JNCC Report
No. 615

Evidence base for application of Acoustic Deterrent Devices (ADDs) as marine mammal mitigation (Version 4)

McGarry, T., De Silva, R., Canning, S., Mendes, S., Prior, A., Stephenson, S. & Wilson, J.

October 2022

ISSN 0963-8091

For further information please contact:
Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough, PE1 1JY
communications@jncc.gov.uk
www.jncc.gov.uk

This report should be cited as:
McGarry, T., De Silva, R., Canning, S., Mendes, S., Prior, A., Stephenson, S. & Wilson, J. 2022. Evidence base for application of Acoustic Deterrent Devices (ADDs) as marine mammal mitigation (Version 4). *JNCC Report* No. *615.* JNCC, Peterborough. ISSN 0963-8091

Evidence Quality Assurance:
This report is compliant with the JNCC Evidence Quality Assurance Policy https://jncc.gov.uk/about-jncc/corporate-information/evidence-quality-assurance/.

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 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 enable 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. The report reviews evidence on the effectiveness of acoustic devices at deterring a range of marine mammal species. A coarse assessment of the risk of injury from all ADDs is also undertaken with a general conclusion that the risk of injury is likely to be low for all devices, although this is context dependent. The report also provides a summary of the key relevant legislation and regulations pertaining to the protection of marine mammals in the UK.

Contents

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
SEL_{cum}	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	Scottish Natural Heritage
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' is a generic term applied to a variety of different devices which, although differing in their sound emitting characteristic, 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.

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, acoustic deterrent devices (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 also differences in the method of deployment and operating functions.

There are several reports that provide extensive reviews of the devices available, their acoustic characteristics, and importantly their proven effectiveness on different species; however, however, a single report, collating and summarising that evidence was considered useful and enable the information to be processed readily by Statutory Nature Conservation Bodies (SNCBs) 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.

1.1.2 Purpose of report

The purpose of this report is primarily to provide a collated reference report for SNCBs in the UK, for use mainly to inform advice in relation to marine industries on the use of acoustic devices to deter marine mammals from areas where there is a risk of injury or death.

This report has been produced with input and review by a steering group, comprised of the Joint Nature Conservation Committee (JNCC), Natural England, Scottish Natural Heritage (SNH), Natural Resources Wales (NRW) and Department of Agriculture, Environment and Rural Affairs (DAERA) of Northern Ireland.

This report has been developed to address two key issues considered by the SNCBs when providing advice in relation to acoustic devices:

1. Is there a device available with a proven track record of deterring the species of concern at the distances required?
2. Can it be feasibly employed as a mitigation measure?
3. Do these devices pose a risk of injury to marine mammals?

The report provides an easily accessible reference to 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 risk to marine mammals (i.e. potential risk of injury from deployment of the device itself). This report will help assess whether proposed acoustic devices and operating methods in mitigation plans are the most appropriate for the purpose intended and may inform discussions on the potential for disturbance arising from the devices.

It should be noted that this report represents a 'live' document which can be updated periodically in light of additional information provided by ADD manufacturers, as new ADD technologies become commercially available.

This report also provides a summary of the key legislation and regulations pertaining to the protection of marine mammals in relation to ADD deployment and refers to the potential for an offence to be committed under the various regulations of the devolved administrations (England, Wales, Scotland and Northern Ireland). Information is provided in relation to marine mammals only. However, it should be noted that an offence could be committed under UK legislation, in relation to other protected species including basking shark, marine turtles and Atlantic sturgeon.

1.1.3 Structure of report

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

Table 1-1: Report navigation.

Section	Overview	Link
Part 1: Project purpose and approach		
1.1 Introduction	Background to the project and purpose of the report	1.1
1.2 Methodology	Description of the approach to the literature review, categorising the devices and production of the database	1.2
1.3 Potential for injury	Exploring the potential for ADDs to cause hearing damage in marine mammals	1.3
1.4 Limitations	Limitations of this report	1.4
Part 2: Acoustic devices		
2.1 Available devices	Full list of devices available, including name, manufacturer, duration of commercial availability and link to manufacturer's website	2.2
2.2 Acoustic device characteristics	Categorisation of devices according to their acoustic characteristics: source level, frequency, constant or intermittent sound, manually controlled or automatically triggered	2.3
2.3 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		
3.1 Training requirements	Training and/or experience required for the deployment of ADDs	3.2
3.2 General principles for deployment	Recommendations for deployment, testing and failsafe planning for mitigation including example ADD protocol and task plan	3.3

Section	Overview	Link
Part 4: UK Legislation and Guidance		
4 Overview	Overview of how legislation relates to ADD deployment	4
4.1 Legislation and Regulations	Key legislation on the protection of marine mammals with relevance to ADD use	4.2
4.2 Wildlife licensing requirements	Marine and/or wildlife licensing requirements, by devolved administration	4.3
4.3 Current guidance documents	Key guidance documents for the assessment of impacts on marine mammals and marine/wildlife licensing	4.4
5 References		
6 Appendix 6.1 to 6.27	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 the 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 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 at a distance of 1m 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 50% with eight respondents out of 16 manufacturers contacted. There were no contact details available for three further manufacturers. Therefore, the technical information gathered for this report relies largely on what was available on the internet and in published papers that had studied the devices.

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.

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 output level, 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.

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

The devices were 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 cetaceans (e.g. harbour porpoise);
- high-frequency cetaceans (e.g. bottlenose dolphin);
- low-frequency cetaceans (e.g. minke whale); and
- pinnipeds.

Where evidence relates to a particular species within the group, that species is listed.

All available evidence is summarised, and references are given. The information comes from a variety of sources, directly from the manufacturer, from reports and peer-reviewed publications.

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 the ADD on a certain species or species group. 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, then the supporting evidence can be assigned the highest evidence score of 3. For other devices the information available as to the effectiveness on a given species might be provided by the manufacturer but without a supporting scientific study; in these instances, the evidence score is 1. This does not mean that those devices might be less effective but simply that the evidence is limited or not reported in more detail.

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 each device reviewed in Table 2-3, a cross-reference has been provided to the device ID so that the reader can find the correct device listed in the two previous tables (Table 2-1: List of available devices and Table 2-2: Acoustic characteristics of devices).

Table 2-3 provides the range of deterrence distances 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 (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 distances 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 distances. Therefore, the deterrence distances presented in the Table 2-3 below, should not be used as a definitive measure of the effectiveness of a device.

The deterrence ranges summarised in Table 2-3 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.

1.2.4 Database development

The information gathered through the literature review and search of ADD technical specifications was used to populate a searchable database. 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
	Score given to each of the ADDs based on the available literature
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 effect ranges in other studies due to difference in propagation between sites.

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

There are concerns within academia and industry, that some of the louder ADD devices may have the potential to result in hearing damage 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 to estimate the cumulative Sound Exposure Level (SEL_{cum}) that marine mammals swimming away from an active ADD could be exposed to.

The modelling assumes a generalised swim speed of 2.5ms^{-1} and utilises the source noise data, frequency and pulse rate specific to each ADD. The modelling assumes 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 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 devices except the SaveWave Orcasaver where, according to the model, it is theoretically possible that PTS could occur in very high frequency cetaceans (e.g. harbour porpoise) at a range of up to 130 m. It is therefore concluded that the risk of injury due to ADD deployment is likely low for all devices.

It is theoretically possible that a temporary threshold shift (TTS) could occur at short ranges for some devices, but this has not been assessed.

1.4 Limitations of this report

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

- Only half 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 conclusions based on the literature review and web-based searches alone, it was sometimes difficult to determine whether a given device was still available. Therefore, the literature review included all devices, irrespective of their commercial availability. In these cases, the report states ‘unknown’ for their commercial availability;
- The level of detail within each publication varies considerably. Not many 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 and there may 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 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, the table reports the range across all the studies; and
- For studies on pingers, the focus was more on whether marine mammals stopped attacking fish or reduced bycatch rather than the range of deterrence. These studies often cited the closest approach.

2 Acoustic devices

2.1 Overview

Part 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 look up information on a particular device or to narrow down 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 (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.

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
1	Ace Aquatec Marine Mammal Mitigation Device (MMD) Low frequency deterrent - 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 (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 (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	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 very high frequency cetaceans	Appendix 6.4
5	Ace Aquatec: Universal Scrammer US2[(1)]	Ace Aquatec	https://www.aceaquatec.com	N (but may be in use)	Aquaculture	Seals	Appendix 6.5
6	Ace Aquatec: Universal Scrammer US3[(2)]	Ace Aquatec	https://aceaquatec.com/products/predator-control/	Y	Aquaculture	Seals and sealions	Appendix 6.6
7	Ace Aquatec: RT1	Ace Aquatec	https://aceaquatec.com/products/predator-control/	Y	Aquaculture	Seals	Appendix 6.7

[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 mentioned above.

[2] See footnote 1. Previously Silent Scrammer.

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
8	Airmar dB plus II (now Mohn Aqua MAG seal deterrent)	Airmar	http://www.airmartechnology.com/uploads/specapps/dbplus.pdf	Y (since 1993)	Aquaculture	Seals	Appendix 6.8
9	Airmar: Gillnet Pinger	Airmar	http://www.airmar.com/productinfo.html?category=AD&name=Acoustic%20Deterrents	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	Aquatec	http://www.aquatecgroup.com	N[3]	Oil and gas industry but also offshore fisheries	Harbour porpoise	Appendix 6.11

[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	Technical specification in this Report
11b	Aquamark 200	Aquatec	http://www.aquatecgroup.com	N[4]	Oil and gas industry and traditional trammel nets	Dolphins	Appendix 6.11
11c	Aquamark 210	Aquatec	http://www.aquatecgroup.com	N[5]	Where predation is severe, 210 is recommended for nets	Dolphins	Appendix 6.11
11d	Aquamark 300	Aquatec	http://www.aquatecgroup.com	N[6]	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

[4] See footnote 3.
[5] See footnote 3.
[6] See footnote 3.

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
13 (a, b, c, d, e)	Dolphin Deterrent Devices & Dolphin Interactive Deterrent	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 Porpoise Pinger	Future Oceans	https://futureoceans.com/pingers/porpoise-pinger/	Y	Gill net fisheries	Harbour porpoise	Appendix 6.15
15b	Future Oceans Dolphin Pinger	Future Oceans	https://futureoceans.com/pingers/dolphin-pinger/	Y	Gill net fisheries	Dolphins	Appendix 6.15
15c	Future Oceans Whale Pinger	Future Oceans	https://futureoceans.com/pingers/whale-pinger/	Y	Gill net fisheries	Whales	Appendix 6.15

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
16a	Banana Pinger (50-120)	Fishtek Marine	https://www.fishtekmarine.com/product/deterrent-pinger-50-120/	Y	Fisheries, reduction of bycatch	Porpoise and dolphin species	Appendix 6.16
16b	Banana Pinger whale (3-20)	Fishtek Marine	https://www.fishtekmarine.com/deterrent-pingers/	Y	Fisheries, reduction of bycatch	Baleen and beaked whales	Appendix 6.16
16c	Banana Pinger Porpoise (10)	Fishtek Marine	https://www.fishtekmarine.com/product/deterrent-pinger-10/	Y	Fisheries, reduction of bycatch	Porpoise	Appendix 6.16
16d	Dolphin Anti-depredation pinger	Fishtek Marine	https://www.fishtekmarine.com/anti-depredation-pinger/	Y	Mitigating fisheries depredation and bycatch, mitigation of marine mammal interactions with construction operations	Dolphin species and porpoise	Appendix 6.16

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
17a	F3 Porpoise – PAL (Programmable Alert system)	F3: Maritime Technology UG Ltd	http://www.f3mt.net/harbour-porpoise---pal.html	Y	Fisheries, reduction of bycatch	Porpoise species	Appendix 6.17
17b	F3: 10 kHz – PAL	F3: Maritime Technology UG Ltd	http://www.f3mt.net/10-khz---pal1.html	Y	Fisheries, reduction of bycatch, Marine construction	Marine mammals	Appendix 6.17
17c	F3: Wideband PAL	F3: Maritime Technology UG Ltd	http://www.f3mt.net/wideband---pal.html	Y	Fisheries, reduction of bycatch, Marine construction	Marine mammals	Appendix 6.17
17d	F3: Whale PAL	F3: Maritime Technology UG Ltd	http://www.f3mt.net/whale---pal.html	Y	Fisheries, reduction of bycatch, Marine construction	Whales	Appendix 6.17
18	LU-1 prototype	Loughborough University	None listed	Unknown	Unknown		Appendix 6.18
19	Lofitech Seal Scarer/FishGuard	Lofitech	http://www.lofitech.no/en/seal-scarer.html	Y	Aquaculture and fisheries	Seals and odontocetes	Appendix 6.19

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
20	Marexi Pinger: Acoustic Pinger V2.2	Marexi Marine Technology	http://www.marexi.com/PDF/Pinger_V22_english.v2_P.pdf	Y	Fisheries	Not given	Appendix 6.20
21a	Genuswave Targeted acoustic startle technology (TAST) Acoustic Startle Device (ASD) 'SalmonSafe'	GenusWave Ltd	http://www.genuswave.com/	Y	Aquaculture	Pinnipeds	Appendix 6.21
21b	Genuswave Targeted acoustic startle technology (TAST) Acoustic Startle Device (ASD) 'FisheriesSafe'	GenusWave Ltd	http://www.genuswave.com	Y	Fisheries	Pinnipeds bycatch reduction signal (porpoise & delphinids) can be included for fisheries application'	Appendix 6.21

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
21c	Genuswave Acoustic Startle Device (ASD) Targeted acoustic startle technology (TAST) '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 6.21
22a	SaveWave SealSalmon Saver (High-impact)	SaveWave	http://savewave.eu/seasalmon-saver-EN.html	Y	Aquaculture, offshore wind mitigation	Dolphins, seals	Appendix 6.22
22b	SaveWave Long Line Saver	SaveWave	http://savewave.eu	N	Unknown, but probably fisheries	Not given	Appendix 6.22
22c	SaveWave Endurance Saver	SaveWave	http://savewave.eu	N	Unknown, but probably fisheries	Not given	Appendix 6.22
22d	SaveWave OrcaSaver	SaveWave	http://savewave.eu/orca-saver-EN.html	Y	Long line fisheries	Orcas	Appendix 6.22

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
23	SeaGuard Seal Deterrent	Gael Force	http://www.gaelforcemarinetechnology.com/Aquaculture-Sea/Seal-Deterrents/SeaGuard-Seal-Deterrent.aspx?lang=nb-no	Y	Aquaculture	Seals	Appendix 6.23
24	FaunaGuard – Porpoise Module[7]	Van Oord and Seamarco	FaunaGuard: Minimising potential impact of generated under water sound | Van Oord	Y	Dredging and marine construction, including piling and drilling & blasting	Porpoise species	Appendix 6.24

[7] Van Oord and Ace Aquatec making FaunaGuard available for rest of the world | Van Oord

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
25	Fauna Guard – Seal Module	Van Oord and Seamarco	FaunaGuard: Minimising potential impact of generated under water sound | Van Oord	Y	Dredging and marine construction, including piling and drilling & blasting	Seals	Appendix 6.25
26	Fauna Guard – Turtle Module	Van Oord and Seamarco	FaunaGuard: Minimising potential impact of generated under water sound | Van Oord	Y	Dredging and marine construction, including piling and drilling & blasting	Turtles	Appendix 6.26
27	Fauna Guard – Fish Module	Van Oord and Seamarco	FaunaGuard: Minimising potential impact of generated under water sound | Van Oord	Y	Dredging and marine construction, including piling and drilling & blasting	Fish	Appendix 6.27

Device ID	Device	Manufacturer	Weblink	Commercial availability	Potential Industry Application	Target species	Technical specification in this Report
28	Seamaster: 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 dolphins	Appendix 6.28
29	SealFENCE 3/4	OTAQ	https://aquaculture.otaq.com/sealfence/	Y	Aquaculture	Seals and sea lions	Appendix 6.29
30 (a, b, c, d)	Terecos DSMS-4	Terecos Ltd	No website available	Y	Unknown	All species	Appendix 6.30
31	L2/L3	Lien	None listed	Unknown	Unknown	Unknown	No details available

2.3 Acoustic device characteristics

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 back 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 defined by EU regulation. There are many EU regulation 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.

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 Low frequency deterrent - pinnipeds	Average within a transmission: 182 dB re 1 µPa rms @ 1 m	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 Ultra Low frequency - fish	Average within transmission: 182 dB re 1 µPa @ 1 m	200 – 900 Hz	Intermittent sound source	Appendix 6.2
3	Ace Aquatec: Marine Mammal Mitigation Device Mid Frequency - pinnipeds and cetaceans	Average within a transmission: 188 dB re 1 µPa @ 1 m.	8 – 24 kHz	Intermittent sound source	Appendix 6.3
4	Ace Aquatec Marine Mammal Mitigation Device (High Frequency) Pinnipeds and Odontocetes	Average within a transmission: 180 dB re 1 µPa @ 1 m.	20 – 70 kHz	Intermittent sound source	Appendix 6.4
5	Ace Aquatec: Universal Scrammer US2 (obsolete)	Average within a transmission: 181 dB re 1 µPa @ 1 m (RMS).	8 – 30 kHz	Intermittent. Transmission duration of 20 sec (double scram 40 sec), and a pulse duration of 20 ms.	Appendix 6.5

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent [1]	Technical specification in this Report
6	Ace Aquatec: Universal Scrammer US3	Average within a transmission: 181 dB re 1 µPa @ 1 m	8 – 11 kHz	Intermittent sound source 2.6 seconds	Appendix 6.6
7	Ace Aquatec: RT1	Average within a transmission: - 180 dB re 1 µPa @ 1 m (ring transducer) - 182 dB re 1 µPa @ 1 m (Flex transducer)	0.9 khz – 1.4 khz	Intermittent sound source 2.6 seconds	Appendix 6.7
8	Airmar dB plus II (now Mohn Aqua MAG seal deterrent)	Nominal SPL output = 198 dB re 1 µPa @ 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 @ 1 m (RMS)	10 kHz	Continuous sound source	Appendix 6.9
10	Aquamark 848	Nominal SPL output = 165 dB re 1 µPa @ 1 m	Primary bandwidth 5 kHz to 30 kHz	AQUAmark chirp repertoire for general deterrence	Appendix 6.10
11a	Aquamark 100	Nominal SPL output = 145 dB re 1 µPa @ 1 m	20 – 160 kHz	Continuous sound source	Appendix 6.11
11b	Aquamark 200	Nominal SPL output = 145 dB re 1 µPa @ 1 m	5 – 160 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
11c	Aquamark 210	Nominal SPL output = 150 dB re 1 µPa @ 1 m	5 – 160 kHz	Continuous sound source	Appendix 6.11
11d	Aquamark 300	Nominal SPL output = 132 dB re 1 µPa @ 1 m	10 kHz	Continuous sound source	Appendix 6.11
12	IFREMER/IX Trawl / Cetasaver V.03	Nominal SPL output = 165 dB re 1 µPa @ 1 m	30 – 150 kHz	Continuous sounds source	Appendix 6.12
13 a, b, c, d, e	Dolphin Deterrent Devices & Dolphin Interactive Deterrent	Nominal SPL output = 165 dB re 1 µPa @ 1 m	5 – 500 kHz (Random)	Intermittent sound source	Appendix 6.13
14	Dukane NetMark 1000	Nominal SPL output of a pulse is 132 dB re 1 µPa @ 1 m	10 kHz	Continuous sound source	Appendix 6.14
15a	Future Oceans Porpoise Pinger	Nominal SPL output = 132 dB re 1 µPa @ 1 m	10 kHz	Continuous sound source	Appendix 6.15
15b	Future Oceans Dolphin Pinger	Nominal SPL output = 145 dB re 1 µPa @ 1 m	70 kHz	Continuous sound source	Appendix 6.15
15c	Future Oceans Whale Pinger	Nominal SPL output = 145 dB re 1 µPa @ 1 m (±4 dB)	3 kHz	Continuous sound source	Appendix 6.15

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent [1]	Technical specification in this Report
16a	Banana Pinger (50-120)	Nominal SPL output = 145 dB re 1 µPa @ 1 m	50 kHz – 120 kHz. Intermittent sound source. Ping duration of 300 ms, and ping interval 4-12 sec	Intermittent sound source. Randomised ping interval and structure	Appendix 6.16
16b	Banana Pinger whale (3-20)	Nominal SPL output = 135 dB re 1 µPa @ 1 m	3 kHz – 20 kHz	Intermittent sound source. Ping duration of 300 ms, and ping interval of 4 sec	Appendix 6.16
16c	Banana Pinger porpoise (10)	Nominal SPL output = 132 dB re 1 µPa @ 1 m	10 kHz	Intermittent sound source. Ping duration of 300 ms, and ping interval of 4 sec	Appendix 6.16
16d	Dolphin Anti-depredation pinger	Nominal SPL output = 175 dB re 1 µPa @ 1 m	40 kHz	Intermittent sound source. Ping duration of 30 ms, and ping interval 4 – 12 sec. Randomised ping interval and structure	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
17a	F3 Porpoise PAL (Programmable Alert System)[8]	Nominal SPL output = 145 dB re 1 µPa @ 1 m	133 kHz	Intermittent. 1-3 signals of 1.3 sec length followed by a variable pause	Appendix 6.17
17b	F3: 10 kHz – PAL	Nominal SPL output = 132 dB re 1 µPa @ 1 m	10 kHz narrow band	Intermittent. One signal, 0.3 sec in length followed by a 4 sec pause	Appendix 6.17
17c	F3: Wideband PAL	Nominal SPL output = 145 dB re 1 µPa @ 1 m	20 – 160 kHz wideband	Intermittent. One signal, 0.3 sec in length followed by a variable pause	Appendix 6.17
17d	F3: Whale PAL	Nominal SPL output = 145 dB re 1 µPa @ 1 m	3 kHz narrow band	Intermittent. One signal, 0.3 sec in length followed by a 4 sec pause	Appendix 6.17
18	LU-1 prototype	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m (Larsen & Eigaard 2014).	40 – 120 kHz	Intermittent	Appendix 6.18

[8] The authors have been informed by the manufacturers of the F3 Porpoise PAL (Programmable Alert System) it uses a porpoise specific communication signal to alert porpoises in the western Baltic to nets. In addition, it can also be used to calibrate acoustic porpoise detection equipment in the field. It is advised that for additional information on the specific functionality of the system, the manufacturers are contacted.

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent [1]	Technical specification in this Report
19	Lofitech Seal Scarer/FishGuard	Nominal SPL output = 191 dB re 1 µPa at 1 m. Measured sound level = 204 dB re 1 µPa @ 1 m (McGarry *et al.* 2017).	10 – 20 kHz	Intermittent sound source	Appendix 6.19
20	Marexi Pinger: Acoustic Pinger V2.2	Nominal SPL output = 132 dB re 1 µPa @ 1 m (± 4 dB).	10 kHz (±2 kHz) tonal.	Continuous sound source	Appendix 6.20
21a	Genuswave TAST-Acoustic StartleDevice (ASD) TAST 'SalmonSafe'	Measured SPL output = ~180 - re 1 µPa @ 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, 2016 a & b). Signal is adjustable	Intermittent: isolated sound (200 ms long) signals are emitted at randomised intervals and very low duty cycles (<1%). (Götz & Janik 2015, Götz & Janik 2016 a, b).	Appendix 6.21

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent [1]	Technical specification in this Report
21b	Genuswave TAST- Acoustic Startle Device (ASD) TAST 'Fisheries Safe'	Pinniped signal = 180-182 dB re 1 µPa @ 1 m (RMS) (Götz & Janik 2015, MMO, in prep) Odontocete bycatch reduction signal: 140-175 dB re 1 µPa @ 1 m (RMS)	Pinniped/Seal signal: see 'SalmonSafe'; Götz & Janik 2015, Götz & Janik 2016a). Bycatch reduction signal for odontocetes: 5-20 kHz for low source level (concept described in Götz & Janik, 2015) Signals are adjustable	Intermittent: isolated signals (200 ms long) emitted at randomised intervals and very low duty cycles (<1%). (Götz & Janik 2015, Götz & Janik 2016 a, b).	Appendix 6.21
21c	Genuswave TAST- Acoustic Startle Device (ASD) TAST 'Mitigation ASD' 'TurbineSafe' 'ConstructionSafe'	Measured SPL output = 180 – 182 dB re 1 µPa @ 1 m (RMS) for signals centred at 1 kHz (Götz & Janik 2015, Götz & Janik 2016a) Up to 185 dB for high-frequency signal (5-20 kHz) 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: isolated signals (200 ms long) emitted at randomised intervals and low duty cycles (Götz & Janik 2015, Götz & Janik 2016a).	Appendix 6.21

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent [1]	Technical specification in this Report
22a	SaveWave SealSalmon Saver (High-impact)	Nominal SPL output = 155 dB re 1 µPa @ 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 6.22
22b	SaveWave Long Line Saver	Nominal SPL output = 155 dB re 1 µPa @ 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 6.22
22c	SaveWave Endurance Saver	Nominal SPL output = 140 dB re 1 µPa @ 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 6.22
22d	SaveWave OrcaSaver	Nominal SPL output = 196 (± 2) dB re 1 µPa @ 1 m (SeaWave 2013)	6.5 kHz (SeaWave 2013)	Intermittent sound source	Appendix 6.22
23	SeaGuard Seal Deterrent	Nominal SPL output = 198 dB re 1 µPa @ 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 options	Appendix 6.23

Device ID	Device	Sound pressure level (SPL) output	Frequency: kilohertz (kHz) or hertz (Hz)	Continuous or intermittent [1]	Technical specification in this Report
24	FaunaGuard - Porpoise Module	Nominal SPL output = 159.7 dB re 1 µPa @ 1 m Average output 165.0 dB re 1 µPa @ 1 m	60 – 150 kHz	Intermittent, with complex tones and random inter-pulse intervals	Appendix 6.24
25	Fauna Guard – Seal Module	Nominal SPL output = 174.1 dB re 1 µPa @ 1 m	1 – 20 kHz	Intermittent, with complex tones and random inter-pulse intervals	Appendix 6.25
26	Fauna Guard – Turtle Module	Nominal SPL output = 172.2 dB re 1 µPa @ 1 m Average output 177.7 dB re 1 µPa @ 1 m	200 Hz – 1 kHz	Intermittent, with complex tones and random inter-pulse intervals	Appendix 6.26
27	Fauna Guard – Fish Module	Nominal SPL output = 186.5 dB re 1 µPa @ 1 m	200 Hz – 1.5 kHz	Intermittent, with complex tones and random inter-pulse intervals	Appendix 6.27
28	Seamaster: Fish Protector	Nominal SPL output = up to 165 dB re 1 µPa @ 1 m	Frequency sweep tones and harmonics 10 – 90 kHz	Continuous sound source	Appendix 6.28
29	SealFENCE 3	Source level 165 dB re 1 µPa @ 1 m RMS (patrol mode) or 189 dB re 1 µPa @ 1 m RMS (protect mode)	9 – 11 kHz	Intermittent with different pulse rates according to mode selected	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
30 (a,b,c,d)	Terecos DSMS-4	Programme 1: Measured SPL output = 177 dB re 1 µPa @ 1 m (RMS) (± 1 dB) @ 6.6 kHz (Lepper *et al.* 2004). Programme 2: Measured SPL output = 179 dB re 1 µPa @ 1 m (RMS) (±1 dB) and 178 dB re 1 µPa @ 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 Continuous sound source	Appendix 6.30
31	L2/L3	No details available			

[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.

2.4 Acoustic devices by species or species group

Table 2-3 organises 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. Details of species impacts/range are provided in Table 2-3 based on the literature review and/or from technical details provided in Appendix A. 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 device by species/species group which were the focus of the research summarised here.

Please refer back to Tables 2-1 and Table 2-2 for more information about the devices, using the Device ID given in column 2 of Table 2-3 below to search for the relevant device.

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Harbour porpoise	Lofitech Seal Scarer [19]	300 -1,200 m	Deterred porpoise 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). Sparling *et al.* (2015) (ORJIP review) found that the device provided consistent and effective deterrence for harbour porpoise with short range deterrence observed for seals, but habituation occurred in several studies with seals. Mikkelsen *et al.* (2017) found that it deterred all porpoises to 190 m, with mixed behavioural reactions between 350 to 525 m. No reports of marine mammal sightings during soft start at active ADD locations (Dudgeon Offshore Wind Farm Ltd 2016). Significant deterrence effect on harbour porpoise out to 7.5 km (Brandt *et al.* (2012). 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 device was 798 m (Brandt *et al.* 2013). Horschle *et al.* (2015) concluded up to 75% reduction in harbour porpoise during use at measured distances of 750 and 1,500 m.	3

[9] This is not a measure of effectiveness of an ADD, but an assessment about the confidence in the evidence around an ADD's effectiveness or otherwise.

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			Increased swim speed, surfacing and jumps during device use on a captive harbour porpoise (Kastelein *et al.* 2015).	
Harbour porpoise	SaveWave SealSalmon Saver [22a] (called 'Black Saver' in this paper)	Not measured	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
Very high frequency cetaceans	Ace Aquatec: MMD High Frequenc) [4]	50 – 6,000 m	TTS modelled to 4 m (using Southall *et al.* 2007 criteria). Modelled exclusion up to 6 km, however potential to cause injury or mortality in close proximity (1-3 m) based on noise modelling, Nedwell *et al.* (2007) criteria (ABPmer 2014).	2
Harbour porpoise	Ace Aquatec: Universal Scrammer (US3) [6]	Likely avoidance between 200 m and 1.2 km. Potential exclusion up to 6 km.	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 2010). 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). ABPmer (2014) found TTS to 4 m (Southall *et al.* 2007 criteria), potential to cause exclusion up to 6 km and potential to cause injury or mortality in very close proximity (1-3 m) (based on noise modelling,	2

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			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 [27]	301 m – 1.2 km	Porpoise detections measured at nine stations between 301 m and 4.5 km. Only weak or minimal response in harbour porpoise; significant decline at 301m with proportional displacement to 1.2 km (Northridge *et al.* 2013). Injury threshold would be exceeded if animal was within 100 m of device for 2.5 hours, or over 24 hours at 500 m (Lepper *et al.* 2014).	2
Harbour porpoise	Fauna Guard – Porpoise Module [24]	Observed efficacy of at least 1,000 m	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 1006 m (Geelhoed *et al.* 2017). Captive animal's respiration rate increased and distance from device significantly increased (Kastelein *et al.* 2017). Sparling *et al.* (2015) concluded that device was useful.	2
Harbour porpoise	Airmar dB plus II [8]	200 m – 3,500 m	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). Porpoises left the site soon after the ADD was activated and the mean distance of approach was 991 m when the ADD was active.	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			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). Potential scope to reduce ADD time below 30 minutes tested (Hoschle *et al.* 2015).	
Harbour porpoise	Aquamark 848 [10]	Up to 1,500 m depending on species	ABPmer (2014) found potential to deter porpoise up to 200 m based on modelled ranges using dBht criteria (Nedwell *et al.* 2007).	2
Harbour porpoise	Aquamark 100 [11a]	100 m	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 (Morizur *et al.* 2009). Significant decrease in click detections and observations of harbour porpoise around nets with active device. Observed that porpoises take ~7 hours to recolonize area (Hardy & Tregenza 2010).	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			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	Aquamark 200[11b]	Approx. 130 m	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
Harbour porpoise	Aquamark 300 [11d]	Not available	The AQUAmark technology has been adapted to meet the NOAA Fisheries Take Reduction Plan pinger regulations, resulting in the AQUAmark 300 product.	
Harbour porpoise	Banana Pinger (50-120) [16a]	Approx. 100 m	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 dolphins or porpoises were observed in very close proximity to the nets fitted with pingers (<100 m) despite being seen in the vicinity (Woolmer 2015). Less porpoises detected moving from 400 m to 0 m from the pinger when activated (Friis 2017).	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Harbour porpoise	Banana Pinger (10) [16c]	Approx. 50 m	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). Reduction in entanglement rates of 1/3rd for cetaceans (Barlow *et al.* 2003) for pingers with same acoustic characteristics.	3
Harbour porpoise	F3 Porpoise PAL [17a]	Up to 250 m in 'good' weather	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
Harbour porpoise	Dukane – NetMark 1000 Pinger [14]	208 m to 375 m	87 - 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). 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).	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			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 (Wilson & Carter 2013).	
Harbour porpoise	Genuswave TAST Acoustic Startle Device (ASD) 'SalmonSafe' [21a]	No measurable effect	No effect on harbour porpoise (Götz & Janik, 2015, Götz & Janik, 2016, Janik & Götz 2013). In 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
Harbour porpoise	Genuswave TAST Acoustic Startle Device (ASD) 'Fisheries Safe' [21b]	No measurable effect (if none is intended). A few hundred metres for bycatch reduction	No effect on harbour porpoise (Götz & Janik, 2015, 2016; Janik *et al.* 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.*, in prep).	3
Harbour porpoise	Genuswave Acoustic Startle Device (ASD) 'Mitigation device' 'TurbineSafe'	Adjustable from a few hundred metres up to several km	Deterrence ranges from a few hundred metres to several kilometres (Hiley *et al*., in prep). No risk of hearing damage at close ranges. 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).	2-3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
	'ConstructionSafe' [21c]			
Harbour porpoise	DDD, DID from STM Products [13]	1.2 to 3 km	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). Sparling *et al.* (2015) concluded they were not currently useful for mitigation for offshore wind farms.	2
Harbour porpoise	Marexi Pinger [20]	Not available	No significant reduction in bycatch of harbour porpoise (Morizur *et al.* 2009).	2
Harbour porpoise	L2/L3 [28]	Not available	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
Porpoise	LU-1 prototype [18]	Not available	CEEs with pingers placed on gill nets found a 94% reduction in by-catch (significant difference) (Larsen *et al.* 2014). Porpoise reacted by moving away from the sensor, an average distance of 22.8 m from the alarm; Swimming and diving pattern and	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			breathing rate recovered to normal immediately after the sounds were switched off. No habituation was recorded (Kastelein *et al.* 1997).	
Hector's dolphin	Aquamark 200 [11b]	Not available	No avoidance reaction or measurable effect on Hector's dolphins to pingers deployed from boat (Stone *et al.* 2000).	2
Hector's dolphin	Dukane - Netmark 1000 Pinger [14]	Not available	Avoidance reaction of Hector's dolphin to pingers deployed from boat in 62% of cases, but not significant (Lepper *et al.* 2014.	2
High frequency cetaceans	Ace Aquatec: MMD Mid Frequency [3]	50 – 1,000 m from source	Predicted range of effect provided by manufacturer.	1
Bottlenose dolphin	SaveWave SealSalmon Saver (High-impact) [22a]	Not available	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
Dolphins	Aquamark 848 [10]	Up to 1,500 m depending on species	Predicted range of effect provided by manufacturer.	1

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Dolphins	Aquamark 200 [11b]	Not available	Significant reduction in by-catch of striped dolphin of 81% (Imbert *et al.* 2007).	2
Bottlenose dolphin	Aquamark 210 [11c]	Not available	Significant reduction in bycatch in the active condition compared to the no-pinger control. These pingers reduced the net interaction rate by 70% in active nets (Brotons *et al.* 2008).	3
Bottlenose dolphin	Aquamark 100 [11a]	Not available	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
Dolphins	Banana Pinger (50-120) [16a]	Approx. 100 m	Studies by scientists at the University of Malta 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 both reduced to 2% and 6% respectively when compared with the original records of damage and depredation before starting the pilot project.	2
Dolphins	Dolphin Anti-depredation Pinger (DDD) [16d]	Approx. 50 m	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
Humpback dolphin and snubfin dolphin	Future Oceans Dolphin Pinger [15b]	Not available	'At risk' interactions decreased from 81% to 50% in active nets (Read *et al.* 2010).	3

Species	**Device or group of devices and [Device ID]**	**Range of deterrence distances**	**Summary**	**Evidence Score[9]**
			The likelihood of the animals leaving an area was not significantly different from the controls (humpback dolphin and Australian snubfin) (Soto *et al.* 2013). Suggested audibility to humpback dolphin and snubfin dolphin approx. 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).	
Common Dolphin	Cetasaver V.03 [12]	Not available	No major changes in dolphin behaviour were observed during the trials (Berrow *et al.* 2008). A reduction in common dolphin bycatch of around 70% during the two years (Morizur 2008).	3
Dolphins	DDD and DID (STM Products) [13]	1.2 to 3 km	Northridge *et al.* (2011) report on efficacy of DDD from various studies, as follows: • no significant difference in observed bycatch when DDDs used on gill net fleet in the southwest; significant reduction in bycatch when using DDDs for bass pair trawl beams; • exclusion to at least 1.2 km and partial exclusion to 3km for a short string of nets; • limited change in behaviour of common dolphin with no evasive behaviour described (Berrow *et al.* 2008); • 31% fewer holes in nets and 28% more fish in monofilament gill nets with active pingers (bottlenose dolphin) (Buscaino *et al.* 2009); • a decrease in click detection of common dolphin with pingers attached to nets (Northridge *et al.* 2008); • Sparling *et al.* (2015) concluded they were not currently useful for mitigation for offshore wind farms.	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Dolphins	Genuswave TAST ASD Mitigation Device 'TurbineSafe' 'ConstructionSafe' [21c]	adjustable	General concept described in Janik & Götz (2013) and Götz & Janik (2015). For Physiological basis see Götz *et al*. (in review)	2
Bottlenose dolphin	Future Oceans Dolphin Pinger [15b]	Not available	No significant difference in behaviour of bottlenose dolphin around active versus control nets in Spanish mackerel gillnet fishery (Read *et al.* 2010).	2
Bottlenose dolphin	Seamaster: Fish Protector [25]	Up to 1 km	Predicted range of effect provided by manufacturer.	1
Bottlenose dolphin	Marexi Pinger [20]	Not available	Less damage to gillnets when device was present and active, than when it was not (Troncone *et al.* 2008).	2
Dolphins	Dukane Netmark 1000 [14]	Not available	Reduction in entanglement rates of 1/3rd for cetaceans (Barlow *et al.* 2003). No significant reduction in bycatch or encounters between nets with active and non-active pingers (Cox *et al.* 2004). Significant (73%) reduction in by-catch in nets with active pingers (Alfaro Shigueto 2010).	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Minke Whale	Lofitech [19]	1,000 m	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).	2
Minke Whale	Genuswave TAST ASD 'SalmonSafe' & FisherySafe [21a, b]	NA	No effect at ~1 km distance (Götz & Janik 2015)	3
Minke Whale	Genuswave TAST ASD 'MitigationDevice' 'TurbineSafe' 'ConstructionSafe' [21c]	Not measured	Use of broadband marine mammal signal	1
Low Frequency Cetaceans	Ace Aquatec: MMD Low Frequency [1]	50 – 1,000 m from source	Measured displacement over ranges of >1 km depending on species. Sound detectable at 7 km (ABPmer 2014)	2
Low Frequency Cetaceans	Aquamark 848 [10]	Up to 1,500 m depending on species	Predicted range of effect provided by manufacturer.	1

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Baleen Whales	Fishtek Marine: Banana Pinger Whale (3-20) [16b]	Approx. 100 m.	Predicted range of effect provided by manufacturer.	1
Humpback whale	Future Oceans Whale Pinger [15c]	Approx. 50 m (manufacturer)	No effect of the pinger on the humpback whales; they neither changed direction, changed speed nor altered their surfacing behaviour in response to the pinger, (Harcourt *et al.* 2014).	3
Seals	Lofitech Seal Scarer [19]	60 to 473 m	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). 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).	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			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 a* 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	Measured displacement over ranges of >1 km depending on species. Sound detectable at 7km (ABPmer 2014).	2
Seals	Ace Aquatec: MMD High Frequency [4]	50 – 2,000 m from source (from manufacturer)	Permanent Threshold Shift (PTS) to 3m and Temporary Threshold Shift (TTS) to 15m (based on Southall *et al. (*2007) criteria). Strong avoidance reaction up to approx. 800 m (based on noise modelling, Nedwell *et al.* 2007) (ABPmer 2014). Rapid habituation in both grey and harbour seals at RL of 146 dB re 1 µPa (Götz & Janik 2010).	2
Grey seals, harbour seals.	Ace Aquatec: Universal Scrammer (US3) [6]	Between 200 m and 1.4 km	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 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 60m in grey seals. Rapid	2

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			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). Fish mortalities (fish farms) reduced by 70% with use (Whyte *et al.* 2015). PTS to 3 m, TTS to 15 m (Southall *et al.* 2007 criteria), Strong avoidance reaction up to approx. 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 approx. 350 m (Lepper *et al.* 2014). Suitable for use in offshore wind farm construction (Sparling *et al.* 2015).	
Seals	Airmar: dB Plus II [8]	<50 m	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 44m from the sound source (Jacobs *et al.* 2002). Deterrence effect observed between 40 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).	3

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
			Significantly fewer seals fed within a river when ADD was deployed compared to no ADD; deterrence range was 50 m (Yurk & Trites 2000). Seal mortality reduced by 50% using ADD at fish farm (Whyte 2015). A seal at 100 m would exceed the threshold 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	Gael Force: SeaGuard Seal Deterrent [23]	40 m	Predicted range of effect provided by manufacturer. Evidence for habituation in context where food motivation is involved at RL of 146 dB re 1 µPa. (Götz 2008; Götz & Janik 2010).	1
Seals	Terecos Ltd: DSMS-4 [27]	Not Available	No reduction in fish mortalities from use of Terecos device (Whyte 2015). Seal injury threshold 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

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Seals	Fauna Guard – Seal Module [25]	Predicted efficacy of at least 100 – 500 m	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
Seals	Genuswave TAST Acoustic Startle Device (ASD) 'SalmonSafe' [21a]	60 – 250 m	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 haulout sites (Götz, 2008). Significant effectiveness on seal predation, i.e. 91-97% reduction in predated fish (Götz & Janik 2016 a, b).	3
Seals	Genuswave TAST Acoustic Startle Device (ASD) 'FisherySafe' [21b]		Significant reduction of seal predation on salmon, i.e. 91-97% reduction in predated fish (Götz & Janik 2016 a, b). 74% increase of catch of on protected test net (MMO, in prep) Reduction in predated fish in jigging and shallow water gillnet fisheries (Gosch *et al*. 2017, 2018)	3
Seals	Genuswave TAST Acoustic Startle Device (ASD) 'Mitigation device' 'TurbineSafe' 'ConstructionSafe' [21c]		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

Species	Device or group of devices and [Device ID]	Range of deterrence distances	Summary	Evidence Score[9]
Seals and sea lions	SealFENCE [26]	Up to 45 m	Predicted range of effect provided by manufacturer	1
Grey Seal	Aquamark 848 [10]	Up to 1,500 m depending on species (from manufacturer)	Very localised strong avoidance reactions in grey seal within 28 m (based on noise modelling, Nedwell *et al.* 2007 criteria) (ABPmer 2014).	2
Grey seal	Aquamark 100 [11a]	Up to 3 m	Very localised strong avoidance reaction within 3 m (based on noise modelling, Nedwell *et al.* 2007 criteria) (ABPmer 2014)	2

[1] These ranges 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. The range of deterrence distances is derived from the literature or manufacturer's information.

3 Deployment of devices as mitigation

3.1 Overview

Manufacturers do not provide generic guidelines on deployment of ADDs, as these devices are designed with simple functionality and therefore do not require detailed device-specific guidelines.

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 operator 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 Training requirements

There were no training requirements specified for any of the devices reviewed for this report. All devices can be 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 member, and not necessarily a trained marine mammal field biologist. If, however, monitoring 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. In considering the appropriate deployment depth, the operator should aim to locate the transducer below the maximum draft of the boat to ensure 360º coverage and at a sufficient depth to avoid interference by surface water noise.

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.

The location of deployment might be another consideration, particularly in coastal areas, channels or where multiple devices are required.

3.3.2 Spares

To ensure reliability of the deployment plan, it is recommended that as a minimum a spare battery is included as part of the kit. A more failsafe approach would be to also include one or more back-up devices. The requirement for this depends on the logistical feasibility of replacing a device, should it malfunction.

3.3.3 Testing

It is recommended that both the main ADD unit and back up unit are tested to see if they are working, e.g. using a hydrophone and monitoring via computer interface with suitable software (e.g. 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.

3.3.4 Duration of deployment

The duration of deployment of an ADD as mitigation is determined on a project-specific basis. Consideration should be given to balancing the need to ensure animals are deterred from the risk zone (i.e. auditory injury zone or collision risk zone) and the need to minimise the noise introduced into the environment, which itself could cause a negative effect. Herschel *et al.* (2013) recommend that the duration of ADD deployment for mitigating loud noises for example should be tailored to allow all animals to swim twice the distance of the estimated auditory injury zone. The duration of ADD deployment can then be informed by published swim speeds of the focal species to calculate the time it would take for an animal, assuming it swims in a straight line directly away from the noise source, to move twice the distance of the injury zone. Selection of the ADD deployed should be based upon available evidence on the distance over which effective displacement of key receptors occurs for a given device (Table 2-3) and the project-specific mitigation needs.

Consideration must also be given to the procedure to follow if there is a break in the noise producing activity. For example, in pile-driving there are planned or unplanned breaks that result in periods of non-piling. The applicant must consider the circumstances that would trigger the need to re-deploy an ADD to ensure that the risk of injury to marine mammals is minimised. Figure 1 shows an example of an ADD deployment protocol in the context of a pile-driving operation.

3.3.5 Task plan

As part of the mitigation plan, and for developments that require careful timing of ADD deployment (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 (Figure 2).

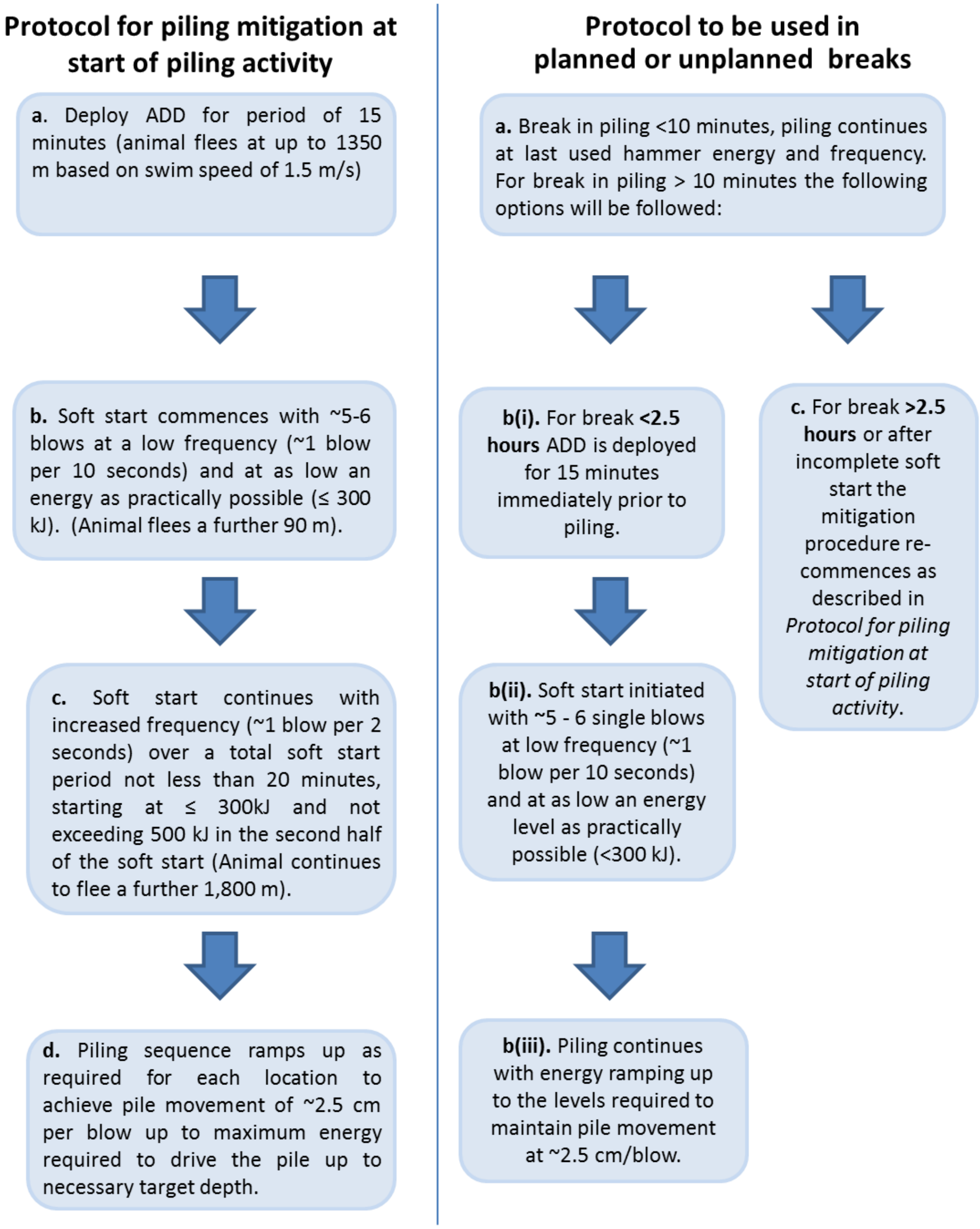

Figure 1: ADD deployment protocol for piling. Note that the fleeing distance has been estimated at each stage of the protocol to demonstrate that the distance cleared is sufficiently greater than the injury range. Reproduced with permission from Beatrice Offshore Wind Farm Ltd (BOWL 2017).

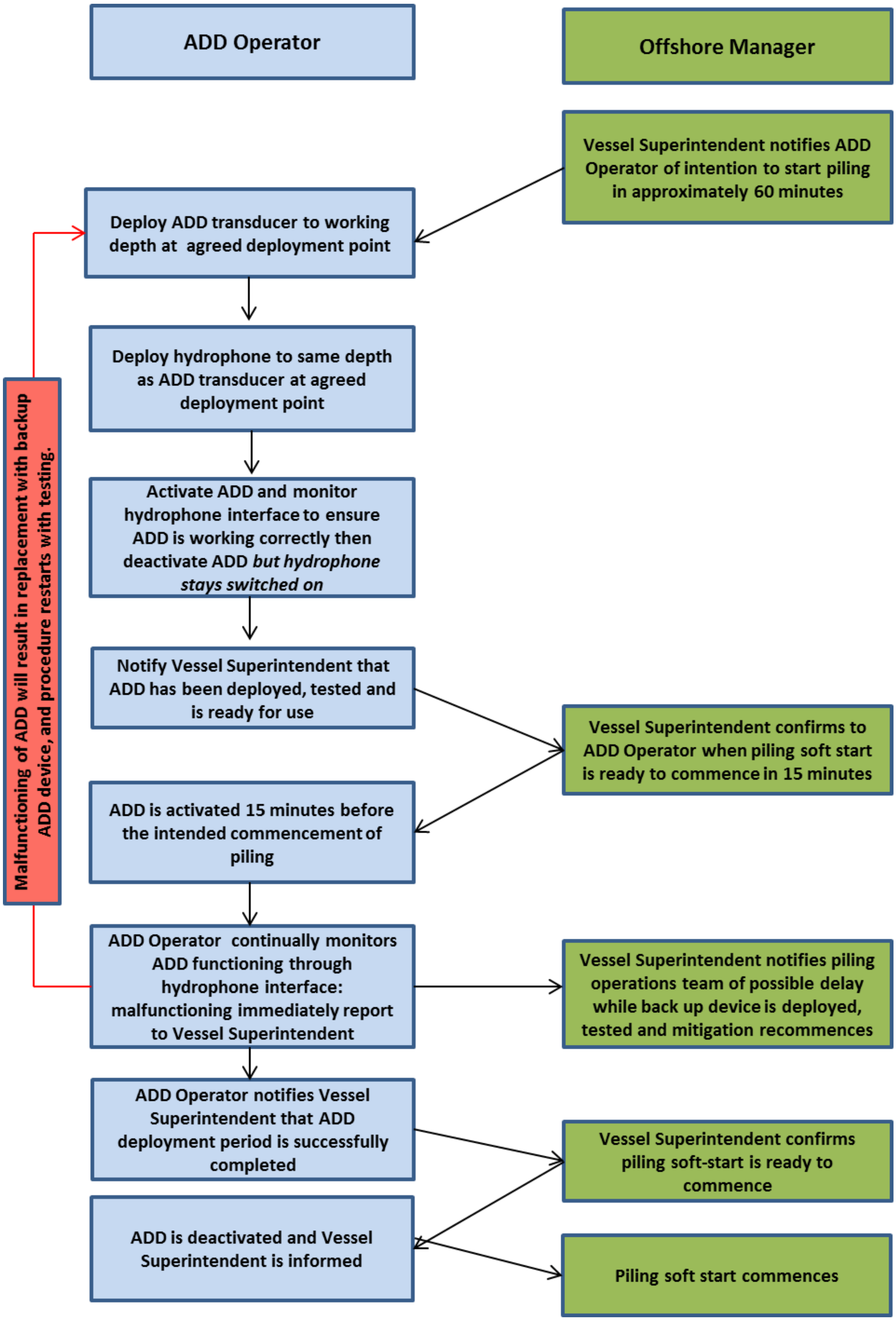

Figure 2: ADD task plan for deployment of an ADD as the primary mitigation measure during pile-driving activity. This task plan was produced for the Beatrice ADD Deployment Protocol as part of the Piling Strategy consent plan (BOWL 2017) (reproduced with permission from BOWL).

4 UK Legislation and Guidance

4.1 Overview

Marine mammals are protected in the UK under a series of regulations. Some of these apply to noise and the potential for hearing damage or disturbance. The majority of acoustic devices available emit loud sounds and therefore could carry a risk of an adverse impact on these species. The risk of injury from ADD deployment is likely to be low (see section 1.3) and would only occur if animals stayed in the vicinity of an operating device for prolonged periods of time. ADDs, if effective, will disturb marine mammals, and the question of whether this could be considered an offence in relation to environmental legislation will depend primarily on how these devices are used, how often, for how long and where they are deployed.

4.2 Legislation and Regulations

There are several key pieces of legislation pertaining to marine mammals within UK and European waters that should be considered in relation to potential ADD deployments. The EC Habitats Directive (92/43/EEC) lists all cetaceans in Annex IV, i.e. species for which a system of strict protection needs to be established, and lists grey and harbour seal, harbour porpoise and bottlenose dolphin in Annex II, requiring the designation of Special Areas of Conservation (SACs) and the avoidance of significant disturbance within the sites.

The EC Habitats Directive is transposed into UK law by the Habitats Regulations by devolved administrations (out to 12 nautical miles (nm)) and beyond 12 nm by the Offshore Marine Conservation Regulations. These make it an offence to deliberately kill, injure, capture or disturb cetaceans. A summary of relevant Habitats Regulations by devolved administration is provided below:

England and Wales (to 12 nm)	The Conservation of Habitats and Species Regulations 2017 consolidate and update the Conservation of Habitats and Species Regulations 2010 (as amended)
Scotland	The Conservation (Natural Habitats &c) Regulations 1994 (as amended)
Northern Ireland	The Conservation (Natural Habitats, etc) Regulations (Northern Ireland) 1995 (as amended)
Offshore	The Conservation of Offshore Marine Habitats and Species Regulations 2017, consolidate and update the Offshore Marine Conservation (Natural Habitats &c) Regulations 2007.

In addition to the Habitats Regulations, The Wildlife and Countryside Act 1981 (as amended), sets out protection for animals listed on Schedule 5 (includes all cetaceans), in England and Wales, from 0 to 12 nm. It makes it an offence to intentionally or recklessly disturb whales and dolphins (but not harbour porpoise).

The Conservation of Seals Act (1970), the Conservation of Offshore Marine Habitats and Species Regulations 2017, the Marine Scotland Act (2010), the Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014; and The Wildlife (Northern Ireland) Order 1985[10], all set out offences relating to seals, protecting them from capture, killing or

[10] Basking sharks are also protected under this Order from intentional or reckless disturbance.

injury either during closed seasons or year-round, and also prohibit disturbance and harassment in Northern Ireland and some parts of Scotland, respectively.

A summary of legislation relevant to the potential for an offence through the deployment of ADDs is provided in Table 4-1.

Also, of relevance to ADD use are European Council Regulation (EC) No 812/2004 "*laying down measures concerning incidental catches of cetaceans in fisheries*" which requires the use of acoustic devices in order to minimise by catch of small cetaceans in areas with "*known or foreseeable high levels of by-catch of small cetaceans*"; and the Marine Strategy Framework Directive (MSFD 2008/56/EEC). Descriptor 11 of the MSFD "Energy including Underwater Noise" has the aim of ensuring that the "*introduction of energy including underwater noise is at levels which do not adversely affect the marine environment*". A UK 'marine noise registry' (MNR), which records the spatial and temporal distribution of impulsive underwater noise (with frequencies between 10 Hz to 10 kHz), was established in 2016.

Table 4-1: Summary of offences in relation to cetaceans and seals.

Species Group	England	Wales	Scotland	N. Ireland	Offshore
Cetaceans: European Protected Species (Habitat Regulations, by devolved administration)					
	Deliberately kill, injure or capture a cetacean; Deliberately disturb cetaceans, including in ways likely to: - impair their ability to survive, to breed or reproduce, to rear or nurture their young, to migrate, to shelter or protect themselves. - affect significantly the local distribution or abundance of the species to which they belong.	Deliberately kill, injure or capture a cetacean; Deliberately disturb cetaceans, including in ways likely to: - impair their ability to survive, to breed or reproduce, to rear or nurture their young, to migrate, to shelter or protect themselves. - affect significantly the local distribution or abundance of the species to which they belong.	Deliberately or recklessly kill, injure or capture a cetacean. Deliberately or recklessly disturb or harass a cetacean or a group of cetaceans, including in ways likely to: - impair their ability to survive, to breed or reproduce, to rear or otherwise care for their young, to migrate, to shelter or protect themselves. - affect significantly the local distribution or abundance of the species to which they belong. Deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean).	Deliberately kill, injure or capture a cetacean; Deliberately disturb cetaceans, including in ways likely to: - impair their ability to survive, to breed or reproduce, to rear or nurture their young, to migrate, to shelter or protect themselves. - affect significantly the local distribution or abundance of the species to which they belong.	Deliberately kill, injure or capture a cetacean; Deliberately disturb cetaceans, including in ways likely to: - impair their ability to survive, to breed or reproduce, to rear or nurture their young, or to migrate. - affect significantly the local distribution or abundance of the species to which they belong.

Species Group	England	Wales	Scotland	N. Ireland	Offshore
Cetaceans: Wildlife and Countryside Act (1981 as amended for England and Wales), Wildlife and Countryside Act (1981) (as amended in Scotland); The Wildlife (Northern Ireland) Order (1985) (as amended).					
	Intentionally or recklessly disturb most wild species of cetacean.	Intentionally or recklessly disturb most wild species of cetacean.	Cetaceans are no longer protected by the Wildlife and Countryside Act 1981 (as amended).	Cetaceans not protected by Wildlife Order.	Not covered by Wildlife and Countryside Act.
Seals: Marine (Scotland) Act 2010; Conservation of Seals Act (1970); Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014; The Wildlife (Northern Ireland) Order 1985 (as amended)					
	Cannot take, kill or injure during closed season or on east and southeast coast at any time.	Cannot take, kill or injure during closed season.	Cannot intentionally or recklessly kill, injure or take a seal at any time except under licence or to alleviate suffering. Cannot intentionally or recklessly harass seals at significant haul out sites.	Cannot intentionally or recklessly kill, injure take or disturb at any time of the year, damage, destroy, or obstruct access to any structure or place used for shelter or protection.	Not applicable.

4.3 Wildlife licensing requirements

4.3.1 Overview

A marine wildlife (protected species) licence or an EPS licence can be required for some activities where there is a potential for offences to a marine EPS or UK protected species (see Table 4-1). As mentioned in Section 1.3, the risk of injury resulting from ADD deployment is likely to be very low, whereas the risk of disturbance is dependent on how these devices are used, how often, for how long and where they are deployed. The deployment of ADDs can be an important component of a mitigation package aimed at preventing the risk of injury to marine mammals arising for example from the detonation of explosives, pile-driving or tidal turbines. An ADD deployment protocol (e.g. Figure 1) included in the Marine Mammal Mitigation Plan and agreed by applicants, licensing authority and SNCBs should ensure that the potential for disturbance from ADD deployment is minimised. However, the risk of injury and a potential offence should be assessed on a case-by-case basis noting differences in EPS legislation between devolved administrations.

For prolonged ADD deployments inside or affecting a SAC with marine mammal qualifying features, a Habitats Regulations Appraisal/Assessment (HRA) may be required.

4.3.2 Marine Licensing in England

In England, depositing any object in the sea, on, or under the seabed, may require a marine licence. The Marine Management Organisation (MMO) licences most activities in English inshore and offshore waters. If the deployment of an ADD could result in injury or disturbance to cetaceans and an offence under the ‘Habitats Regulations’, then derogations (EPS licence) can be issued to make lawful specific activities provided that specific tests can be met.

The guidance document “The protection of marine European Protected Species from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area” can be referred to for further information on the interpretation of the regulations.

4.3.3 Marine Licensing in Scotland

Certain activities require a marine licence before they can be carried out in Scotland’s seas. Licensable activities include (but are not limited to): depositing substances/objects into the sea or onto the seabed, the removal of substances/objects, construction, and explosives. Activities likely to disturb or injure a cetacean in Scottish inshore waters may additionally require an EPS licence.

Marine Scotland licenses most commercial activities in Scottish inshore and offshore territorial waters. SNH has responsibility for EPS licences for conservation work in inshore waters, survey and research. There must be a licensable activity for Marine Scotland/SNH to be able to issue a licence to disturb an EPS.

Where sound is to be produced (such as an ADD), applicants must provide the source level and frequency. The guidance document “The protection of marine European Protected Species from injury and disturbance” (Marine Scotland 2014) should be used to determine whether an offence may occur.

4.3.4 Marine Licensing in Northern Ireland

The Department of Agriculture, Environment and Rural Affairs (DAERA) licences activities in Northern Irish inshore waters. The MMO licences activities in Northern Irish offshore waters.

Certain activities, including the deployment of ADDs, may require a marine licence. If the deployment of an ADD could result in injury or disturbance to cetaceans and an offence under the ‘Habitats Regulations’, then derogations can be issued to make lawful specific activities provided that specific tests can be met. A Wildlife licence could also be issued under Wildlife (Northern Ireland) Order 1985 (as amended) for certain activities that could result in injury or disturbance to Schedule 5 marine species (harbour and grey seal). As of 2016 these are issued by the Department of Agriculture, Environment and Rural Affairs (DAERA) Marine and Fisheries division.

4.3.5 Marine Licensing & Protected Species Licensing in Wales

Natural Resources Wales (NRW) determines marine licences on behalf of Welsh Ministers for all marine licensable activities in the Welsh Zone (inshore and offshore). NRW also has the responsibility for protected species licensing in Wales associated with activities in the Welsh inshore and offshore zone. If the deployment of an ADD could result in injury or disturbance to cetaceans and an offence under the ‘Habitats Regulations’, then derogations can be issued to make lawful specific activities provided that specific tests can be met. Wildlife and Countryside Act 1981 licences cannot be issued for the purposes of development. Further information can be found at NRW’s protected species licensing web page.

The guidance document “The protection of marine European Protected Species from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area”, can also be referred to for further information on the interpretation of the regulations.

4.3.6 Marine Licensing in UK Offshore Waters

The MMO and BEIS licence most activities in UK offshore waters. Certain activities, including the deposit of any substance or object, may require a marine licence. If the deployment of an ADD could result in injury or disturbance to cetaceans and an offence under the ‘Habitats Regulations’, then derogations (EPS licence) can be issued to make lawful specific activities provided that specific tests can be met.

The guidance document “The protection of marine European Protected Species from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area”, can be referred to for further information.

4.4 Current guidance documents

The listed guidance documents below should be used in relation to specific requirements by devolved administration. There may be additional or updated guidance available, and applicants should always contact the relevant conservation organisation.

England, Wales and Offshore waters

The protection of marine European Protected Species from injury and disturbance Guidance for the marine area in England and Wales and the UK offshore marine area: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/681834/Protection_Marine_EP_Injury_Disturbance.pdf.

England

Guidance on Activities that may require a Marine Licence: https://www.gov.uk/guidance/do-i-need-a-marine-licence.

Marine Species Protection: Cetaceans: https://www.gov.uk/government/publications/protected-marine-species/cetaceans-dolphins-porpoises-and-whales.

Marine Species Protection: Seals https://www.gov.uk/government/publications/protected-marine-species/seals.

Wales

Marine Licensing: https://naturalresources.wales/permits-and-permissions/marine-licensing/?lang=en

Marine Vertebrates Conservation: https://cdn.naturalresources.wales/media/687230/gn003-marine-vertebrate-conservation-legislation-in-wales.pdf

Protected Species Licensing: https://naturalresources.wales/permits-and-permissions/protected-species-licensing/?lang=en

Scotland

Marine European Protected Species Guidance. Marine Scotland, July 2020: Marine European protected species: protection from injury and disturbance - gov.scot (www.gov.scot)

Guidance for Marine Licence Applicants, Marine Scotland 2015: http://www.gov.scot/Resource/0052/00524064.pdf.

Northern Ireland

Marine Wildlife Licensing, Guidance for Applicants, July 2016. DAERA. https://www.daera-ni.gov.uk/publications/marine-wildlife-licensing-guidance-applicants.

https://www.daera-ni.gov.uk/articles/marine-wildlife-licensing.

Offshore

Understanding marine wildlife licences and report an incident guidance: https://www.gov.uk/guidance/understand-marine-wildlife-licences-and-report-an-incident.

5 References

ABPmer. (2014). Marine Mammal Acoustic Deterrent Device Review. Report for Tidal Lagoon (Swansea Bay) plc as part of Oral Representations for the PINS Issue Specific Hearing.

Alfaro Shigueto, J. (2010). Experimental trial of acoustic alarms to reduce small cetacean bycatch by gillnets in Peru. Final Report to: Rufford Small Grants Foundation.

Barlow, J. & Cameron, G.A. (2003). Field Experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. *Marine Mammal Science* 19(2):265-283.

Berg Soto, A, Cagnazzi, D., Everingham, Y., Parra, G.J., Noad, M. & Marsh, H. (2013). Acoustic alarms elicit only subtle responses in the behaviour of tropical coastal dolphins in Queensland, Australia. *Endangered Species Research*, Vol. 20: 271-282.

Berrow, S., Cosgrove, R., Leeney, R.H., O'Brien, J., McGrath, D. & Dalgard, J. (2008). Effect of acoustic deterrents on the behaviour of common dolphins (*Delphinus delphis*). *J. Cetacean Res. Manage*, 10(3), 227-233.

Bordino, P., Albareda, D., Palmerio, A., Mendez, M. & Botta, S. (2002). Reducing incidental mortality of Franciscana dolphin *Pontoporia blainvillei* with acoustic warning devices attached to fishing nets. *Mar Mamm Sci* 18: 833−842.

Brandt, M.J., Höschle, C., Diederichs, A., Betke, K., Matuschek, R., Witte, S. & Nehls, G. (2012). Far-reaching effects of a seal scarer on harbour porpoises, *Phocoena phocoena*. *Aquatic Conservation*: Marine and Freshwater Ecosystems.

Brandt, M.J., Hoeschle, C., Diederichs, A., Betke, K., Matuschek, R. & Nehls, G. (2013). Seal scarers as a tool to deter harbour porpoises from offshore construction sites. *Marine Ecology Progress Series*, 475, 291–302.

Brotons, J.M., Munilla, A., Grau, A.M.& Rendell, L. (2008). Do pingers reduce interactions between bottlenose dolphins and nets around the Balearic Islands? *Endangered Species Research*, Vol. 5: 301-308.

Buscaino, G., Buffa, G., Sarà, G., Bellante, A. & Josè Tonello, A. (2009). Pinger affects fish catch efficiency and damage to bottom gillnets related to bottlenose dolphins. *Fish Sci* 75:537−544.

Carlström, J., Berggren, P., Dinnetz, F. & Borjesson, P. (2002). A field experiment using acoustic alarms (pingers) to reduce harbour porpoise bycatch in bottom-set gillnets. *ICES J Mar Sci* 59: 816−824.

Carlström, J., Berggren, P. & Tregenza, N.J.C. (2009). Spatial and temporal impact of pingers on porpoises. *Can J Fish Aquat Sci* 66: 72−82.

Cornwall Wildlife Trust, Cornwall Seal Group, Cornish Seal Sanctuary. (2013). Investigation into the attraction of Atlantic grey seals (*Halichoerus grypus*) to the Fishtek Banana Pinger. A report by: Cornwall Wildlife Trust, Cornwall Seal Group, Cornish Seal Sanctuary.

Cox, T.M., Read, A.J., Solow, A. & Tregenza, N.C. (2001). Will Harbour porpoises (*Phocoena phocoena*) habituate to pingers? *Journal of Cetacean Research and Management*. 3(1): 81-86.

Cox, T.M., Read, A.J., Swanner, D., Urian, K. & Waples, D. (2004). Behavioral responses of bottlenose dolphins, *Tursiops truncatus*, to gillnets and acoustic alarms. *Biol Conserv* 115: 203−212.

Crosby, A., Tregenza, N. & Williams, R. (2013). The Banana Pinger Trial: Investigation into the Fishtek Banana Pinger to reduce cetacean bycatch in an inshore set net fishery. Report for the Wildlife Trusts.

Culik, B.M., Koschinski, S., Tregenza, N. & Ellis, G.M. (2001). Reactions of harbor porpoises *Phocoena phocoena* and herring *Clupea harengus* to acoustic alarms. *Marine Ecology Progress Series* 211, 255-260.

Culik, B., Conrad, M. & Chladek, J. (2017). Acoustic protection for marine mammals: new warning device PAL. Published in the Proceedings of the 43rd Jahrestagung für Akustik, Kiel, 6.-9.3.201. http://www.daga2017.de/.

Culik, B. & Dorrien, C. (2017) In: ICES. 2017. Report of the Working Group on Bycatch of Protected Species (WGBYC), 12–15 June 2017, Woods Hole, Massachusetts, USA. ICES CM 2017/ACOM:24. 82 pp.

Dähne, M., Tougaard, J., Carstensen, J., Armin, R. & Nabe-Nielsen, J. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. *Mar Ecol Prog Ser Vol*. 580: 221–237, 201.

Desportes, G., Amundin, M., Larsen, F., Bjørge, A., Poulsen, L.R., Stenback, J. & Petersen, N. (2006). NIPPER: nordic interactive pinger for porpoise entanglement reduction. Final report to Nordic Council of Ministers Fjord & Bælt, Kerteminde. www.kolmarde.

Dudgeon Offshore Wind Farm Ltd. (2016). Dudgeon Offshore Wind Farm - Piling Summary and Lessons Learned.

Ferraro, G. B., Bruno C., Stockdale T., Blasi M. F. (2018) Acoustic deterrent devices as a possible solution for reducing depredation of artisanal gill nets by bottlenose dolphin (Tursiops truncatus) in the Aeolian Archipelago (Italy). 32nd Conference of the European Cetacean Society, Italy

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

Franse, R. (2005) Effectiveness of Acoustic Deterrent Devices (pingers). Universiteit Leiden. Centrum voor Milieuwetenschappen Leiden. Pg 33.

Friis, C.L. (2017). Deterrent effect of a "seal safe" pinger on harbor porpoises (*Phocoena phocoena*). Masters Project. Department of Physics, Chemistry and Biology. Linkoping University.

Gazo, M., Gonzalvo, J. & Aguilar, A. (2008). Pingers as deterrents of bottlenose dolphins interacting with trammel nets. *Fisheries Research*, 92: 70-75.

Gearin, P.J., Gosho, M.E., Laake, J.L., Cooke, L., DeLong, R.L. & Hughes, K.M. (2000). Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbour porpoise, *Phocoena phocoena*, in the state of Washington. *J Cetacean Res Manag* 2: 1−9.

Geelhoed, S.C.V., von Asmuth, R., Al Abbar, F., Leopold, M.F. & Aarts, G.M. (2017). Field testing the efficiency of the FaunaGuard Porpoise Module (FG-PM) in the Marsdiep area. Wageningen Marine Research report C076/17.

Gönener, S. & Bilgin, S. (2009). The effect of pingers on harbour porpoise, *Phocoena phocoena*, bycatch and fishing effort in the turbot gill net fishery in the Turkish Black Sea coast. *Turk J Fish Aquat Sci* 157: 151−157.

Gordon, J., Blight, C., Bryant, E. & Thompson, D. (2015). Tests of Acoustic Signals for Aversive Sound Mitigation with Common Seals. Sea Mammal Research Unit report to Scottish Government.

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

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

Götz, T. (2008). Aversiveness of sound in marine mammals: Psycho-physiological basis, behavioural correlates and potential applications. PhD thesis at the University of St. Andrews.

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

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

Götz, T. & Janik, V. M. (2013). Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series*, Volume 492, 31 October 2013, Pages 285 – 302.

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

Götz, T. & Janik, V. M. (2016a). Non-Lethal Management of Carnivore Predation: Long-Term Tests with a Startle Reflex-Based Deterrence System on a Fish Farm. *Animal Conservation* 19, 212–221

Götz, T., Janik, V.M. (2016b). The Startle Reflex in Acoustic Deterrence: An Approach with Universal Applicability? *Animal Conservation* 19: 225–226.

Götz, T., Pacini, A.E., Nachtigall, P.E., Janik, V.M. (under review): The startle reflex in echolocating *odontocetes*: basic physiology and practical implications. *Journal of Experimental Biology*

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

Harcourt, R., Pirotta, V., Heller, G., Peddemors, V. & Slip, D. (2014). A whale alarm fails to deter migrating humpback whales: an empirical test. *Endangered Species Research*, Vol. 25: 35–42, 2014.

Hardy, Y. & Tregenza, N. (2010). Can acoustic deterrent devices reduce bycatch in the Cornish inshore gillnet fishery? Field studies. Cornwall Wildlife Trust, Truro.

Hardy, T., Williams, R., Caslake, R. & Tregenza, N. (2012). An investigation of acoustic deterrent devices to reduce cetacean bycatch in an inshore set net fishery. *Journal of Cetacean Research Management* 12(1): 85–90.

Hiley, H., Janik, V.M. & Götz, T. (in prep): Startling sounds elicit strong movement response in harbour porpoise.

Harris, R.N. (2011). The effectiveness of an Acoustic Deterrent Device for seals. *In* Seal and Salmon Research Project. Report to the Scottish Government. 1-12.

Harris, R.N., Harris, C.M., Duck, C.D. & Boyd, I.L. (2014). The effectiveness of a seal scarer at a wild salmon net fishery. *ICES Journal of Marine Science*.

Imbert, G., Laubier, L., Malan, A., Gaertner, J.C. & Dekeyser, I. (2007). La thonaille ou courantille volante: rapport final à la région Provence-Alpes-Côte D'azur. Rapport final au Conseil Régional Provence-Alpes-Côte d'Azur. Centre d'Océanologie de Marseille, Marseille.

Jacobs, S.R. & Terhune, J.M.l. (2002). The effectiveness of acoustic harassment devices in the Bay of Fundy, Canada: seal reactions and a noise exposure model. *Aquatic Mammals* 2002, 28.2, 147–158.

Janik, V. M. & Götz, T. (2013). Acoustic deterrence using startle sounds: long-term effectiveness and effects on odontocetes. Report for Marine Scotland. https://www.gov.scot/publications/acoustic-deterrence-using-startle-sounds-long-term-effectiveness-effects-odontocetes/

Johnston, D.W. (2002). The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. *Biological Conservation*, Volume 108, Issue 1, November 2002, Pages 113-118.

Kastelein, R.A., de Haan, D., Goodson, A.D., Stall, C. & Vaghan, N. (1997). The effects of various sounds on a harbour porpoise (*Phocoena phocoena*). In: Read, A.J., Wiepkema, P.R. & Nachtigall, P.E (editors). *'The biology of the harbour porpoise* (1997). Pp. 367-383.

Kastelein, R.A., Helder-Hoek, L., Gransier, R., Terhune, J.M., Jennings, N. & de Jong, C.A. (2015). Hearing thresholds of harbor seals (*Phoca vitulina*) for playbacks of seal scarer signals, and effects of the signals on behavior. *Hydrobiologia*, 756:89-103.

Kastelein, R.A., Hoek, L., Jennings, N., de Jong, C.A.F., Terhune, J.M. & Dieleman, M. (2010). Acoustic Mitigation Devices (AMDs) To Deter Marine Mammals from pile driving areas at sea: Audibility and Behavioural Response of a Harbour Porpoise and Harbour Seals. COWRIE Ref: SEAMAMD-09 - Technical Report.

Kastelein, R.A., Horvers, M., Helder-Hoek, L., Van de Voorde, S., ter Hofstede, R. & van der Meif, H. (2017). Behavioral Responses of Harbor Seals (*Phoca vitulina*) to FaunaGuard Seal Module Sounds at Two Background Noise Levels. *Aquatic Mammals* 2017, 43(3), 347-363.

Kastelein, R.A., Hoek, L., Gransier, R., de Jong, C.A., Terhune, J.M. & Jennings, N. (2015). Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for playbacks of seal scarer signals, and effects of the signals on behaviour. *Hydrobiologia*, 756:75-88.

Koschinski, S. & Culik, B. (1997). Deterring harbour porpoises (*Phocoena phocoena*) from gillnets: Observed reactions to passive reflectors and pingers Report of the International Whaling Commission (1997).

Kraus, S. & Brault, S. (1999). A springtime field test of the use of pingers to reduce incidental mortality of harbor porpoises in gillnets. IWC SC/51/SM/WP10, International.

Kraus, S., Read, A., Anderson, E., Baldwin, K., Solow, A., Spradlin, T. & Williamson, J. (1997). Acoustic alarms reduce incidental mortality of porpoises in gill nets. *Nature* 388: 525.

Kyhn, L.A., Jørgensen, P.B., Carstensen, J., Bech, N. I., Tougaard, J., Dabelsteen, T. & Teilmann, J. (2015). Pingers cause temporary habitat displacement in the harbour porpoise *Phocoena phocoena*. *Mar Ecol Prog Ser*, 526, 253-265.

Laake, J., Rugh, D. & Baraff, L. (1998). Observations of Harbour Porpoise in the Vicinity of Acoustic Alarms on a Set Gill Net. U.S Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-84,40 p.

Larsen, F. & Eigaard, O.R. (2014). Acoustic alarms reduce bycatch of harbour porpoises in the Danish North Sea gill et fisheries. *Fisheries Research* 153, 108-112.

Larsen, F. & Krog, C. (2007). Fishery trials with increased pinger spacing. Paper presented to the Scientific Committee of the International Whaling Commission. IWC SC/ 59/ - SM2, International Whaling Commission, Cambridge.

Leeney, R.H., Berrow, S., McGrat, D., O'Brien, J., Cosgrove, R. & Godley, B.J. (2007). Effects of pingers on the behaviour of bottlenose dolphins. *J. Mar. Biol. Ass. U.K.* (2007), 87, 129–133.

Lepper, P.A., Gordon, J., Booth, C., Theobald, P., Robinson, S.P., Northridge, S. & Wang, L. (2014). Establishing the sensitivity of cetaceans and seals to acoustic deterrent devices in Scotland. Scottish Natural Heritage Commissioned Report No. 517.

Mate, B.R. & Harvey, J.T. (1986). Acoustical deterrents in marine mammal conflicts with fisheries. A workshop held February 17-18, 1986 at Newport, Oregon. Oregon State University, Publ. No. ORESU-W-86-001. 116 pp.

McGarry, T., Boisseau, O., Stephenson, S. & Compton, R. (2017). Understanding the Effectiveness of Acoustic Deterrent Devices on Minke Whale (*Balaenoptera acutorostrata*), a low frequency cetacean. ORJIP Project 4, Phase 2. RPS Report EOR0692. Prepared on behalf of The Carbon Trust. November 2017.

Mikkelsen, L., Hermannsen, L., Beedholm, K., Madsen, P.T. & Tougaard, J. (2017). Simulated seal scarer sounds scare porpoises, but not seals: species-specific responses to 12 kHz deterrence sounds. *R. Soc. open sci*. 4: 170286.

MMO (in prep). Assessing Non-Lethal Seal Deterrent Options: Fishing Trials MMO Project No: 1131, 41 pp.

Morizur, Y. (2008). Tests d'efficacité du repulsive acoustique CETASAVER à bord des chalutiers commerciaux français - (Effectiveness of acoustic deterrent CETASAVER testing on board French commercial trawlers). Ifremer. Centre de Brest, Sciences et Technologie Halieutiques.

Morizur Y., Le Niliot, P., Buanic, M. & Pianalto, S. (2009). Expérimentations de répulsifs acoustiques commerciaux sur les filets fixes à baudroies en mer d'Iroise. IFREMER, Issyles-Moulineaux.

Mustad Longline & SeaWave. (2013). OrcaSaver Customer Information Pack 2013.

National Marine Fisheries Service. (2018). 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p

Northridge, S., Vernicos, D. & Raitsos-Exarchopolous, D. (2003). Net depredation by bottlenose dolphins in the Aegean: first attempts to quantify and to minimise the problem. IWC SC/55/SM25, International Whaling Commission, Cambridge.

Northridge, S., Kingston, A., Murphy, S. & Mackay, A. (2008). Monitoring, impact and assessment of marine mammal bycatch. Final report to Defra, Project MF0736, University of St. Andrews, Sea Mammal Research Unit, St. Andrews.

Northridge, S., Gordon, J., Booth, C., Calderan, S., Cargill, A., Coram, A., Gillespie, D., Lonergan, M. & Webb, A. (2010). Assessment of the impacts and utility of acoustic deterrent devices. A report commissioned by SARF and prepared by SMRU.

Northridge, S., Kingston, A., Mackay, A. & Lonergan, M. (2011). Bycatch of Vulnerable Species: Understanding the Process and Mitigating the Impacts. Final Report to Defra Marine and Fisheries Science Unit, Project no MF1003.

Northridge, S., Coram, A. & Gordon, J. (2013). Investigations on Seal Depredation at Scottish Fish Farms. Edinburgh: Scottish Government.

Olesiuk, P.F., Nichol, L.M., Sowden, M.J. & Ford, J.K.B. (2002). Effect of the sound generated by an acoustic harrassment device on the relative abundance and distribution of harbour porpoises (*Phocoena phocoena*) in retreat passage, British Columbia. *Marine Mammal Science*, 18(4): 843-862.

Read, A.J. & Waples, D. (2010). A pilot study to test the efficacy of pingers as a deterrent to bottlenose dolphins in the Spanish mackerel gillnet fishery. Bycatch reduction of marine mammals in Mid-Atlantic fisheries. Final report, Project 08-DMM-02, Duke University, Beaufort, SC.

SMRU (Sea Mammal Research Unit). (2001). Reduction of porpoise bycatch in bottom set gillnet fisheries. Report to the European Commission Study Contract 97/095, SMRU, University College Cork, Cornish Fish Producer's Organisation, and Irish South and West Fishermen's Organisation, Cork.

Soto, A.B., Cagnazzi, D., Everingham, Y., Parra, G.J., Noad, M. & Marsh, H. (2013). Acoustic alarms elicit only subtle responses in the behaviour of tropical coastal dolphins in Queensland, Australia. *Endangered Species Research*, 20, 271-282.

Sparling, C., Sams, C., Stephenson, S., Joy, R., Wood, J., Gordon, J., Thompson, D., Plunkett, R., Miller, B. & Götz, T. (2015). The use of Acoustic Deterrents for the mitigation of injury to marine mammals during pile driving for offshore wind farm construction. ORJIP Project 4, Stage 1 of Phase 2. Final Report.

Stone, G.S., Cavagnaro, L., Hutt, A., Kraus, S., Baldwin, K. & Brown, J. (2000). Reactions of Hector's dolphins to acoustic gillnet pingers. New Zealand Department of Conservation Technical Report Series, Wellington.

Trippel, E.A., Strong, M.B., Terhune, J.M. & Conway, J.D. (1999). Mitigation of harbour porpoise (*Phocoena phocoena*) bycatch in the gillnet fishery in the lower Bay of Fundy. *Can J Fish Aquat Sci* 56: 113−123.

Troncone, R., Diaz Lopez, B. & Shirai, J.A.B. (2008). Trial of acoustics deterrents for prevention of bottlenose dolphin depredation on gillnets. Conference: EUROPEAN CETACEAN SOCIETY · At: Egmondaan Zee, The Netherlands · Ordinal: 22nd.

Van der Meij, H., Kastelein, R., Van Eekelen, E. & Van Koningsveld, M. (2015). Faunaguard: A Scientific Method for Deterring Marine Fauna. Terra et Aqua: Number 138, March 2015 p17-24.

Vella, A. 2016. Resolving bottlenose dolphin-fisheries association problems in Maltese waters, central Mediterranean. 41st CIESM Congress, Kiel

Waples, D.M., Thorne, L.H., Hodge, L.E., Burke, E.K., Urian, K.W. & Read, A.J. (2013). A field test of acoustic deterrent devices used to reduce interactions between bottlenose dolphins and a coastal gillnet fishery. *Biological Conservation*, 157, 163-171.

Whyte, K.F. (2015). Investigating Seal Depredation at Scottish Salmon Farms. MSc Thesis, University of St Andrews.

Wilson, B. & Carter, C. (2013). The Use of Acoustic Devices to Warn Marine Mammals of Tidal-Stream Energy Devices. Report prepared for Marine Scotland, Scottish Government.

Woolmer, A. (2015). Commercial Trial of Fishtek "Banana Pinger" Cetacean Deterrent. Report for the Welsh Fishermen's Association.

Yurk, H. & Trites, A.W. (2000). Experimental Attempts to Reduce Predation by Harbor Seals on Out-Migrating Juvenile Salmonids. *Transactions of the American Fisheries Society*, 129,1360-1366.

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 low (50%) and, therefore, there are information gaps in some of the technical specifications presented.

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

Parameter	Manufacturer’s specification	Notes
Source level	Average within a transmission: 182 dB re 1 uPa rms @ 1 m	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, randomised pulses of sound that avoids habituations and hearing loss
Duty cycle	0.9-11% (min/max)	
Range	70 m radius effective range	
Battery	Automatically charges from universal AC supply with 12 V deep-cycle non-spillable gel battery	
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. 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 and remotely 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.

6.2 Ace Aquatec: Marine Mammal Mitigation Device (MMD) Ultra low frequency – Fish

Parameter	Manufacturer's specification	Notes
Source level	Average within transmission: 182 dB re 1 µPa @ 1 m	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 40m 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 (MMD) Mid-frequency – Pinnipeds and Cetaceans

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 188 dB re 1 µPa @ 1 m.	Manual or automatic control over volume
Frequency (frequency range and swept band or single frequency)	8 – 24 kHz.	Measured fundamental frequency at 12.1 kHz with harmonics at 17 kHz and 23 kHz (Lepper *et al.* 2003).
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 12V deep-cycle 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

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: 180 dB re 1 µPa @ 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 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 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 40m 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 @ 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: US3 mid-frequency deterrent – 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 @ 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	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 2.6s bursts of 3-11 ms rise time pulses; in a randomised pulse train to create a startle response.
Duty cycle	0.8-5%	-
Range	60m	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

	or Wi-Fi connection and remote control.	
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: RT1 (for aquaculture)

Parameter	Manufacturer's specification	Notes
Source level	Average within a transmission: - 180 dB re 1 µPa @ 1 m (ring transducer) - 182 dB re 1 µPa @ 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)	0.9 - 1.4 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	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	-
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	20 m – 40 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

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

Parameter	Manufacturer's specification	Notes
Source level	Nominal sound pressure level output = 198 dB re 1 µPa @ 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 utilise 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 sound pressure level output = 132 dB re 1 µPa @ 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 91m at bridles and net ends.	-
Functionality	None specified	-

6.10 Aquatec Group: Aquamark 848

Parameter	Manufacturer's specification	Notes
Source level	Nominal sound pressure level output = 165 dB re 1 µPa @ 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	Observed Specification			
	a	b	c	d
Device	Aquamark 100	Aquamark 200	Aquamark 210	Aquamark 300
Source level	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m (Dawson *et al.* 2013)	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m (Dawson *et al.* 2013).	Nominal sound pressure level output = 150 dB re 1 µPa @ 1 m (Dawson *et al.* 2013).	Nominal sound pressure level output = 132 dB re 1 µPa @ 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	Observed Specification	Notes
Source level	Nominal sound pressure level output = 165 dB re 1 µPa @ 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 organised 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, DiD)

Parameter	Manufacturer's Specification				
Device	a	b	c	d	e
	DDD 03L	DDD 03N	DDD 03H	DDD 03U	DiD
Source level	Nominal sound pressure level output = 165 dB re 1 µPa @ 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	Observed Specification	Notes
Source level	Nominal sound pressure level output of a pulse is 132 dB re 1 µPa @ 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 Pinger, 70 kHz Dolphin Pinger & 3 kHz Whale Pinger

NOTE: The Future Oceans pingers were previously called Fumunda.

Parameter	Manufacturer's Specification		
Device	a	b	c
	10 kHz Porpoise Pinger	70 kHz Dolphin Pinger	3 kHz Whale Pinger
Source level	Nominal sound pressure level output = 132 dB re 1 µPa @ 1 m.	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m.	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m (± 4dB).
Frequency (frequency range and swept band or single frequency)	10 kHz (includes multiple ultrasonic harmonics).	70 kHz.	3 kHz (±5 kHz) (includes multiple ultrasonic harmonics).
Continuous/ intermittent	Continuous.		
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 50 m on gill 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 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 porpoise (10)	Dolphin anti-depredation Pinger
Source level	145 dB (±3 dB) re 1 µPa @ 1 m.	135 dB (±3 dB) re 1 µPa @ 1 m.	132 dB (±3 dB) re 1 µPa @ 1 m.	175 dB (±3 dB) re 1 µPa @ 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).	375 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	Dependant on use and in consultation with	Dependant on use and in consultation with	Dependant on use and in consultation with

	company. Generally, every 200 m attached to headline of fishing gear.	company. Generally, every 100 m attached to headline of fishing gear.	company. Generally, every 100 m attached to headline of fishing gear.	company. Generally, every 100 m attached to headline of fishing gear.
Functionality	Auto-immersive switch which switches off out of water, battery indicator light for fisher and manager functionality checking, rated for use down to 1000 m, 5+ year lifespan indicator lights switch off when in water to avoid attracting pinnipeds. Randomised ping structure to prevent habituation. Removable pinger capsule for easy battery replacement.	Auto-immersive switch which switches off out of water, battery indicator light for fisher and manager functionality checking, rated for use down to 1000 m, 5+ year lifespan indicator lights switch off when in water to avoid attracting pinnipeds. Removable pinger capsule for easy battery replacement.	Auto-immersive switch which switches off out of water, battery indicator light for fisher and manager functionality checking, rated for use down to 1000 m, 5+ year lifespan indicator lights switch off when in water to avoid attracting pinnipeds. Removable pinger capsule for easy battery replacement.	Auto-immersive switch which switches off out of water, battery indicator light for fisher and manager functionality checking, rated for use down to 1000 m, 5+ year lifespan indicator lights switch off when in water to avoid attracting pinnipeds. Removable pinger capsule for easy battery replacement.

6.17 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 PAL
Source level	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m.	Nominal sound pressure level output = 132 dB re 1 µPa @ 1 m.	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m.	Nominal sound pressure level output = 145 dB re 1 µPa @ 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 – 160 kHz wideband.	3 kHz narrow band.
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.
Range	250 m in 'good' weather.	150 – 200 m.	250 – 350 m.	250 – 350 m.
Battery	2 years continuous operation, with 4 years shelf life. Typical use is 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.
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.			

6.18 Loughborough University: LU-1 Prototype

Parameter	Observed Specification	Notes
Source level	Nominal sound pressure level output = 145 dB re 1 µPa @ 1 m (Larsen & 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.	-

6.19 Lofitech: Seal Scarer

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

Parameter	Manufacturer's specification	Notes
Source level	Nominal sound pressure level output = 191 dB re 1 µPa @ 1 m.	Measured sound level = 204 dB re 1 µPa @ 1 m (McGarry *et al.* 2017).
Frequency (frequency range and swept band or single frequency)	10 – 20 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 ms^{-1} (McGarry *et al.* 2017).
Range	300m from source.	Measured displacement over ranges of >1 km depending on species (see Section 2.4.3).
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.

6.20 Marexi Marine Technology: Acoustic Pinger V2.2

Parameter	Manufacturer's Specification	Notes
Source level	Nominal sound pressure level output = 132 dB re 1 µPa @ 1 m (±4 dB).	-
Frequency (frequency range and swept band or single frequency)	10 kHz (±2 kHz) tonal.	- Signal 1: Frequency modulated signal between 30-150 kHz. - Signal 2: Click train at 90 kHz. (Berrow *et al.* 2008)
Continuous/ intermittent	Continuous.	-
Duty cycle	Pulse duration of 300 ms (±1 5ms) and a pulse interval of 4 sec (±0.2 sec).	-
Range	None specified.	-
Battery	±9500 h (>13-month 24hr/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.	-

6.21 GenusWave Ltd: Targeted Acoustic Startle Technology (TAST)- Genuswave Acoustic Startle Device (ASD)

Parameter	Observed Specification		
	a	**b**	**c**
Device	'SalmonSafe'	'FisherySafe'	'Mitigation Device' 'TurbineSafe' 'ConstructionSafe'
Source level	**Seal signal:** 180-182 dB re 1 µPa @ 1 m (RMS)	**Pinniped/seal signal:** 180-182 dB re 1 µPa @ 1 m (RMS) **Odontocete signal ('pinger capability')**: 140-175 dB **re** 1 µPa @ 1 m (RMS)	**Pinniped signal:** 180-182 dB re 1 µPa @ 1 m (RMS) **Odontocete signal**: 150 dB to 185 dB dB re 1 µPa @ 1 m (RMS) (depending on required deterrence range). **Combined marine mammals signal:** up to 185 dB re 1 µPa @ 1 m (RMS).
Frequency (frequency range and swept band or single frequency)	**Seal signal:** 700 Hz to 1500 Hz (-10 dB)	**Seal signal:** 0.05 kHz to 1.5 kHz **Odontocete signal**: 700-1.5 kHz (-10dB)	**Seal signal:** 500 Hz to 1500 Hz **Odontocete signal**: 5-20 kHz **Combined marine mammal signal:** 700 Hz to 20 kHz
Continuous/ intermittent	Intermittent	Intermittent	Intermittent
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
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 & Janik 2015) 60 m around haulouts (Götz 2008)	Seals: up to 250 m around fish farms (Götz & Janik 2015) up to 500 m offshore 60 m around haulouts (Götz 2008)

			Porpoise: up to several km (Hiley *et al*. (in prep)).
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.
Device testing	Testing function available via master unit	Testing function available via master unit	Testing function available via master unit
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.
Functionality	The ASD constitutes a modular system of independent but synchronized units that can be coordinated & 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.		

6.22 Savewave: SealSalmon Saver, OrcaSaver, Long Line Save, Endurance Saver

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

Parameter	Observed Specification			
Device	a	b	c	d
	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 & SeaWave 2013).
Source level	Nominal sound pressure level output = 155 dB re 1 µPa @ 1 m	Nominal sound pressure level output = 155 dB re 1 µPa @ 1 m	Nominal sound pressure level output = 140 dB re 1 µPa @ 1 m	Nominal sound pressure level output = 196 ±2 dB re 1 µPa @ 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
Continuous/ intermittent	Intermittent	Intermittent	Intermittent	Intermittent
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 ms randomised. Pulse interval 4 – 30 sec randomised.	Pulse duration from 200 ms to 1 sec
Range	-	-	-	-
Battery	-	-	-	-
Training requirements	-	-	-	-
Device testing	-	-	-	-
Deployment	-	-	-	-
Functionality	-	-	-	-

6.23 Gael Force: SeaGuard Seal Deterrent

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 sound pressure level output = 198 dB re 1 µPa @ 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 m^2 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.

6.24 Fauna Guard Porpoise Module

Parameter	Manufacturer's Specification	Notes
Source level	159.7 dB SPL	Average output is 165.0 dB SPL
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	
Battery	12 V deep-cycle non-spillable gel battery (50 aH)	Battery charger & 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 @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.

6.25 Fauna Guard Seal Module

Parameter	Manufacturer's Specification	Notes
Source level	174.1 dB SPL	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% @72 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 @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.

6.26 Fauna Guard Turtle Module

Parameter	Manufacturer's Specification	Notes
Source level	172.2 dB SPL	average output is 177.7 dB SPL
Frequency (frequency range and swept band or single frequency)	200 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 @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.

6.27 Fauna Guard Fish Module

Parameter	Manufacturer's Specification	Notes
Source level	186.5 dB SPL	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 @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.

6.28 Seamaster: Fish Protector

Parameter	Manufacturer's Specification	Notes
Source level	Nominal sound pressure level output up to 165 dB re 1 µPa @ 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.	-

6.29 SealFENCE 3 (OTAQ)

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

Parameter	Manufacturer’s specification	Notes
Source level	Patrol mode: sound pressure level output = 165 dB re 1 µPa @ 1 m RMS. Protect mode: sound pressure level output = 189 dB re 1 µPa @ 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™ Air Wireless Link for ACM	-

6.30 Terecos Ltd: DSMS-4

NOTE: The DSMS-4 unit has four different programmes which involve two different pulse sequences. The table 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 sound pressure level output = 177 dB re 1 µPa @ 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 @ 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 sound pressure level output = 179 dB re 1 µPa @ 1 m (RMS) (±1 dB) and 178 dB re 1 µPa @ 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 @ 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 sound pressure level output = 178 dB re 1 µPa @ 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.	-