

Therefore, when deploying multiple ADDs, whilst more evidence is needed to understand the potential additive effects, more consideration of the implications of overlapping duty cycles is required. The design of mitigation protocols for ADD deployment and operation should consider potential operational benefits against potential ecological risks. In evaluating information available for consideration when designing mitigation protocols for ADD

deployment, in the absence of specific guidance for the deployment of ADDs, other guidelines (such as those which focus on minimising the risk of injury from piling noise (JNCC 2010a)) have been considered.

Factors to consider to minimise risk to the animal

The design of mitigation protocols for ADD deployment, and the consideration of whether one or multiple ADDs are appropriate, will need to consider certain factors, which will be influenced by situation-specific contextual information. Section 3.3 sets out principles for practical deployment of ADDs in general whilst this section (3.4) sets out the considerations of multiple ADD deployment in terms of risk to the animal.

Factors to consider, to minimise risk to an animal, include:

- whether one ADD is sufficient to cover the risk zone (i.e. if multiple or concurrent activities can still be mitigated using one ADD);

- whether one ADD is sufficient to target multiple species/hearing groups if desired (i.e. if a single device has the capability to deter all the necessary species/hearing groups from the risk zone) or whether multiple devices that target different hearing groups are required;

- if it is determined that more than one ADD is required, it is important to consider that:

  o if activities (such as piling events) occur in close proximity to one another, whilst the geographical extent of ensonification from ADDs deployed at these piling locations may be more limited than ADDs spaced at larger distance, the potential for additive noise effects and the potential for barrier effects should be considered; and

  o if activities (such as piling, UXO clearance) occur several kilometres apart, sound fields from individual ADDs may not overlap or interact (and therefore the potential for additive noise effects would not need to be considered), but the overall area of ensonification will be far larger than a single ADD, and consideration should still be given to the potential for barrier effects.

The use of multiple ADDs is therefore highly context dependent and in each case, consideration should be given to the potential for auditory injury, the potential for exclusion from key habitats as well as the potential for barrier effects to occur. There is a lack of sufficient research on the deployment of multiple ADDs, with much of the evidence from aquaculture, and therefore there may be additional unknown risks to be considered.

Furthermore, the use of multiple ADDs will be dependent on activity/platform type and associated practical limitations. Protocols must consider whether the ADD needs be deployed from a stationary or towing platform, for which there will be different practical safety implications to consider, alongside other risks such as entanglement for marine mammals.

As such, it is essential that any mitigation protocol which considers multiple ADDs should be designed to align with existing guidelines and in consultation with appropriate experts, licencing authorities and ADD operators.

3.4.3   Active ADDs and marine mammal sightings

There is a large amount of evidence, as detailed in Table 2-3, which shows animals move away from an ADD and therefore ADDs can be successfully used as tools for mitigation. Literature includes evidence for clear reductions in animal encounters/detections during

ADD activation (Rose 2019; Thompson *et al.* 2020; Voss *et al.* 2023), behavioural responses such as fleeing or moving away, increasing speed and extending dives (Boisseau *et al.* 2021; Elmegaard *et al.* 2023).

Whilst ADD operation duration has been given consideration in section 3.4.1, this section covers the operational considerations of deploying ADDs in the event of an animal sighting within a mitigation zone/risk zone. In particular, operational responses to a marine mammal sighting within the risk zone should consider the following:

- if an animal is sighted or detected within the mitigation zone, prior to ADD activation; or

- if an animal is sighted during ADD operation.

Current JNCC guidance for minimising the risk of injury from UXO or other explosives (JNCC 2010b, 2023), piling noise (JNCC 2010a) and geophysical surveys (JNCC 2017) states that operations should be delayed by at least 20 minutes (JNCC 2010a) if a marine mammal has been sighted within the mitigation zone or detected via PAM before operations commence.

There is evidence which suggests that if an animal is sighted within a risk zone during ADD operation, the ADD will be more effective in deterring the animal (i.e. minimising risk to the animal) if the ADD remains active (rather than turning it off and on again). Tixier *et al.* (2015) showed an ADD was only effective in deterring killer whales when individuals were first exposed to the activated ADD (during 20 / 15 minutes longline net hauling periods, with the ADD turned off after each period). Behavioural responses disappearing after successive exposures, therefore Tixier *et al.* (2015) suggested that killer whales became habituated to the ADD (and withstand potentially harmful hearing disturbance to access the prey resource made available by the longliners). SMRU Ltd (2007) highlighted that whilst any learned association from animals to ADD signals will be likely associated with a negative re-enforcer (e.g. piling, UXO clearance) there is the potential for habituation to these ADD signals. Northridge *et al.* (2010) also found that harbour porpoises appeared to be less averse to sites where ADDs had been used for several years, but suggested varying signals may aid in minimising this risk and therefore could be considered in future ADD deployment in areas with higher historical ADD usage.

For other sound producing activities where specific operational guidance is available (i.e. piling) (JNCC 2010a) if a marine mammal is detected in the mitigation zone it is deemed to have entered "voluntarily" (some scientific evidence for this "voluntary" hypothesis exists (e.g. Northridge *et al.* (2010), Stone (2023)), but is largely based on a common-sense approach and field observations. Note, however, that other factors, such as food availability, may result in marine mammals approaching noise-producing operations). For example, Northridge *et al.* (2010) found the highest levels of harbour porpoise activity were recorded only 200 m (the closest monitoring site) from active ADDs. Northridge *et al.* (2010) therefore suggested that the exclusion effect is voluntary rather than obligatory. Similarly, both harbour porpoises and harbour seals have been observed within hearing range of active ADDs (Olesiuk *et al.* 2002). Recently, Stone (2023) reported nine sightings of marine mammals within the mitigation zone when ADDs were active during pile driving activities. Some animals disappeared and/or were recorded as swimming away, but others, seals in particular, were not deterred and appeared close to the piles. Stone (2023) detailed a grey seal coming within 1 m from the pile and ADD, and a harbour seal attempting to climb the pile while the ADD was active, remaining in the mitigation zone for 51 minutes. The report included recommendations for ADD use (as part of recommendations for items to be considered when the piling guidelines are next revised), which included continued monitoring alongside the use of ADDs and applying caution in the use of ADDs to reduce the risk of TTS and far-field disturbance.

Whilst careful consideration of active ADD deployment is required when designing mitigation to avoid potential habitation or voluntary risk behaviour, it is important to re-iterate there is substantial evidence of ADDs working to deter animals efficiently from potential injury zones (as detailed in Table 2-3), and importantly, evidence of animals returning to the area after ADD operation (Voss *et al.* 2023).

As previously highlighted, it is essential that any mitigation protocol should be designed to align with existing guidelines and in consultation with appropriate experts, licencing authorities and ADD operators.

4   Conclusion

This report aims to provide high level guidance on ADD use and aspects to consider when deploying ADDs, alongside more detailed information on available ADDs (at the time of writing). The report collates information from manufacturers and available literature and summarises available evidence on devices available for use in marine industries such as fisheries and offshore renewables. Detailed and specific information on ADDs and their associated acoustic characteristics has been collected from ADD manufacturers. In addition, relevant literature has been reviewed to provide confidence scorings for the information available on the effects of ADDs on marine mammals, with reference to a specified species or species group.

This report has been produced with input and review by a steering group, comprising the JNCC, Natural England, NatureScot, NRW and DAERA.

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6 Appendix: Acoustic Device Technical Information

The following appendices provide a summary of technical information for each of the devices discussed in the report.

Note: the response rate from manufacturers was relatively low (61%) and, therefore, there are information gaps in some of the technical specifications presented.

6.1 Ace Aquatec: Marine Mammal Mitigation Device (A-MMD) Low frequency deterrent – Pinnipeds

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 182 dB re 1 uPa at 1 m (RMS)	Manual or automatic control over volume
Frequency (frequency range and swept band or single frequency)	Flex (Setting 1): 0.9 – 1.4 kHz Ring (Setting 2): 1.0 – 2.0 kHz	0.8-5 kHz available and user controlled.
Continuous/ intermittent	Intermittent.	Manual selection of 9x short duration, random pulses of sound that avoids habituations and hearing loss
Duty cycle	0.9–11% (min/max)	-
Range	70 m radius effective range	-
Battery	12 V deep-cycle non-spillable gel battery (50aH)	Recharge intervals depend on rate. System trickle charges; DC rapid charger connected to mains AC in.
Training requirements	No training required, plug and play.	Full manual provided and training available if required.
Device testing	Device testing is carried out by Neptune Sonar on site using in water testing with hydrophones. Voltage readings are monitored during use through the Ace Aquatec portal and alerts given if voltages change internally. Test function available manually/remotely.	Suggested field-testing using hydrophone and third-party monitoring via suitable computer software
Deployment	Typically, via rope or crane from side of installation vessel to 10 m. Cables link control box and battery to transducer; manually/remotely activated via base station	Standard is 35 m cable, longer cable (can be ordered if required. Ruggedised housing for rough weather, fully submersible to 100 m
Functionality	Simple on/off (Scram/Mute) function via OLED screen + keypad, then set the rate.	Manual settings also possible controlling duty cycle, tone quality, pulse interval, sound varieties. Remote updates of sound patterns /other software available.

6.2   Ace Aquatec: Marine Mammal Mitigation Device (MMD) Ultra low frequency – Fish (not commercially available)

Ultra-low frequency and high frequency variants of the MMD can be made available upon request but not offered as standard.

Parameter	Manufacturer's specification	Notes
Source level	Average within transmission: 182 dB re 1 µPa at 1 m (RMS)	Manual or automatic control over volume
Frequency (frequency range and swept band or single frequency)	200–900 Hz.	The system can be programmed with a defined frequency spread within this band
Continuous/ intermittent	Intermittent.	Duration between pulses is on a random cycle.
Duty cycle	0.9–11%	-
Range	70 m	-
Battery	Automatically charges from universal AC supply with 12V deep-cycle non spillage gel battery.	Recharge intervals depend on rate (24 – 48 hours typically). The system also trickle charges and has a DC booster charger connected to mains AC.
Training requirements	No training required as plug and play.	Full manual provided and training available if required.
Device testing	Device testing is carried out by Neptune Sonar on site using in water testing with hydrophones. Voltage readings are monitored during use through the Ace Aquatec portal and alerts given if voltages change internally. Hydrophone testing may also be carried out on site.	Suggested testing using hydrophone and monitoring via suitable computer software (e.g. PAMGuard).
Deployment	Cable links transducer to control unit, manually activated.	Standard is for 40 m cable, but able to order longer cable if required.
Functionality	Simple on/off switch and set rate.	Manual settings also possible controlling duty cycle, tone quality, pulse interval, sound varieties. Remote updates of sound patterns available.

6.3 Ace Aquatec: Marine Mammal Mitigation Device (A-MMD) Mid-frequency – Pinnipeds and Cetaceans

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 188 dB re 1 µPa at 1 m.	Manual or automatic control over volume
Frequency (frequency range and swept band or single frequency)	8 – 20 kHz.	Measured fundamental frequency at 12.1 kHz with harmonics at 17 kHz and 23 kHz (Lepper *et al.* 2004).
Continuous/ intermittent	Intermittent.	Duration between pulses is on a random cycle.
Duty cycle	0.8–11%	-
Range	<1000 m	-
Battery	Automatically charges from universal AC supply with 12V deep-cycle non-spillable gel battery.	Recharge intervals depend on rate (24 – 48 hours typically). The system also trickle charges and has a DC booster charger connected to mains AC.
Training requirements	No training required as plug and play.	Full manual provided and training available if required.
Device testing	Device testing is carried out by Neptune Sonar on site using in water testing with hydrophones. Voltage readings are monitored during use through the Ace Aquatec portal and alerts given if voltages change internally.

Hydrophone testing may also be carried out on site. | Suggested testing using hydrophone and monitoring via suitable computer software (e.g. PAMGuard). |
| Deployment | Cable links transducer to control unit, manually activated. | Standard is for 25 m cable, but able to order longer cable if required. |
| Functionality | Simple on/off switch and set rate. | Manual settings also possible controlling duty cycle, tone quality, pulse interval, sound varieties.

Remote updates of sound patterns available. |

6.4   Ace Aquatec: Marine Mammal Mitigation Device (MMD) High Frequency – Pinnipeds and Odontocetes (not publicly available)

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 180 dB re 1 µPa at 1 m.	-
Frequency (frequency range and swept band or single frequency)	20 – 70 kHz.	-
Continuous/ intermittent	Intermittent.	Duration between pulses is on a random cycle.
Duty cycle	0.8–11%	-
Range	-	-
Battery	Automatically charges from universal AC supply with 12 V deep-cycle non-spillable gel battery.	Recharge intervals depend on rate (24 – 48 hours typically). The system also trickle charges and has a DC booster charger connected to mains AC.
Training requirements	No training specified.	Full manual provided and training available if required.
Device testing	Device testing is carried out by Neptune Sonar on site using in water testing with hydrophones. Voltage readings are monitored during use through the Ace Aquatec portal and alerts given if voltages change internally. Hydrophone testing may also be carried out on site.	Suggested testing using hydrophone and monitoring via suitable computer software (e.g. PAMGuard).
Deployment	Cable links transducer to control unit, manually activated.	Standard is for 40 m cable, but able to order longer cable if required.
Functionality	Simple on/off switch and set rate.	Manual settings also possible controlling duty cycle, tone quality, pulse interval, sound varieties. Remote updates of sound patterns available.

6.5   Ace Aquatec: Universal Scrammer (US2) (obsolete)

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 181 dB re 1 µPa at 1 m (RMS).	-
Frequency (frequency range and swept band or single frequency)	8 – 30 kHz.	-
Continuous/ intermittent	Transmission duration of 20 sec (double scram 40 s), and a pulse duration of 20 ms.	Pulse uniformity shortens from 14 ms to 3.3 ms followed by an upshift in the frequency of the tonal components and their equivalent distribution (Lepper *et al.* 2004).
Duty cycle	~3% 5.5 scrams an hour.	-
Range	None specified	-
Battery	None specified	-
Training requirements	None specified	-
Device testing	None specified	-
Deployment	None specified	-
Functionality	None specified	-

6.6   Ace Aquatec: Mid-Frequency Acoustic Startle Response Device (US3) (formerly Universal Scrammer) – seals/sealions (for aquaculture)

Note: Ace Aquatec devices are differentiated into MMD's and the US3 and RT1; the frequency bands for the MMDs are open. Those for the US3 and RT1s are restricted.

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 181 dB re 1 µPa at 1 m	Testing undertaken at Neptune Sonar calibration testing facility, Driffield and St Andrews University.
Frequency (frequency range and swept band or single frequency)	8–11 kHz (with 8-20 kHz ability if required)	Measured by firing a scram and listening with a D/70 Hydrophone, s/n 34376 attached to a Keysight MXA N9020B Vector signal analyser
Continuous/ intermittent	Intermittent.	Transmission consists of 2.6 s bursts of 3–11 ms rise time pulses; in a randomised pulse train to create a startle response.
Duty cycle	0.8–5%	-
Range	50 m	Goetz (2008) Low duty cycle, and low average energy avoid hearing impairment and impact on non-target species
Battery	Automatically charges from universal AC supply, with 12V deep-cycle non- spillable gel battery	-
Training requirements	No training required as the system is plug and play	Full manual provided and training available if required
Device testing	Device testing is carried out by Neptune Sonar on site using in water testing with hydrophones. Voltage readings are monitored during use through the Ace Aquatec portal and alerts given if voltages change internally. Hydrophone testing may also be carried out on site	-
Deployment	20 m – 40 m cables. Mains and battery. Internet connectivity with 4G	Ruggedised housing for rough weather, fully submersible to 100 m, cabling to 200 m
Functionality	Fully automated determining the pulse trains, volume and frequency after initial portal set up. Compatible with A.I camera triggers for seal detection using A.I algorithms	A.I trigger monitors and labels wildlife around the farm, avoiding scrams when non target wildlife is detected, and triggering scrams only when a predator is detected. This system is autonomous.

6.7 Ace Aquatec: Low-Frequency Acoustic Startle Response Device (RT1/FS1) (for aquaculture)

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 180 dB re 1 µPa at 1 m (ring transducer) 182 dB re 1 µPa at 1 m (Flex transducer)	Flex or ring is the style of transducer manufactured and supplied, each with slightly different resonances. Source level measured by Neptune Sonar and St Andrews University.
Frequency (frequency range and swept band or single frequency)	Flex (Setting 1): 0.8 kHz – 1.2 kHz Ring (Setting 2): 1.0 kHz – 2.0 kHz	Measured by firing a scram and listening with a D/70 Hydrophone, s/n 34376 attached to a Keysight MXA N9020B Vector signal analyser
Continuous/ intermittent	Intermittent.	Randomised pulse train, with 3-11 ms rise time pulses, of 2.6 sec duration to create a startle response.
Duty cycle	0.2–5% duty cycle	-
Range	100 m (Can be heard up to 1 km)	Low duty cycle, and low average energy avoid hearing impairment and impact on non-target species.
Battery	Automatically charges from universal AC supply, with 12 V deep-cycle non-spillable gel battery	Recharge intervals depend on rate. System trickle charges; DC rapid charger connected to mains AC in.
Training requirements	No training required as the system is plug and play	-
Device testing	Device testing is carried out by Neptune Sonar on site using in water testing with hydrophones. Voltage readings are monitored during use through the Ace Aquatec portal and alerts given if voltages change internally. Hydrophone testing may also be carried out on site.	-
Deployment	35 m cables. Mains and battery. Internet connectivity with 4G or Wi-Fi connection and remote control.	Ruggedised housing for rough weather, fully submersible to 100 m

Parameter	Manufacturer's specification	Notes
Functionality	Fully automated determining the pulse trains, volume and frequency after initial portal set up. Compatible with sonar triggers for seal detection using A.I algorithms.	A.I triggers monitors and labels wildlife around the farm, avoiding scrams when non target wildlife is detected, and triggering scrams only when a predator is detected. This system is autonomous.

6.8 Airmar dB Plus II (now Mohn Aqua MAG seal deterrent) (discontinued)

Note: dB Plus II (became Mohn Aqua MAG seal deterrent) been discontinued by Airmar, confirmed by Airmar in 2024.

Parameter	Manufacturer's specification	Notes
Source level	Nominal SPL output = 198 dB re 1 µPa at 1 m (RMS).	Measured sound level = 192 dB re 1 µPa (RMS) at the fundamental frequency of 10.3 kHz (Lepper *et al*. 2014).
Frequency (frequency range and swept band or single frequency)	None specified	A broadband spectral response at the beginning of each pulse, with detectable energy levels between 1.5 kHz to 50 kHz (Lepper *et al*. 2014).
Continuous/ intermittent	Continuous.	Sequence of pulsed sinusoidal tonal bursts (Lepper *et al*. 2014).
Duty cycle	Each tonal burst is ~1.4 ms in duration with 40 ms interval. A 2.25 sec long sequence is then formed from 57–58 tone bursts. The sequence is then repeated with ~50% duty cycle allowing ~2 sec quiet period (Lepper *et al*. 2014).	Low-power mode option where duty cycle is reduced from 2.5 sec ON – 2 sec OFF, to 2.5 sec ON – 6.5 sec OFF. Manufacturer advises against using this mode for long periods as it will result in less optimal protection from predators.
Range	System provides up to 3000 m^2 of protection for a typical aquaculture application.	-
Battery	In remote locations, a wind generator or 4-panel solar array is the recommended power supply. Locations with shore power should 94andomi mains with a 24 Volt battery.	Normal mode operates when the battery voltage is above 22 VDC; power save mode is automatically activated when the battery voltage drops below 22 VDC; shut down mode is activated whenever the battery voltage drops below 22 VDC.
Training requirements	None specified	-
Device testing	None specified	-
Deployment	Typical deployment involves four transmitters each being fired in turn, each with a 2 sec quiet period.	-
Functionality	Simple on/off switch. Has a soft start feature with a 70 sec ramp up to full power when the transmitter is first switched on.	Must be locked in the Off-switch position whenever a person is underwater and within 150 metres of a transducer.

6.9   Airmar: Gillnet Pinger

Parameter	Manufacturer's specification	Notes
Source level	Nominal SPL output = 132 dB re 1 µPa at 1 m.	-
Frequency (frequency range and swept band or single frequency)	10 kHz.	-
Continuous/ intermittent	Continuous.	-
Duty cycle	Pulse duration 300 ms with repeat intervals of 4 s.	-
Range	Can be detected by mammals within a 91 m radius.	-
Battery	"D" cell alkaline battery.	Over one-year of continuous operation from a single "D" cell alkaline battery.
Training requirements	No training specified.	-
Device testing	None given.	-
Deployment	Designed for placement every 91 m at bridles and net ends.	-
Functionality	None specified	-

6.10 Aquatec Group: Aquamark 848

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output = 165 dB re 1 µPa at 1 m.	-
Frequency (frequency range and swept band or single frequency)	Primary bandwidth 5 kHz to 30 kHz. Harmonic energy to 120 kHz.	-
Continuous/ intermittent	AQUAmark chirp repertoire for general deterrence; Pseudo-clicks for echo-location confusion; Pseudo-noise for echo-location masking; Random composite of all modes.	-
Duty cycle	None specified	-
Range	Up to 1500 m depending on species and nature of interaction.	-
Battery	None specified	-
Training requirements	None specified	-
Device testing	None specified	-
Deployment	None specified	-
Functionality	None specified	-

6.11 Aquatec Group: Aquamark 100, 200, 210, 300

Parameter	Manufacturer's Specification			
Device	a	b	c	d
	Aquamark 100	Aquamark 200	Aquamark 210	Aquamark 300
Source level	Nominal SPL output = 145 dB re 1 µPa at 1 m (Dawson *et al*. 2013)	Nominal SPL output = 145 dB re 1 µPa at 1 m (Dawson *et al*. 2013).	Nominal SPL output = 150 dB re 1 µPa at 1 m (Dawson *et al*. 2013).	Nominal SPL output = 132 dB re 1 µPa at 1 m (Dawson *et al*. 2013).
Frequency (frequency range and swept band or single frequency)	20 – 160 kHz (Dawson *et al*. 2013).	5 - 160 kHz (Dawson *et al*. 2013)	5 - 160 kHz (Dawson *et al*. 2013).	10 kHz (Dawson *et al*. 2013).
Continuous/ intermittent	Continuous (Dawson *et al*. 2013).	Continuous (Dawson *et al*. 2013).	Continuous (Dawson *et al*. 2013).	Continuous (Dawson *et al*. 2013).
Duty cycle	Signal duration of 200 – 300 ms, with a signal interval of 5 – 30 sec (Dawson *et al*. 2013).	Signal duration of 200 – 300 ms, with a signal interval of 4 – 21 sec (Dawson *et al*. 2013).	Signal duration of 50 – 300 ms, with a signal interval of 5 – 30 sec (Dawson *et al*. 2013).	Signal duration of 300 ms, with a signal interval of 4 sec (Dawson *et al*. 2013).
Range	None specified			
Battery	None specified			
Training requirements	None specified			
Device testing	None specified			
Deployment	None specified			
Functionality	None specified			

6.12 IFREMER/IX Trawl: Cetasaver V.03

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output = 165 dB re 1 µPa at 1 m (Dawson *et al.* 2013)	-
Frequency (frequency range and swept band or single frequency)	30 – 150 kHz (Dawson *et al.* 2013)	Signal 1: Frequency modulated signal between 30–150 kHz. Signal 2: Click train at 90 kHz. (Berrow *et al.* 2008)
Continuous/ intermittent	Continuous (Dawson *et al.* 2013).	Signal 1: 1 sec duration (random time and frequency randomised sweeps of base square wave). Signal 2: Click train of 0.1 sec duration, with a constant click time and repetition. (Berrow *et al.* 2008)
Duty cycle	None specified	Signal 1: repeated at a minimum of every 2 sec, maximum of 5.5 sec with an average of 4 sec. Click train of 0.1 sec duration, with a constant click time and repetition. (Berrow *et al.* 2008)
Range	None specified	-
Battery	None specified	-
Training requirements	None specified	-
Device testing	None specified	-
Deployment	None specified	-
Functionality	None specified	-

6.13   STM Products: Dolphin Deterrent Devices (03L, 03N, 03H, 03U) and Dolphin Interactive Deterrent DiD)

Parameter	Manufacturer's Specification				
Device	a	b	c	d	e
	DDD 03L	DDD 03N	DDD 03H	DDD 03U	DiD01
Source level	Nominal SPL output = 165 dB re 1 µPa at 1 m.				
Frequency	5 – 500 kHz (Random).				
Continuous/ intermittent	Intermittent (low).	Intermittent (normal).	Intermittent (high).	Intermittent (ultra-high).	Interactive.
Duty cycle	Av. Duration between each pulse is 150 sec. Pulse duration can be random or vary between 500 ms and 9000 ms.	Av. Duration between each pulse is 90 sec. Pulse duration can be random or vary between 500 ms and 9000 ms.	Av. Duration between each pulse is 40 sec. Pulse duration can be random or vary between 500 ms and 9000 ms.	Av. Duration between each pulse is 25 sec. Pulse duration can be random or vary between 500 ms and 9000 ms.	Device remains in standby until it detects the presence of mammals in the area. It's then the device will emit noise.
Range	None specified				
Battery	Av. Battery charge duration is 300 hours. Up to 1000 charging/ discharging cycles.	Av. Battery charge duration is 120 hours. Up to 1000 charging/ discharging cycles.	Av. Battery charge duration is 40 hours. Up to 1000 charging / discharging cycles.	Av. Battery charge duration is 8-12 hours. Up to 1000 charging/ discharging cycles.	Mammal frequency dependent. Up to 1000 charging/ discharging cycles.
Training requirements	None specified				
Device testing	None specified				
Deployment	Minimum quantity of 5 units to be deployed. Horizontal distance between two devices from 200 m to 400 m.	Minimum quantity of 5 units to be deployed. Minimum net length 1 km.	For short fixed or moving nets, trawler – purse seine – long lines.	For squid fishing with single line.	For set nets, trawlers, purse seine, longlines and aquaculture, at least 600 m far from a DDD.
Functionality	None specified				

6.14 Dukane: NetMark 1000

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output of a pulse is 132 dB re 1 μPa at 1 m (Dawson *et al.* 2010).	-
Frequency (frequency range and swept band or single frequency)	10 kHz.	-
Continuous/ intermittent	Continuous.	-
Duty cycle	-	Signal duration of 300 ms with 4 sec signal duration (Dawson *et al.* 2010).
Range	None specified	-
Battery	None specified	-
Training requirements	None specified	-
Device testing	None specified	-
Deployment	None specified	-
Functionality	None specified	-

6.15 Future Oceans: 10 kHz Porpoise and Dolphin Pinger, 60kHz - 120kHz Dolphin Pinger and 3 kHz Whale Pinger

Note: The Future Oceans pingers were previously called Fumunda.

Parameter	Manufacturer's Specification		
Device	a	b	c
	10 kHz Porpoise and Dolphin Pinger	60 kHz – 120 kHz Dolphin Pinger	3 kHz Whale Pinger
Source level	Nominal SPL output = 132 dB re 1 µPa at 1 m.	Nominal SPL output = 145 dB re 1 µPa at 1 m.	Nominal SPL output = 145 dB re 1 µPa at 1 m (± 4dB).
Frequency (frequency range and swept band or single frequency)	10 kHz (includes multiple ultrasonic harmonics).	60 kHz – 120 kHz	3 kHz (±5 kHz) (includes multiple ultrasonic harmonics).
Continuous/ intermittent	Intermittent		
Duty cycle	Pulse duration of 300 ms with an interval of 4 sec.		
Range	None specified		
Battery	1 x Lithium battery. Will last 12 months based on 12 hours per day use 365 days a year.		1 x Lithium battery. Will last 120 days based on 12 hours per day use 365 days a year.
Training requirements	None specified		
Device testing	None specified		
Deployment	Recommended spacing is one every 100 m on gill nets.	Recommended spacing is one every 200 m on gill nets.	Recommended spacing is one every 100 m on nets.
Functionality	Immersive switch (i.e. will start sounding when the pinger is fully submersed and then turn off when out of the water).		

6.16 Future Oceans: Netshield Whale, Seal and Dolphin Anti-predation Pinger and Netshield Dolphin Anti Depredation Pinger

Parameter	Manufacturer's specification	
Device	a	b
	3 kHz -12 kHz Netshield Whale, Seal and Dolphin Anti-predation Pinger	60 kHz -120 kHz Netshield Dolphin Anti Depredation Pinger
Source level	Nominal SPL output = 150 dB re 1 µPa re 1 m	Nominal SPL l output = 175 dB re 1 µPa re 1 m
Frequency (frequency range and swept band or single frequency)	3 kHz – 12 kHz	60 kHz – 120 kHz
Continuous/ intermittent	Intermittent	Intermittent
Duty cycle	Pulse duration of 300 ms with an interval of 4 sec.	Pulse duration of 300 ms with an interval of 4 sec.
Range	None specified	None specified
Battery	Cell 1.5 volt Alkaline	Cell 1.5 volt Alkaline
Training requirements	None	None
Device testing	None specified	None specified
Deployment	One every 200 metres	One every 200 metres

6.17 Fishtek Marine: Banana Pingers and Dolphin Anti- depredation Pinger

Parameter	Manufacturer's specification			
Device	a	b	c	d
	Banana Pinger (50–120)	Banana Pinger whale (3–20)	Banana Pinger US (10)	Dolphin anti-depredation Pinger
Source level	145 dB (±3 dB) re 1 µPa at 1 m.	135 dB (±3 dB) re 1 µPa at 1 m.	132 dB (±3 dB) re 1 µPa at 1 m.	175 dB (±3 dB) re 1 µPa at 1 m.
Frequency (frequency range and swept band or single frequency)	50 kHz – 120 kHz (±2 kHz).	3 kHz – 20 kHz (±2 kHz).	10 kHz (±2 kHz).	40 kHz (±2 kHz).
Continuous/ intermittent	Intermittent.	Intermittent.	Intermittent.	Intermittent.
Duty cycle	2.0 – 7.5%.	7.5%.	7.5%.	0.2 – 7.5%.
Range	100 m	100 m	50 m	1000 m
Battery	4500 hours of battery life (replaceable 'C' cell alkaline battery).	750 hours of battery life (replaceable 'C' cell alkaline battery).	4500 hours of battery life (replaceable 'C' cell alkaline battery).	175 hours of battery life (replaceable 'C' cell alkaline battery).
Training requirements	Instructions on how the devices should be mounted on the nets are provided in the instruction manual. Bespoke advice offered on contact with company.	Instructions on how the devices should be mounted on the nets are provided in the instruction manual. Bespoke advice offered on contact with company.	Instructions on how the devices should be mounted on the nets are provided in the instruction manual. Bespoke advice offered on contact with company.	Instructions on how the devices should be mounted on the nets are provided in the instruction manual. Bespoke advice offered on contact with company.
Device testing	Battery indicator lights showing functionality.	Audible when submersed in water. Battery indicator lights showing functionality.	Audible when submersed in water. Battery indicator lights showing functionality.	Battery indicator lights showing functionality.
Deployment	Dependant on use and in consultation with company. Generally, every 200 m attached to headline of fishing gear.	Dependant on use and in consultation with Company. Generally, every 100 m attached to headline of fishing gear.	Dependant on use and in consultation with Company. Generally, every 100 m attached to headline of fishing gear.	Dependant on use and in consultation with Company. Generally, every 100 m attached to headline of fishing gear.

Parameter	Manufacturer's specification			
Functionality	Auto immersive switch which switches off out of water, battery indicator light for fisher and manager functionality. Rated down to 1000 m, 5+ year lifespan. Indicator lights switch off when in water to avoid attracting pinnipeds. Randomised ping structure to prevent habituation. Removeable pinger capsule for easy batter replacement.	Auto immersive switch which switches off out of water, battery indicator light for fisher and manager functionality. Rated down to 1000 m, 5+ year lifespan. Indicator lights switch off when in water to avoid attracting pinnipeds. Randomised ping structure to prevent habituation. Removeable pinger capsule for easy batter replacement.	Auto immersive switch which switches off out of water, battery indicator light for fisher and manager functionality. Rated down to 1000 m, 5+ year lifespan. Indicator lights switch off when in water to avoid attracting pinnipeds. Constant ping structure. Removeable pinger capsule for easy batter replacement.	Auto immersive switch which switches off out of water, battery indicator light for fisher and manager functionality. Rated down to 1000 m, 5+ year lifespan. Indicator lights switch off when in water to avoid attracting pinnipeds. Randomised ping structure to prevent habituation. Removeable pinger capsule for easy batter replacement.

6.18 F3: Maritime Technology UG Ltd: F3 Programmable Alert (PAL) Systems

Parameter	Manufacturer's Specification			
Device	a	b	c	d
	Porpoise PAL	10 kHz PAL	Wideband PAL	Whale PALv3
Source level	Nominal SPL output = 145 dB re 1 µPa at 1 m.	Nominal SPL output = 132 dB re 1 µPa at 1 m.	Nominal SPL output = 145 dB re 1 µPa at 1 m.	Nominal SPL output = 145 dB re 1 µPa at 1 m.
Frequency (frequency range and swept band or single frequency)	133 kHz porpoise clicks. Narrow band porpoise click train.	10 kHz narrow band.	20 kHz – 160 kHz wideband.	10 kHz – 160 kHz
Continuous/ intermittent	Intermittent. 1-3 signals.	Intermittent. One signal.	Intermittent. One signal.	Intermittent. One signal.
Duty cycle	Pulse duration is 1 sec, with the repeat interval 8 – 24 sec randomised.	Pulse duration is 0.3 sec, with the repeat interval 4 sec.	Pulse duration is 0.3 sec, with the repeat interval 4 – 30 sec randomised.	Pulse duration is 0.3 sec, with the repeat interval 4 sec. Secondary signal repeated 8-20 s randomised.
Range	250 m in 'good' weather.	150 – 200 m.	250 – 350 m.	250 – 350 m.
Battery	1 to 1.5 years continuous operation, with 4 years shelf life. Typical use is 1.5 – 3 years. Easily replaceable in all devices. Larger batteries with 4 years normal operation and 8 years shelf life are available upon request and fit in the same housing.			
Training requirements	Instructions on how the PAL devices should be mounted on the nets are provided in the instruction manual.			
Device testing	Audible in air at close range. Bat detector. Transparent housing and LED upon request.			
Deployment	PALS must me mounted on the net float lines every 200 m.	PALS must me mounted on the net float lines every 100 m.	PALS must me mounted on the net float lines every 200 m.	PALS must me mounted on the net float lines every 200 m. Also used for killer whale-attack prevention, in that case is equipped with an empennage and towed behind the boat using an otter board.

Parameter	Manufacturer's Specification
Functionality	PAL devices are positively buoyant for both battery types and have been pressure tested to a depth of 320 m. Each device has a salt-water switch and turns off in air 20 minutes after being retrieved. All PAL devices are programmable and can be adapted throughout their life span to emit acoustic and visual signals reflecting latest research results and varying customer requirements.

6.19 Loughborough University: LU-1 Prototype

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output = 145 dB re 1 µPa at 1 m (Larsen and Eigaard 2014).	-
Frequency (frequency range and swept band or single frequency)	40 – 120 kHz.	-
Continuous/ intermittent	Intermittent.	-
Duty cycle	Pulse duration of 300 ms. Random pulse interval between 5 and 30 sec.	-
Range	None specified.	-
Battery	None specified.	-
Training requirements	None specified.	-
Device testing	None specified.	-
Deployment	None specified.	-
Functionality	Manual.	-

6.20 Lofitech: Seal Scarer

Note: The control unit is housed in waterproof box with transducer suspended underwater via a 25 m cable. It is possible to order the units with longer cables if required.

Parameter	Manufacturer's specification	Notes
Source level	Nominal SPL output = 189 dB re 1 μPa at 1 m.	Measured sound level = 204 dB re 1 μPa at 1 m (McGarry *et al.* 2017).
Frequency (frequency range and swept band or single frequency)	13 – 15 kHz.	Measured fundamental frequency at 14.6 kHz with harmonics at 29.2 kHz, 43.6 kHz, and 72.8 kHz (McGarry *et al.* 2017).
Continuous/ intermittent	Intermittent.	Duration between pulses is on a random cycle.
Duty cycle	Pulse length 500 ms^{-1} with variable length between pauses.	Measured pulse length 752 m s^{-1} (McGarry *et al.* 2017).
Range	300m from source.	Measured displacement over ranges of >1 km depending on species (see section 2.3).
Battery	Auto-Marin 12 V (0.4A) with 90–120 Ah.	Recharge intervals are 3-4 days.
Training requirements	No training specified.	-
Device testing	None given.	Suggested testing using hydrophone and monitoring via suitable computer software (e.g. PAMGuard).
Deployment	Cable links transducer to control unit, manually activated.	Standard is for 25 m cable, but able to order longer cable if required.
Functionality	Simple on/off switch.	No further settings and no soft start.

6.21 Marexi Marine Technology: Acoustic Pinger V2.3

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output = 145 dB re 1 µPa at 1 m (±4 dB).	-
Frequency (frequency range and swept band or single frequency)	10 kHz (±2 kHz) tonal	-
Continuous/ intermittent	Intermittent.	-
Duty cycle	Pulse duration of 300 ms (±1 5 ms) and a pulse interval of 4 sec (±0.2 sec).	-
Range	<500 m	-
Battery	±9500 h (>13-month 24 hr/day continuously.	Once the device has consumed its useful life, it should be replaced for another.
Training requirements	None specified.	-
Device testing	None specified.	-
Deployment	None specified.	-
Functionality	Immersive switch.	-

6.22 Marexi Marine Technology: Acoustic Pinger M2.1

Parameter	Manufacturer's Specification	Notes
Source level	165 dB re 1µP at 1m (±4dB)	-
Frequency (frequency range and swept band or single frequency)	70 kHz (±2 kHz) tonal	-
Continuous/ intermittent	Intermittent	-
Duty cycle	Pulse duration of 300 ms (±1 5ms) and duty cycle of 2–10 seconds (±0.2s)	-
Range	<1000 m	500 m depth
Battery	1 week	Replaceable internal battery
Training requirements	Not necessary.	-
Device testing	Commercial fishery.	-
Deployment	200 m between devices	-
Functionality	Automatic	Water switch

6.23 Marexi Marine Technology: Acoustic Pinger H1.0

Parameter	Manufacturer's Specification	Notes
Source level	140 – 165dB re 1µP at 1m (±4dB)	-
Frequency (frequency range and swept band or single frequency)	3 – 600 kHz (sequence controlled by algorithms)	±5 kHz
Continuous/ intermittent	Intermittent	-
Duty cycle	Pulse duration of 10–500 ms (±1 5 ms) and a pulse interval of 2 – 10 s (±0.2 sec).	-
Range	<1000 meters	at 500 meters depth
Battery	±43 h	Induction Rechargeable
Training requirements	Not necessary.	-
Device testing	Tested in commercial fishery	-
Deployment	<500 meters between devices.	-
Functionality	Automatic	Water switch

6.24 GenusWave Ltd: Targeted Acoustic Startle Technology (TAST) – Genuswave Acoustic Startle Devices (ASD)

Parameter	Manufacturer's Specification				
Device	a	b	c	d	e
	'Salmon Safe'	'FisherySafe'	'Mitigation Device' 'TurbineSafe' 'Construction Safe'	'OdontoceteSafe', 'FisherySafe' 'OrcaSafe'	'Whale Safe'
Source level	**Seal signal:** 180 dB re 1µPa at 1m (RMS) SPL: ~175 dB re 1µPa SEL: 173 dB dB re Pa²·s	**Pinniped/seal signal:** 180-182 dB re 1 µPa at 1 m (RMS) **Odontocete signal ('pinger capability')**: 140-175 dB re 1 µPa at 1 m (RMS)	**Pinniped signal:** 180-182 dB re 1 µPa at 1 m (RMS) **Odontocete signal**: 150 dB to 185 dB dB re 1 µPa at 1 m (RMS) (depending on required deterrence range) **Combined marine mammals signal:** up to 185 dB re 1 µPa at 1 m (RMS)	Typical broadband SPL (RMS): 180 dB re 1µPa at 1m (RMS) Broadband Sound Exposure Level (SEL): 173 dB re Pa²·s Values are typical examples. Source levels are fully adjustable to comply with any regulatory requirements	Typical SPL (RMS)**:** 180 dB re 1µPa at 1m (RMS) Sound Exposure Level (SEL): 173 dB re Pa²·s Values are typical examples. Source level is fully adjustable to comply with any regulatory requirements
Frequency (frequency range and swept band or single frequency)	**Seal signal:** 0.7 kHz to 1.5 kHz (-10dB bandwidth)	**Option 1:** 0.7kHz to 1.5kHz, see also SalmonSafe **Option 2:** 1.5 kHz -2.5kHz. Band-limited signals.	**Seal signal:** 0.7 khZ to 1.5 kHz **Odontocete signal:** 5-20 kHz **Combined marine mammal signal:** 0.8 kHz to 20 kHz	5 to 20kHz Band-limited signals	0.4 kHz to 1.8kHz (centred at 0.7kHz). Band-limited signals
Continuous/ intermittent	Intermittent	Intermittent	Intermittent	Intermittent. Isolated short non-impulsive (steady state) signals	Intermittent. Isolated short non-impulsive (steady state) signals

Parameter	Manufacturer's Specification				
Duty cycle	0.8% to 1%. Duty cycle can be adjusted. Up to 3-4% on large fish farms	0.6%-4% (can be adjusted)	0.6% for porpoise signal 0.8% for pinniped signal	0.5% to 1.2% (adjustable)	1% (adjustable)
Range	up to 250 m around fish farms (Götz & Janik 2015) 60 m around haulouts (Götz 2008)	up to 250 m around fish farms (Götz and Janik 2015) 60 m around haulouts (Götz 2008)	Seals: up to 250 m around fish farms (Götz and Janik 2015) up to 500 m offshore 60 m around haulouts (Götz 2008)	Killer whales: up to 200 m. Bottlenose dolphin: 500 – 800 m (Janik *et al.* 2023)	Humpback whales: ~50–100 m
Battery	Choice of 12 V, 24 V, 36 V, charging module with battery management system to connect to mains power (240 v)	Incorporated battery for net deployment. Choice of 12 V, 24 V, 36 V, charging module with battery management system to connect to mains power (240 v) for boat-based deployment	Choice of 12 V, 24 V, 36 V, charging module with battery management system to connect to mains power (240 v)	-	-
Training requirements	None, training provided as part of leasing deal.	None, training provided as part of leasing deal.	None, training provided as part of leasing deal.	-	-
Deployment	Pod (main control unit) mounted on custom-made frame together with battery box (which includes main power charger).	Depends on application; boat-based deployment or net-based deployment with floating or submerged pod and battery box (if required).	Custom solution for each application including structure, underwater, surface or boat-based installations.	-	-

Parameter	Manufacturer's Specification
Functionality	The ASD constitutes a modular system of independent but synchronized units that can be coordinated and updated via a radio link and controlled from a master unit/base station. The units can also be operated on their own and the pods can be fully submerged (e.g. for gillnet deployment or around a tidal turbine or construction site). All acoustic parameters (i.e. duty cycle, emission schedule, signal characteristics and source level can be updated remotely - if units are not submerged) to respond dynamically to situations. The device can therefore also be adjusted to comply with any given regulatory frameworks where allowed noise doses are limited.

6.25 Savewave: SealSalmon Saver, Long Line Saver, Endurance Saver, OrcaSaver and OrcaSaver 2

Note: Limited web information for these devices. Hi Impact Endurance and OrcaSaver are not commercially available anymore. OrcaSaver2 currently available.

Parameter	Manufacturer's Specification				
Device	a	b	c	d	e
	Seal Salmon Saver (High impact) (Franse *et al*. 2005)	Long Line Saver (Franse *et al*. 2005)	Endurance Saver (Franse *et al*. 2005)	OrcaSaver (Mustad Longline and SeaWave 2013).	OrcaSaver 2
Source level	Nominal SPL output = 155 dB re 1 µPa at 1 m	Nominal SPL output = 155 dB re 1 µPa at 1 m	Nominal SPL output = 140 dB re 1 µPa at 1 m	Nominal SPL output = 196 ±2 dB re 1 µPa at 1 m	Nominal SPL output = 200 dB dB re 1 µPa at 1 m
Frequency (frequency range and swept band or single frequency)	Double signal 5 – 30 kHz and 30 – 160 kHz wide band sweeps, harmonics up to 180 kHz	Single signal 5 – 60 kHz wide band sweeps, harmonics up to 180 kHz	Single signal 5 – 90 kHz wide band sweeps, harmonics up to 180 kHz	6.5 kHz	10 kHz to 100kHz
Continuous/ intermittent	Intermittent	Intermittent	Intermittent	Intermittent	Continuous
Duty cycle	Pulse duration 200 – 900 ms randomised. Pulse interval 4 – 16 sec randomised	Pulse duration 200 – 400 ms randomised. Pulse interval 4 – 16 sec randomised.	Pulse duration 200 – 400 randomised. Pulse interval 4 – 30 sec randomised.	Pulse duration from 200 ms to 1 sec	100%
Range	-	-	-	-	0 to 1000 meter
Battery	-	-	-	-	-
Training requirements	-	-	-	-	-
Device testing	-	-	-	-	-
Deployment	-	-	-	-	-
Functionality	-	-	-	-	-

6.26 Gael Force: SeaGuard Seal Deterrent (previously Airmar dB Plus II)

Note: Based on the Gael Force specification the only main change is the battery efficiency. Therefore, unless the Gael Force manufacturer's specification describes a parameter slightly differently, it has been assumed that the source levels, frequencies, and type of signal are the same as the original Airmar device.

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output = 198 dB re 1 µPa at 1 m (RMS).	Measured sound level = 192 dB re 1 µPa (RMS) at the fundamental frequency of 10.3 kHz (Lepper *et al*. 2014).
Frequency (frequency range and swept band or single frequency)	-	A broadband spectral response at the beginning of each pulse, with detectable energy levels between 1.5 kHz to 50 kHz (Lepper *et al*. 2014).
Continuous/ intermittent	Continuous and intermittent options.	Sequence of pulsed sinusoidal tonal bursts (Lepper *et al*. 2014).
Duty cycle	Multiple and random firing patterns, where the length and breaks of the firing pulses can be varied.	-
Range	System provides up to 3000 m2 of protection for a typical aquaculture application.	-
Battery	28 V DC, 48 V DC and 90 V – 250 V AC version available.	50% more efficient than the Airmar dBPlus 11.
Training requirements	None specified	
Device testing	None specified	
Deployment	Typical deployment involves four transmitters each being fired in turn, each with a 2 sec quiet period.	-
Functionality	Simple on/off switch. Has a soft start feature with a 70s ramp up to full power when the transmitter is first switched on.	Must be locked in the Off-switch position whenever a person is underwater and within 150 m of a transducer.

6.27 Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard Porpoise Module

Parameter	Manufacturer's Specification	Notes
Source level	Average: 159.7 dB re 1 µPa at 1 m Peak: 165.0 dB re 1 µPa at 1 m	-
Frequency (frequency range and swept band or single frequency)	60–150 kHz	
Continuous/ intermittent	Intermittent	Complex tones include harmonics, sweeps, impulsive sounds and random inter-pulse intervals to reduce the possibility of habituation/remain novel
Duty cycle	System = 14% at 72 scrams/hr	Average Tone Duty = 97.4% Average Tone Length = 7.2 sec
Range	Observed efficacy of/at 1000 m (Voss *et al.* 2023)	reduced detection rates up to 2.5 km
Battery	12 V deep-cycle non-spillable gel battery (50 aH)	Battery charger and waterproof battery enclosure supplied as required
Training requirements	Full manual provided and training via video call available if required.	
Device testing	Upon build, tested to 5000 'scrams' post-and pre- hire at service centre	Suggested field-testing using hydrophone and third-party monitoring via suitable computer software
Deployment	Cable links transducer to control unit, manually/ remotely activated.	Standard is 40 m cable; longer cable can be ordered if required.
Functionality	Simple on/off (Scram/Mute) function via OLED screen + keypad	Manual settings also possible controlling: duty cycle, volume, ramp- up time, and sound varieties. Remote updates of sound patterns available.

6.28 Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard Seal Module

Parameter	Manufacturer's Specification	Notes
Source level	Average: 162.2 dB re 1 µPa at 1 m Peak: 174.1 dB re 1 µPa at 1 m	average output is 162.2 dB SPL
Frequency (frequency range and swept band or single frequency)	1–20 kHz	
Continuous/ intermittent	Intermittent	Complex tones include harmonics, sweeps, impulsive sounds and random inter-pulse intervals to reduce the possibility of habituation/remain novel
Duty cycle	System = 22.1% at72 scrams/hr	Average Tone Duty = 95.3% Average Tone Length = 11.6 sec
Range	Observed efficacy of/at 100-500 m	
Battery	12 V deep-cycle non-spillable gel battery (50 aH)	Recharge intervals depend on rate. System trickle charges, DC rapid charger connected to mains AC.
Training requirements	Full manual provided and training via video call available if required.	
Device testing	Upon build to 5000 'scrams' post-and pre- hire at service centre	Suggested field-testing using hydrophone and third-party monitoring via suitable computer software
Deployment	Cable links speaker to control unit, manually/remotely activated.	Standard is 35 m cable; longer cable can be ordered if required.
Functionality	Simple on/off (Scram/Mute) function via OLED screen + keypad	Manual settings also possible controlling: duty cycle, volume, ramp- up time, and sound varieties. Remote updates of sound patterns available.

6.29 Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard Turtle Module

Parameter	Manufacturer's Specification	Notes
Source level	Average: 172.2 - 181.7 dB re1µPa at1m Peak: 177.7 - 186.5dB re1µPa at1m	-
Frequency (frequency range and swept band or single frequency)	100 Hz – 1000 Hz	
Continuous/ intermittent	Intermittent	Complex tones include harmonics, sweeps, impulsive sounds and random inter-pulse intervals to reduce the possibility of habituation/remain novel
Duty cycle	System = 9.5% at 72 scrams/hr	Average Tone Duty = 91.3% Average Tone Length = 5.2 sec
Range	TBC	
Battery	12 V deep-cycle non-spillable gel battery (50 aH)	Recharge intervals depend on rate. System trickle charges, DC rapid charger connected to mains AC.
Training requirements	Full manual provided and training via video call available if required.	
Device testing	Upon build, tested to 5000 'scrams' post-and pre- hire at service centre	Suggested field-testing using hydrophone and third-party monitoring via suitable computer software
Deployment	Cable links speaker to control unit, manually/remotely activated.	Standard is 35 m cable; longer cable can be ordered if required.
Functionality	Simple on/off (Scram/Mute) function via OLED screen + keypad	Manual settings also possible controlling: duty cycle, volume, ramp- up time, and sound varieties. Remote updates of sound patterns available.

6.30 Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard Fish Module

Parameter	Manufacturer's Specification	Notes
Source level	Average: 181.7 dB re1 µPa at1 m Peak: 186.5 dB re 1µPa at 1m	Average output is 181.7 dB SPL
Frequency (frequency range and swept band or single frequency)	200 Hz – 1500 Hz	
Continuous/ intermittent	Intermittent	Complex tones include harmonics, sweeps, impulsive sounds and random inter-pulse intervals to reduce the possibility of habituation/remain novel
Duty cycle	System = 1.8% at 72 scrams/hr	Average Tone Duty = 24.5% Average Tone Length = 3.7 sec
Range	Observed efficacy of/at 100-500m	
Battery	12 V deep-cycle non-spillable gel battery (50 aH)	Recharge intervals depend on rate. System trickle charges, DC rapid charger connected to mains AC.
Training requirements	Full manual provided and training via video call available if required.	
Device testing	Upon build, tested to 5000 'scrams' post-and pre- hire at service centre	Suggested field-testing using hydrophone and third-party monitoring via suitable computer software
Deployment	Cable links speaker to control unit, manually/remotely activated.	Standard is 35 m cable; longer cable can be ordered if required.
Functionality	Simple on/off (Scram/Mute) function via OLED screen + keypad	Manual settings also possible controlling: duty cycle, volume, ramp-up time, and sound varieties. Remote updates of sound patterns available.

6.31 Van Oord/SEAMARCO and Ace Aquatec: Fauna Guard Minke Whale Module

Parameter	Manufacturers Specification	Notes
Source level	Peak output 186.5 dB re 1 µPa at 1m	Average output 181.7dB re1µPa at1m
Frequency (frequency range and swept band or single frequency)	200 Hz – 1,500 Hz	-
Continuous/ intermittent	Intermittent	Complex tones include harmonics, sweeps, impulsive sounds, and random inter-pulse intervals to reduce the possibility of habituation/ to remain novel
Duty cycle	System = 14% at 72 scrams/hr	Average Tone Duty = 97.4%
Average Tone Length = 7.2 sec	-	-
Range	TBC	-
Battery	12V deep-cycle non-spillable gel battery (50 aH)	Recharge intervals depend on rate.
System trickle charges; DC rapid charger connected to mains AC in.	-	-
Training requirements	Full manual and explainer video provided. Additional training via video call available if required.	-
Device testing	Upon build, tested to 5000 'scrams.' Re-tested post- and pre- hire at service centre in UK.	-

6.32 Seamaster: Fish Protector

Parameter	Manufacturer's Specification	Notes
Source level	Nominal SPL output up to 165 dB re 1 µPa at 1 m.	-
Frequency (frequency range and swept band or single frequency)	Frequency sweep tones and harmonics 10 – 90 kHz.	-
Continuous/ intermittent	Continuous.	-
Duty cycle	Pulse duration of 1.9 sec with a 15 sec interval.	-
Range	Up to 1 km.	-
Battery	Rechargeable batteries, approximately 12 hours of continuous use and battery life of around 5 years.	-
Training requirements	None specified.	-
Device testing	None specified.	-
Deployment	None specified.	-
Functionality	Immersive switch becomes active after 60 sec of being immersed.	-

6.33 OTAQ: SealFence 3/SealFence4

Note: SealFence 3 and SealFence 4 have the same acoustic characteristics.

Parameter	Manufacturer's Specification	Notes
Source level	Patrol mode: SPL output = 165 dB re 1 µPa at 1 m RMS. Protect mode: SPL output = 189 dB re 1 µPa at 1 m RMS.	Source levels have been verified by the National Physics Laboratory (NPL)
Frequency (frequency range and swept band or single frequency)	10 kHz.	-
Continuous/ intermittent	Intermittent, although if more than one unit used it can result in continuous signal	-
Duty cycle	Patrol mode: 2 sec transmissions with 10 sec gap between pulses Protect mode: 3 sec transmissions with random pulse gaps of between 3 and 9 sec	Transmission period formed from a sequence of tone bursts so overall duty cycle is: Patrol mode: 0.7% Protect mode: 1.3%
Range	40 m	Provided by manufacturer
Battery	24 vDC power input.	Internal battery charger requires AC mains supply
Training requirements	Training provided as part of contract hire agreement	-
Device testing	Devices can be continuously monitored, controlled and logged via wireless Active Condition Monitoring (ACM) system	-
Deployment	System comprises mounting kit for attaching to circular or steel cage structures	25 m projector cable. High performance polyurethane moulding
Functionality	OceanTALK^{TM} Air Wireless Link for ACM	-

6.34 Terecos Ltd: DSMS-4

Note: The DSMS-4 unit has four different programmes which involve two different pulse sequences. The table below has been split out into these four programmes for clarity.

Parameter	Manufacturer's Specification	Notes
Programme 1 – Sequence 1 (a)		
Source level	None specified.	Measured SPL output = 177 dB re 1 µPa at 1 m (RMS) (±1 dB) at 6.6 kHz (Lepper *et al.* 2004). No equivalent source levels of greater than 146 dB re 1 µPa at 1 m (RMS) at frequencies above 27 kHz (Lepper *et al.* 2014).
Frequency (frequency range and swept band or single frequency)	None specified.	Fundamental frequencies ranging from 1.8 kHz – 3.8 kHz with uniformly distributed harmonic components (Lepper *et al.* 2004).
Continuous/ intermittent	Continuous.	Repetitive five segment (16 ms duration) continuous tonal blocks forming an up and down frequency sweep (Lepper *et al*. 2004).
Programme 2 (b)		
Source level	None specified.	Measured SPL output = 179 dB re 1 µPa at 1 m (RMS) (±1 dB) and 178 dB re 1 µPa at 1 m (RMS) (±1 dB) at 4.7 kHz and 6.8 kHz respectively (Lepper *et al.* 2014). No equivalent source levels of greater than 145 dB re 1 µPa at 1 m (RMS) at frequencies above 27 kHz (Lepper *et al.* 2014).
Frequency (frequency range and swept band or single frequency)	None specified.	Multi-component continuous tones with observed peak level frequencies of 4.7 kHz and 6.8 kHz. Both contain complex multiple frequency components with a broad energy distribution away from the peak level tonal component.
Continuous/ intermittent	Continuous.	Randomly timed sequence of continuous and time variant multi-component tonal blocks (Lepper *et al.* 2004).
Programme 3 – Sequence 2 (c)		
Source level	None specified.	Measured SPL output = 178 dB re 1 µPa at 1 m (RMS) (±1 dB) at 4.9 kHz (Lepper *et al.* 2004).
Frequency (frequency range and swept band or single frequency)	None specified.	Fundamental frequencies ranging from 2.4 kHz – 6.0 kHz with uniformly distributed harmonic components (Lepper *et al.* 2004).

Continuous/ intermittent	Continuous.	Sequence of eight segments (8 ms duration) continuous tonal blocks forming an up and down frequency sweep combined with variable continuous multi-component tonal blocks (Lepper *et al.* 2004).
Programme 4 – Sequence 1 and Sequence 2 (d)		
Source level	None specified.	Combined Sequence 1 and Sequence 2 (See programme 1 and 3).
Frequency (frequency range and swept band or single frequency)	None specified.	Combined Sequence 1 and Sequence 2 (See programme 1 and 3).
Continuous/ intermittent	Continuous	Randomly timed combined sequence of Seq. 1, Seq. 2 tonal blocks, continuous multi- component tonal blocks and time variant multi-component tonal blocks (Lepper *et al.* 2004).
Duty cycle	None specified.	-
Range	None specified.	-
Battery	None specified.	-
Training requirements	None specified.	-
Device testing	None specified.	-
Deployment	None specified.	-
Functionality	None specified.	-