Abatement of underwater noise pollution from pile-driving and explosions in UK waters

Report of the workshop held on

Tuesday 12 November 2019

at

The Royal Society
London, SW1Y 5AG

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The workshop was organised under the aegis of the UK Acoustics Network (UKAN), through funding provided by the Engineering and Physical Sciences Research Council (EPSRC).

This reported may be cited as:

Merchant, N.D., Robinson, S.P. (2020). Abatement of underwater noise pollution from pile-driving and explosions in UK waters. Report of the UKAN workshop held on Tuesday 12 November 2019 at The Royal Society, London. 31pp.
doi: 10.6084/m9.figshare.11815449

Cover image: Beatrice Offshore Windfarm Ltd (BOWL) windfarm under construction, August 2018. Credit: Nathan Merchant.

Executive Summary

Underwater noise pollution from the installation of offshore wind turbine foundations and the detonation of unexploded ordnance (UXO) is recognised as an issue of growing concern by UK regulators and policymakers. Marine mammals, fish and invertebrate species can be adversely affected by exposure to noise from these activities. Some of these species are protected under UK law, and in order to issue a license authorising these activities it needs to be shown that there is no satisfactory alternative to the activity. However, for both pile-driving and UXO, technologies are available which reduce the amount of noise emitted at source (noise abatement). Such technologies are being routinely deployed in other parts of the North Sea in order to reduce the risk of impact on marine life, particularly marine mammals.

The aim of the workshop was to explore the technical feasibility of applying noise abatement measurements to offshore windfarm construction and UXO detonation to improve the quality of the acoustic habitat in UK seas. Drawing on expertise developed by operators implementing noise abatement measures elsewhere in the North Sea, the workshop considered the technologies available and their benefits, and assessed what technical challenges there may be to implementation in UK waters. As well as technical input, representatives from industry, non-governmental organisations, government agencies, and Statutory Nature Conservation Bodies offered their perspectives on the issue, and a structured break-out session allowed time for more focused groups to discuss ways forward.

The key outcomes of the workshop are summarised below.

No new policy or regulation would be needed to implement noise abatement in UK waters for offshore wind turbine installation or disposal of unexploded ordnance

- It is at the discretion of regulators to determine whether to require noise abatement technologies as a condition of a marine licence. Such decisions are informed by the advice of Statutory Nature Conservation Bodies and scientific advisers.

- Although in principle economic considerations should not influence regulatory decisions over enforcement of legislation such as the Habitats Regulations, there is a perception that cost implications are a factor in the present status quo of no noise abatement requirements for wind turbine installation.

It is feasible to deploy noise abatement technologies at all locations where offshore windfarms are proposed in UK waters

Offshore wind turbine installation

Available noise abatement technologies have different constraints related to water depth and oceanographic conditions. However, feasible technological solutions are available for water depths throughout UK waters proposed for offshore windfarm construction.

- **Percussive pile driving.** Bubble curtains have been widely demonstrated to be effective in waters up to 45 m. They become less effective as water depth increases due to dispersion of the bubbles. Casing-based systems (e.g. IHC Noise Mitigation System) are also demonstrated up to 45 m and are constrained by the availability of large enough systems for the water depth. Encapsulated resonator systems (e.g. Hydrosound damper, AdBm Noise Abatement System) are in principle unlimited by water depth. Adverse weather conditions (high current speeds and wave heights) may present challenges at certain times and locations.

- **Alternative turbine foundations and piling methods.** Wind turbine foundations may also be installed using vibratory piling or suction buckets if sediments are soft enough, and gravity bases and floating foundations are also potential alternatives.

Disposal of unexploded ordnance

Bubble curtains may be applied to impede noise emission from detonations, subject to the abovementioned constraints. An alternative to explosive (high order) detonation is *deflagration* (low order detonation), by which the explosive material is burned without exploding, the process being initiated by a small shaped charge. Field measurements comparing low- and high-order detonations indicate that peak sound levels and the overall acoustic energy of detonation can be greatly reduced via deflagration. Deflagration is new to civilian applications but has been used by the UK military since the early 2000s.

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Introduction and Aims

Underwater noise pollution is increasingly recognised as a widespread marine pollutant which can have significant effects on marine mammals, fish and invertebrates. The management of manmade underwater noise is addressed specifically in some policy and legislation, e.g. Descriptor 11 of the UK Marine Strategy, and may be addressed indirectly under existing protections, such as the Habitats Regulations.

Reducing the risk of impact to marine ecosystems can be achieved by reducing the amount of noise pollution (noise **abatement**), or through **mitigation** measures. At present, underwater noise abatement measures are comparatively rare in UK waters, but various mitigation measures are often applied. However, these measures do not reduce (and may increase) the amount of noise pollution emitted into the marine environment. These measures can be categorised as:

1. **Spatiotemporal restrictions**, e.g. interrupting noise-generating activities if marine mammals are sighted within a designated exclusion zone around the operation (JNCC, 2010), or at the planning stage by imposing constraints on when and where noise emissions are permitted due to known sensitivities (e.g. a fish spawning area during a particular period).
2. **Introduction of additional noise**, e.g. the use of acoustic deterrent devices (ADDs) deployed with the intention to disperse marine mammals prior to more harmful noise levels being emitted, or the use of ramp-up of the piling hammer energy with similar intent (JNCC, 2010).

These mitigation measures may reduce the risk of impact for certain species. However, they do not address effects on non-target species (e.g. species which would not be deterred from or able to detect an ADD) or less mobile species (e.g. many benthic dwelling organisms). These measures also rely on adequate information on animal distributions (to decide when/where spatiotemporal restrictions are needed) or in situ observations, and so can only be effective if such information is available and up to date (Faulkner et al., 2018). Furthermore, the displacement of animals caused by ADDs (to reduce risk of auditory injury) can exceed that attributable to the activity itself if noise abatement is applied (Dähne et al., 2017).

Applying noise abatement avoids this trade-off between deterring animals to avoid auditory injury and minimising behavioural disturbance: both are reduced by reducing the noise emitted at source. Indeed, this is consistent with the established principle that pollution should be abated at source where possible, and at the cost of the polluter (e.g. European Union, 2010).

Noise abatement can be achieved one of two ways (Figure 1):

1. **by making manmade noise sources quieter**, such as by modifying or replacing technology (e.g. alternative piling foundations) or by operational interventions (e.g. bubble curtains around pile driving operations);
2. **by reducing the amount of noise generating activity**, e.g. installing fewer wind turbines or carrying out fewer unexploded ordnance detonations.

Given the anticipated growth of UK offshore windfarm construction to meet UK Government renewable energy targets (The Crown Estate, 2019), noise abatement via source quieting appears the more suitable option for the offshore wind sector.

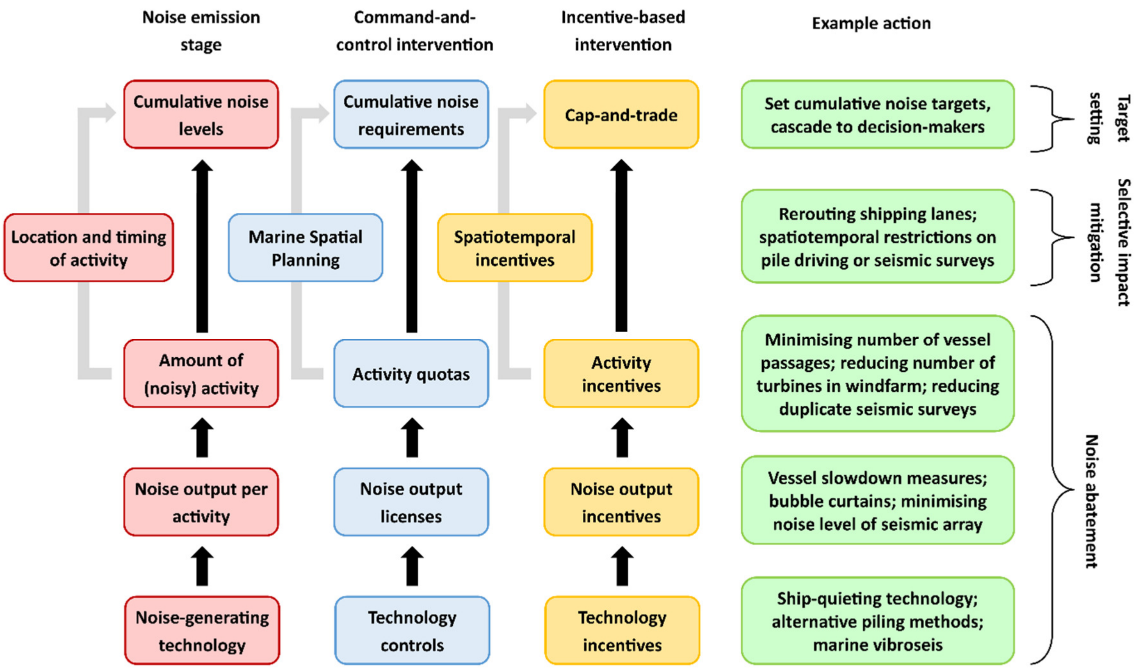


Figure 1. Stages of noise emission, corresponding command-and-control and incentive-based interventions, and examples of actions for each stage (Merchant, 2019). Noise abatement measures feature in the lowermost three rows.

In other parts of the North Sea, noise abatement measures are routinely applied to pile driving operations (Figure 2). This approach to managing underwater noise pollution from offshore windfarm construction was pioneered in Germany (Umweltbundesamt, 2011) and has led to the further development of noise abatement technologies, improving efficacy and reducing costs.

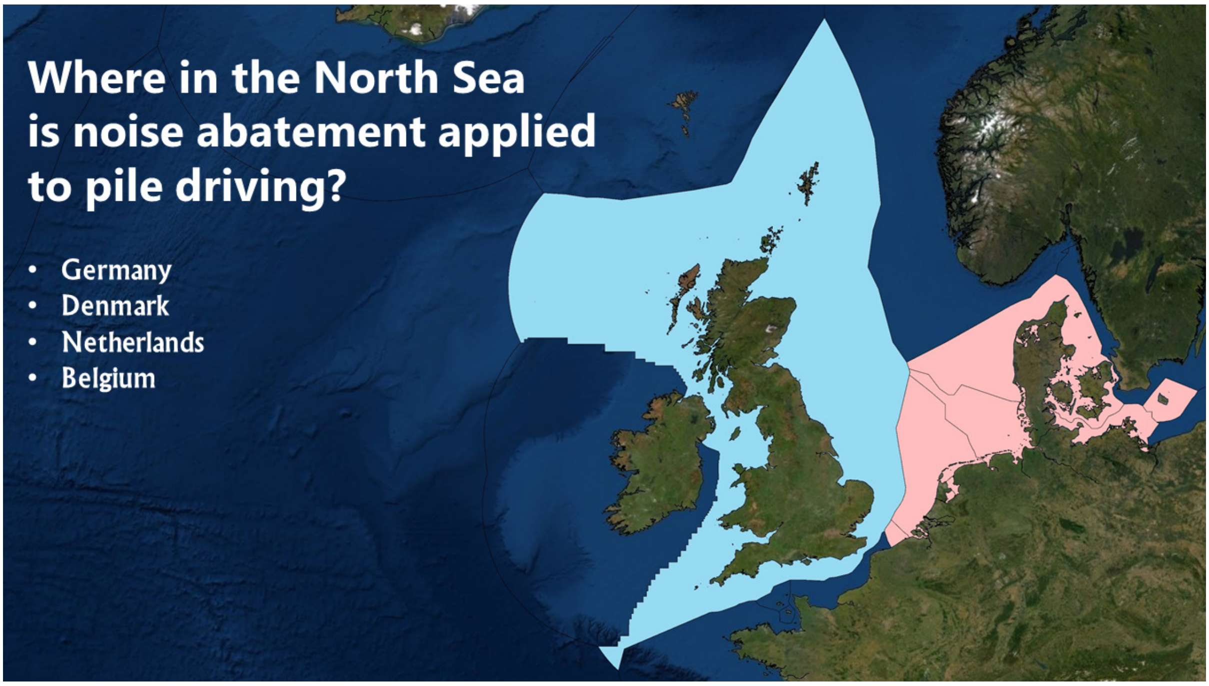


Figure 2. National waters in which noise abatement measures have (pink) and have not (blue) been applied for pile driving.

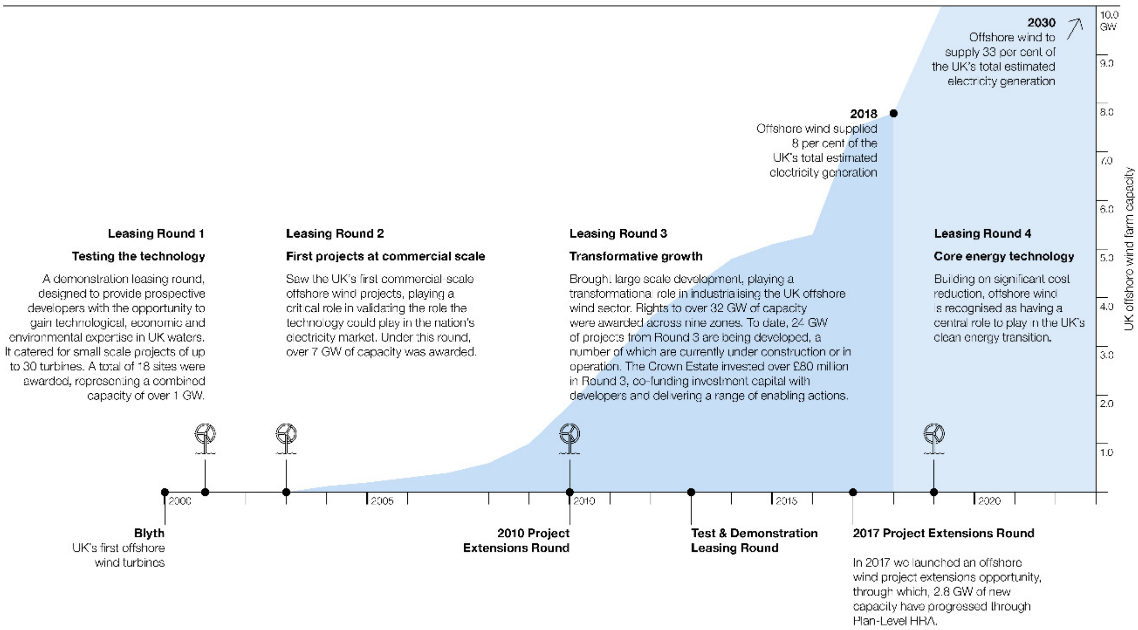


Figure 3. Historic and projected UK offshore wind generation in gigawatts (GW) (The Crown Estate, 2019).

The UK Offshore Wind Sector Deal commits to delivering 30 GW of electricity production via offshore wind by 2030, 33% of estimated electricity generation (The Crown Estate, 2019). As of 2018, offshore wind supply is ~8 GW, suggesting rapid expansion of offshore wind in the coming decade to meet this target (Figure 3; Figure 4c). At the same time, much of the area envisaged for offshore wind farms (particularly in the southern North Sea) has been designated as Special Areas of Conservation for harbour porpoise (pSACs; Figure 4a). This protected species is known to be displaced by pile driving for offshore wind turbine foundations by up to ~25 km (Dähne et al., 2013), and may face population-level consequences as a result of this disturbance (King et al., 2015).

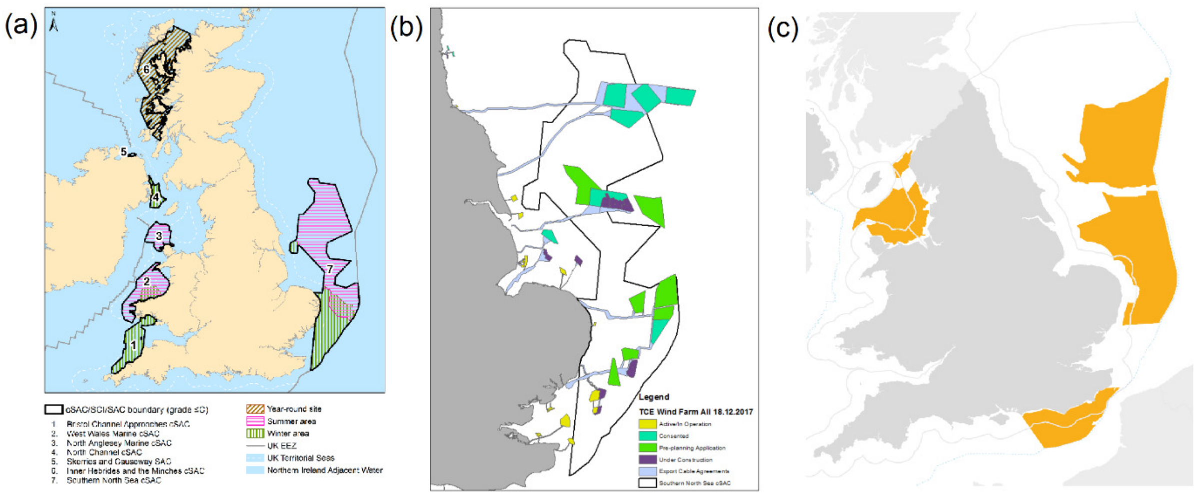


Figure 4. (a) Locations of the seven designated marine Special Area of Conservation sites in the UK territorial seas and Northern Ireland adjacent waters (figure produced by JNCC); (b) locations of existing, consented, and planned wind farms near southern North Sea pSAC as of December 2017 (Wilson et al., 2019); (c) Round 4 areas in England and Wales (adapted from The Crown Estate, 2020).

This predicament presents a dilemma for policymakers and regulators: how to meet offshore renewable energy targets without compromising the conservation status of protected species, and while minimising wider impacts of this offshore development on marine ecosystems. Noise abatement during offshore wind turbine installation has been demonstrated to reduce the footprint of displacement for harbour porpoises (Nehls et al., 2016; Dähne et al., 2017) and to reduce the risk of hearing loss (Dähne et al., 2017).

The workshop presented an opportunity for key stakeholders to revisit the status quo of unabated noise pollution from UXO detonation and from pile driving during offshore wind farm construction in UK waters, with the following aims:

- To **review** the state of the art in noise abatement methods for pile driving and UXO detonation
- To **gather** stakeholder perspectives on the implementation of noise abatement in UK waters
- To **clarify** the role of noise abatement in delivering UK policy objectives and regulatory requirements

The subsequent sections provide the workshop agenda, summaries of the presentations and discussions, and the workshop conclusions.

Workshop agenda

8:30	Coffee and register
9:15	Welcome and housekeeping: Stephen Robinson (NPL)
9:20	Introduction and aims: Nathan Merchant (Cefas)

Session 1: Noise abatement technologies in practice. Chair: Prof. Peter Liss (UEA)

9:35	Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises: Michael Dähne (German Oceanographic Museum)
9:50	Overview of the efficiency of previously applied noise mitigation systems and outlook: Michael Bellman (ITAP)
10:05	The IHC Noise Mitigation System: Bob Jung (IHC)
10:20	Review of noise abatement systems and low-noise installation methods for offshore wind turbine foundations: Ursula Verfuss (SMRU Consulting) & Ian Gloyne-Phillips (NIRAS)
10:35	Measurements of UXO detonation and deflagration: Paul Lepper (Loughborough University)
10:50	Panel discussion: Technical feasibility of noise abatement systems in UK waters
11:10	Coffee

Session 2: Stakeholder perspectives on noise abatement. Chair: Prof. Peter Liss

11:30	An offshore windfarm developer perspective: Matej Simurda (Ørsted)
11:40	An offshore windfarm developer perspective: Eva Philipp (Vattenfall)
11:50	An NGO perspective: Tania Davey (The Wildlife Trusts)
12:00	Monitoring of compliance with German noise threshold regulations: Carina Juretzek (BSH)
12:15	An SNCB perspective: Rebecca Walker (Natural England) & Caroline Carter (SNH)
12:25	A regulatory perspective: Paul Stevenson & Jessica Duffill Telsnig (MMO)
12:40	Panel discussion: Feasibility of noise abatement in a UK regulatory context
13:00	Lunch

Session 3: Breakout discussions

13:50	Set up break-out groups
14:00	Break out discussion: Next steps to manage underwater noise pollution from piling and UXO
14:45	Coffee
15:15	Breakout group rapporteurs report back. Plenary discussion.
16:00	Summary and next steps: Nathan Merchant and Stephen Robinson
16:15	Finish

Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises

Michael D Dähne (German Oceanographic Museum)

Michael advised of the physical consequences of noise on marine mammals and the options for mitigation (Figure 5). Noise and fleeing from noise sources can disrupt hunting and feeding, leading to a reduction in fitness or a reduction in growth. This, plus the influence of noise on a mammal's ability to communicate acoustically (masking), may lead to a reduction in population growth rates. Evidence of the effects of noise were observed at Alpha Ventus, Germany's first offshore wind farm (Dähne et al., 2013). Before pile driving took place in 2009 harbour porpoises were common throughout the designated development area but once pile driving took place the porpoises fled out to ~20 km around the noise disturbance. Limits for noise emissions from pile driving were subsequently set ($SEL_{05} \leq 160$ dB re 1 μPa^2 s at a distance of 750 m) and in 2013 licenses for pile driving were only granted if the anticipated generated piling noise was below the precautionary limit. German authorities are now developing threshold limits for the Baltic Sea.

It is possible to protect marine mammals from noise but there has to be a willingness to do so. Technology such as bubble curtains do protect mammals from sound, especially when more than one system is used in tandem, but these can be costly. The cheaper option of deterrents can be used but this displaces mammals from the area with the potential impacts as detailed above. More international collaboration is required to weigh up the trade-off between costs to developers and the potential for mammal injury and stress.

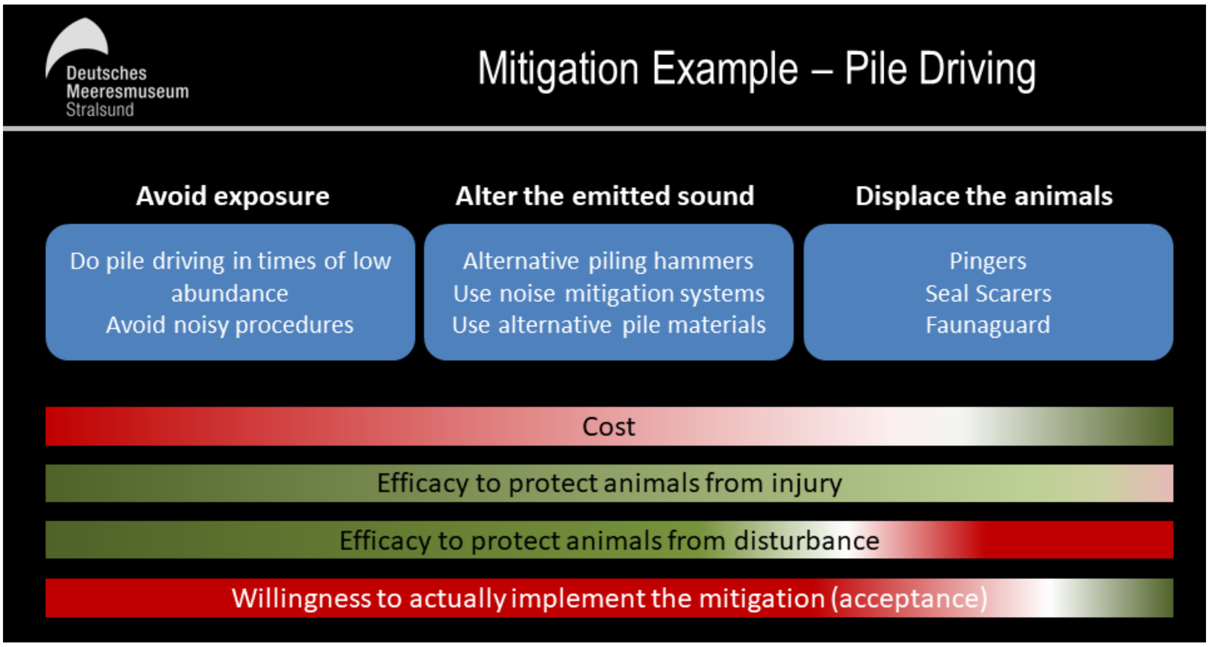


Figure 5. Options for reducing the risk of impact to marine mammals from pile driving, and their associated cost and efficacy in reducing risk of injury and disturbance.

Overview of the efficiency of previously applied noise mitigation systems and outlook

Michael Bellman (ITAP)

The two motivating factors for the application of noise abatement systems are the Marine Strategy Framework Directive (MSFD), which applies across the EU, and national legislation/regulation, which varies from country to country. As pile size increases (due to larger turbines), it is important to adapt and improve technologies so that statutory limits for underwater noise can still be met.

Noise mitigation systems fall into three categories:

- **Big Bubble Curtains (BBC)** are independent from foundations but a separate vessel and compressor are required which generate their own noise. Bubble curtains which emit more air and therefore reduce sound further are currently under development.

- **Shell-in-shell systems** (e.g. IHC-NMS, see p13) are integrated into the pile and their efficacy depends on the weight and dimensions of the piles and the seabed composition.

- **Encapsulated resonator systems** (e.g. Hydro Sound Damper; HSD) consist of a curtain of resonating elements surrounding the pile, which can be tuned to attenuate particular frequencies. They can be effective and unlike above systems are unlimited by deep waters or higher water currents. However, they often need to be project specific.

Michael summarised field measurements of the efficacy of these systems (Figure 6).

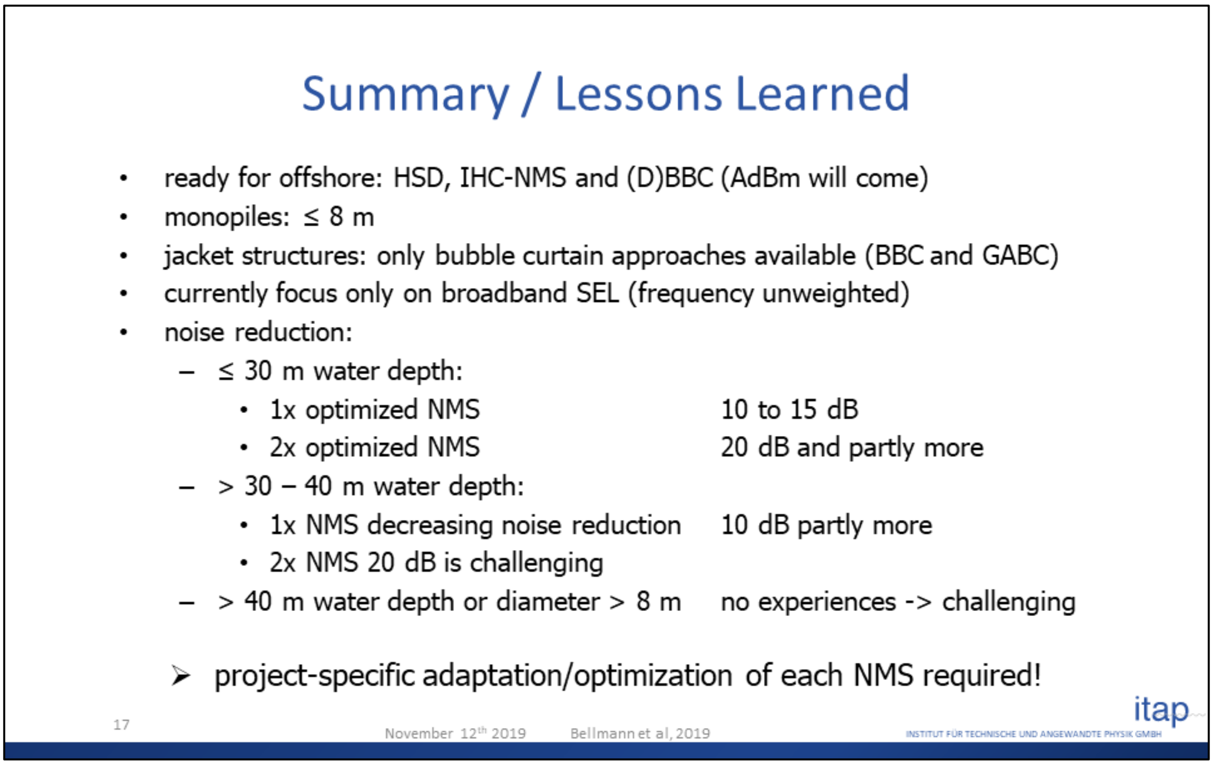


Figure 6. Summary of lessons learned in measurements of the efficacy of noise abatement technologies in German waters. HSD = Hydrosound damper; IHC-NMS = IHC Noise Mitigation System; (D)BBC = (double) Big Bubble Curtain; AdBm is a company with a proprietary encapsulated resonator technology; GABC = Grout Annulus Bubble Curtain; SEL = sound exposure level.

The IHC Noise Mitigation System

Henk van Vessem (IHC)

IHC-IQIP is a company based in Holland which is involved in piling projects in the North Sea. IHC have developed various technologies to meet the requirements of the German legislation on noise emissions from pile driving. These include:

- **The Hydrohammer® HiLo (High frequency Low energy).** This adaptive piling technique reduces noise and pile fatigue and can operate within standard hammer ranges.
- **The Noise Mitigation System (NMS)** contributes with a consistent and reliable 360° mitigation during piling activities (Figure 7). Mitigates up to 98-100% of waterborne noise. At frequencies of 10 kHz, noise reduction can be up to 45 dB.
- **The Hydrohammer® PULSE (Piling Under Limited Stress Equivalent) system** is a new way of dampening the noise emission directly at source and in many cases eliminates the need for Big Bubble Curtains. Adjustable cushioning is used on the hammer which reduces noise emissions by 3-6 dB sound exposure Level (SEL) and 9-12 dB peak sound pressure level (SPL_{peak}). In this way, the passive noise mitigation system reduces waterborne (and airborne) noise and $CO2$ emission (since BBC may not be required). The system can be operated at the current standard hammer ranges. Available in 2020.
- **Blue Piling** is a new program limiting the noise emission directly at source for future larger monopiles, reducing the noise impact by extended impact duration. Expected to be operational in 2022.

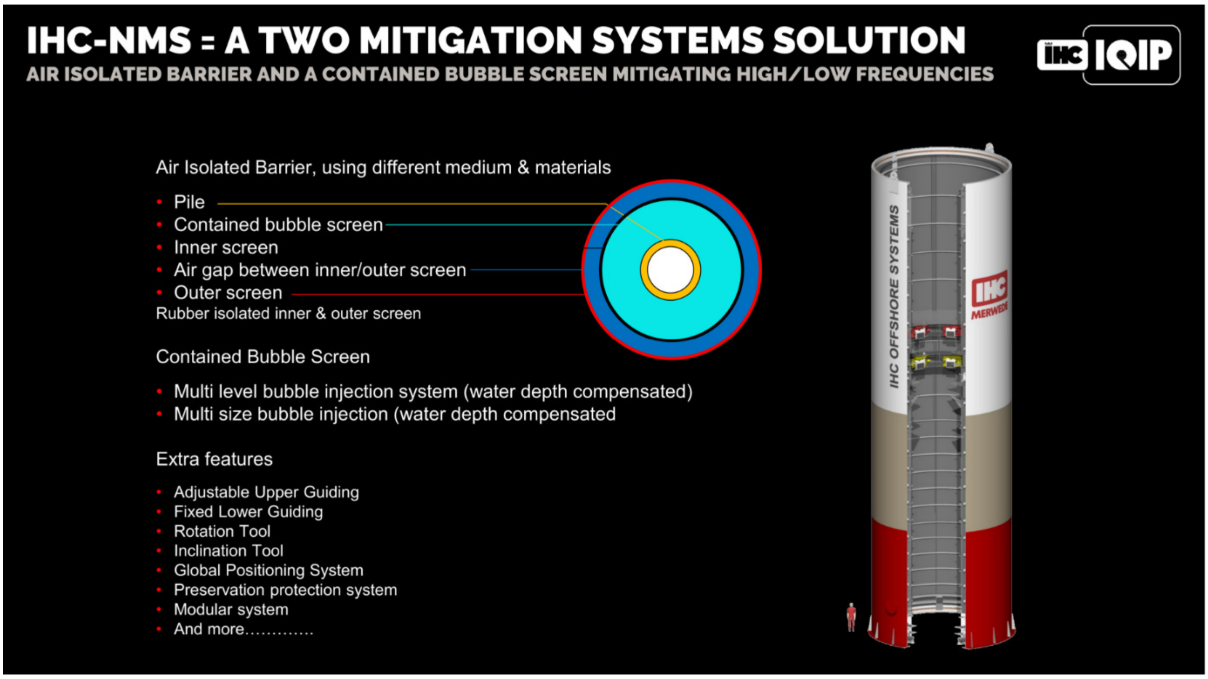


Figure 7. Schematic illustrating the IHC Noise Mitigation System (NMS).

Review of noise abatement systems and low-noise installation methods for offshore wind turbine foundations

Ian Gloyne-Phillips (NIRAS) & Ursula Verfuss (SMRU Consulting)

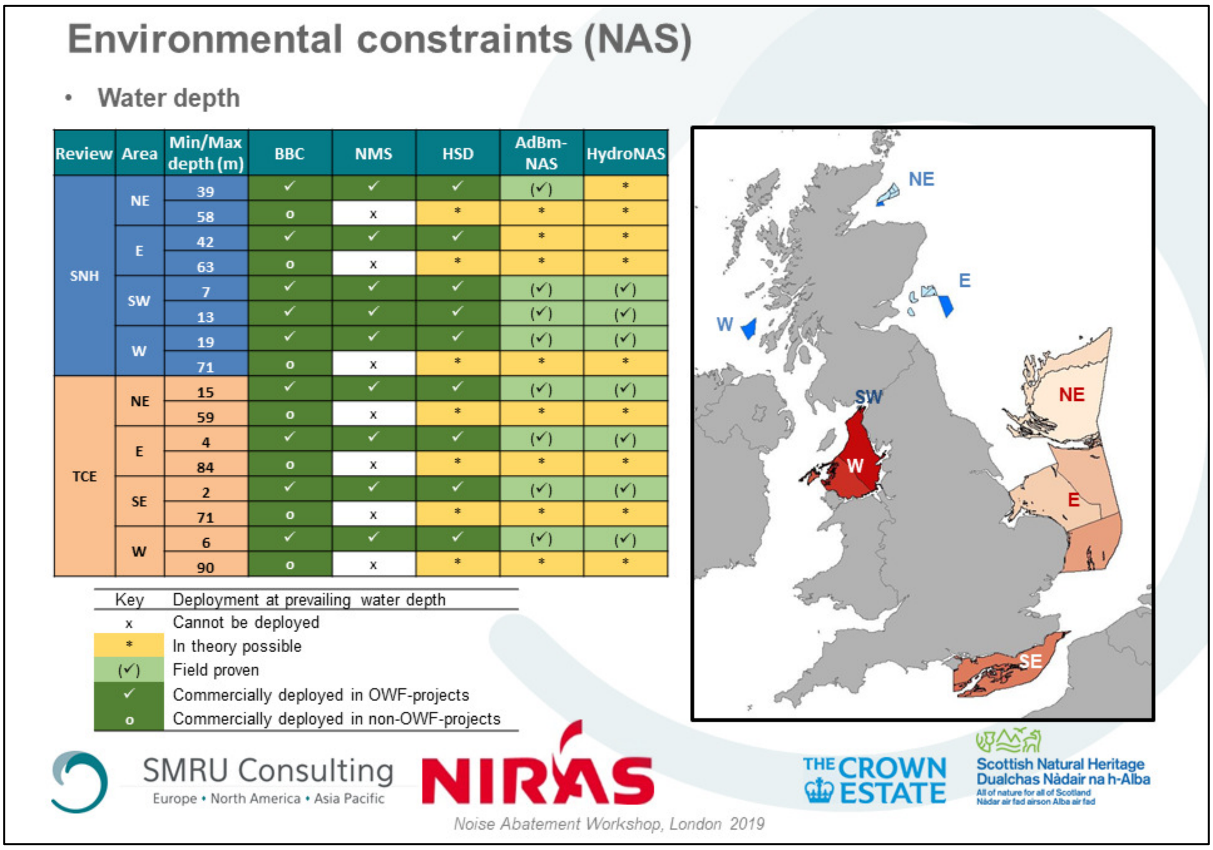
This presentation was based on two reviews carried out by SMRU Consulting and NIRAS:

1. On the use of noise abatement systems in Scottish waters (Verfuss et al., 2019), for Scottish Natural Heritage.
2. On noise reduction methods including alternative foundations and installation methods (NIRAS, 2019), for The Crown Estate.

The presentation considered noise abatement options in light of the following factors:

- Potential noise reduction
- Environment constraints
- Other considerations.

The review of environmental constraints concluded that viable noise abatement options are available for all Scottish, Welsh and English waters currently proposed for offshore windfarm development (Figure 8). Different systems have different strengths and weaknesses, but practical abatement options are available in all cases, albeit with a cost implication. Ian also noted that in addition to noise from the installation itself, additional noise sources need to be considered, such as related vessel noise.



Review	Area	Min/Max depth (m)	BBC	NMS	HSD	AdBm-NAS	HydroNAS
SNH	NE	39	✓	✓	✓	(✓)	*
		58	o	x	*	*	*
	E	42	✓	✓	✓	*	*
		63	o	x	*	*	*
	SW	7	✓	✓	✓	(✓)	(✓)
		13	✓	✓	✓	(✓)	(✓)
	W	19	✓	✓	✓	(✓)	(✓)
		71	o	x	*	*	*
TCE	NE	15	✓	✓	✓	(✓)	(✓)
		59	o	x	*	*	*
	E	4	✓	✓	✓	(✓)	(✓)
		84	o	x	*	*	*
	SE	2	✓	✓	✓	(✓)	(✓)
		71	o	x	*	*	*
	W	6	✓	✓	✓	(✓)	(✓)
		90	o	x	*	*	*

Key	Deployment at prevailing water depth
x	Cannot be deployed
*	In theory possible
(✓)	Field proven
✓	Commercially deployed in OWF-projects
o	Commercially deployed in non-OWF-projects

Figure 8. Summary of applicability of noise abatement systems in Scottish, Welsh, and English wind farm development areas.

Measurements of UXO detonation and deflagration

Paul Lepper (Loughborough University)

There are large numbers of UXO (unexploded ordnance) in UK seas, some of which date back to World War I. Many are located within planned windfarm projects (and their cable routes) and as windfarm construction expands, the numbers of high-order detonations (i.e. explosions) of UXO is of increasing concern. The extent to which UXO have degraded over time is unknown, leading to high variability in how loud a detonation will be. As yet, there is no measurement standard.

This presentation reported on an ongoing BEIS-funded project led by NPL and Loughborough University to assess the noise reduction achieved by low-order disposal of UXO via deflagration. Deflagration is a technique whereby the explosive within the UXO is rapidly burned at subsonic speeds using plasma from a small shaped charge.

Controlled experiments were conducted in Limehillock Quarry, Aberdeenshire. Low- and high-order disposals were carried out for a range of charge sizes between 15 g and 18.7 kg. A comparison was also made of charges with and without an enclosing shell. Approximately 17 explosions took place with all data recorded on pressure gauges and hydrophones. There were significant noise reductions if using deflagration, with noise levels dependent only on the size of the low-order charge (Figure 9).

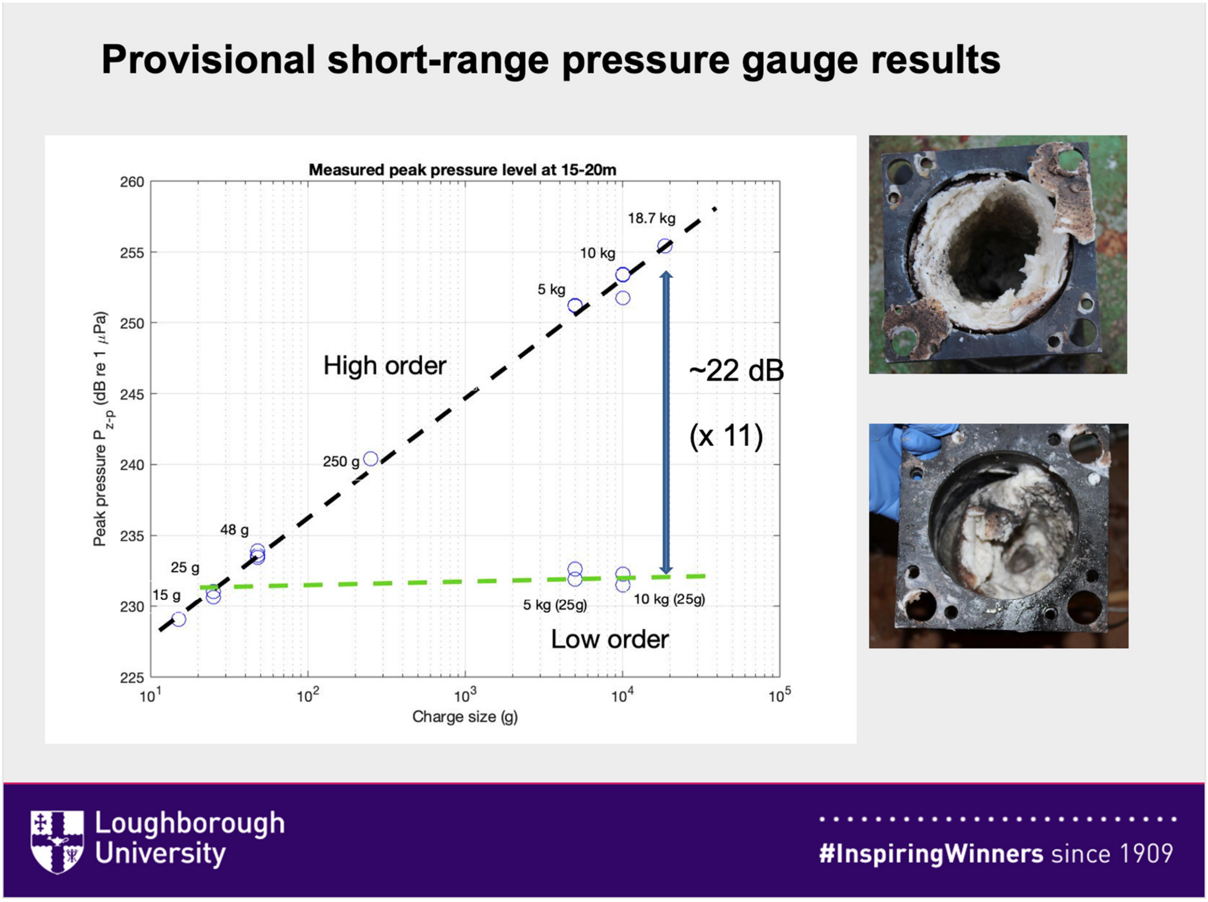


Figure 9. Measured zero-to-peak sound pressure levels from low- and high-order detonations for a range of charge masses.

Panel discussion: Technical feasibility of noise abatement systems in UK waters

Q. What problems are there in using deflagration in the real world?

A. Industry will need to think of process. Deflagration could lead to material displacement, but this could be collected by ROVs [*remotely operated underwater vehicles*], which could also be used to put charges in place.

Q. What, if anything, is unique about UK waters?

A. UK waters are not unique, but the legislation to manage noise levels is different.

Q. In other countries different bodies are responsible for UXO removal; in some countries it is the responsibility of the military.

A. We have spoken with the military. How the military dispose of UXO is less well publicised but there are many contractors looking at UXO disposal so if all can find a way of bringing these groups under one umbrella to share experiences that would be good. As to who takes control of the disposal of UXO, that is open.

Q. The presentations shown so far have looked at monopiles up to 5m in diameter but monopiles are becoming bigger and bigger. How will we cope with this?

A. Blue piling technology should be able to cope with larger monopiles. We use bubble curtains already and we may need to enhance mitigation methods in the next few years to cope with larger monopiles and also the vessels that will be required to accompany the installation of these.

Q. We offer impact assessment for UXOs, but it is hard to access advanced models. Is there a way industry can join together to access these models?

A. There is and will be some data available, but the challenge is how to get the right information to feed into your model. There have been comparisons of models which are available to the public, but the reaction of animals is very hard to model as animal behaviour can vary by season and by activity. Again, there needs to be a way for industry to work collaboratively in the future.

Q. Did you measure particles in the water after deflagration?

A. In our study no but this is a very interesting question. It should be noted that there are some residuals after both high and low order detonations.

Session 2: Stakeholder perspectives on noise abatement

An offshore windfarm developer perspective

Matej Simurda (Ørsted)

This presentation set out the process that Ørsted follows in selecting noise mitigation options for offshore windfarm installation. Information initially required includes foundation type, water depth, seabed properties, and the hammer type and hammer energy required. An initial model is then run which predicts noise level generated by pile driving. If these levels do not comply with regulatory threshold levels, the process is repeated with different permutations until a solution is found which does comply. These permutations include the various noise mitigation technologies which have been tested and employed by Ørsted (Figure 10). Most noise mitigation systems are more efficient at high frequencies. If jacket foundations are used instead of monopiles, the noise abatement options are more limited. The key to a smooth development is this foundation stage which should take place approximately 1.5 years before foundation work commences.

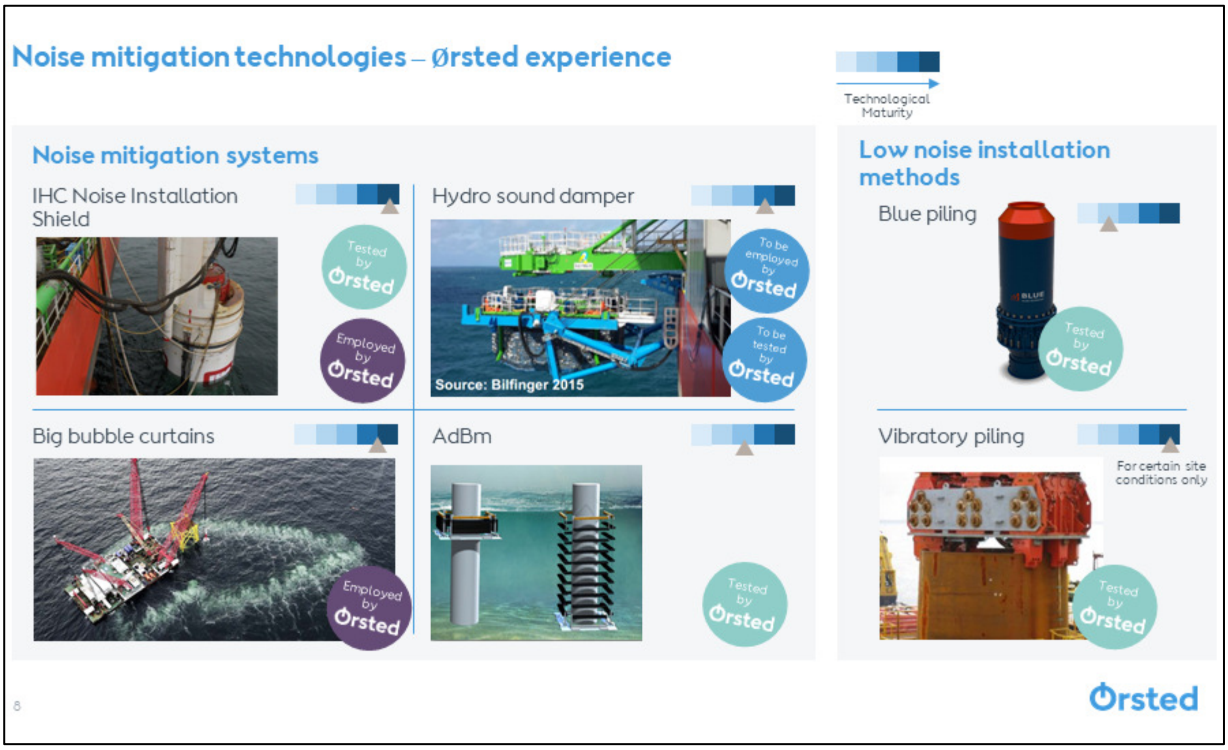


Figure 10. Ørsted experience of using various noise mitigation technologies.

An offshore windfarm developer perspective

Eva Philipp (Vattenfall)

Eva presented some lessons learned from German offshore wind construction projects since 2009, including a summary of the noise mitigation systems deployed in German waters during 2011-2018 (Figure 11).

GESCHA 2, a collaborative project sponsored by windfarm developers, sought to understand the relationship between broadband sound level and harbour porpoise disturbance, and how successful noise abatement measures have been in German waters. Piling during 2014-2016 was found to be 9 dB quieter overall than during 2010-2013, with noise abatement systems reducing noise emissions by 15 dB overall. A dose-response relationship between noise level and harbour porpoise displacement was identified for noise levels exceeding an SEL_{05} of 165 dB re 1 μPa^2 s. Half of the animals fled before the onset of an acoustic deterrent device prior to piling, indicating that other activities (e.g. vessel activity related to the operation) lead to displacement prior to piling.

The side effects of deploying noise abatement systems need to be considered. For example, to deploy a bubble curtain the possibility of extra disturbance of vessels and compressors must be taken into account, as well as the additional CO_2 produced.

Noise mitigation - current industry experience/practice in Germany

Noise mitigation systems used 2011-2018 for WTG foundations

FOU Constr. Year	OWP Project	No of foundations & Ø	Big Bubble curtain variation (BC; Small (S), Double (D), Triple (T), Linear (L))	Sleeve solutions (IHC NMS, Hydrosound damper (HSD))	Water depth
2018	Hohe See	71 MPs , Ø 8m	BBC, DBBC	IHC	40m
2017	Arkona	60 MPs, Ø up to 7,75m	DBBC	HSD	23- 37m
2017	Merkur	66 MPs, Ø 7,6 m - 7,8m	BBC	IHC	28 - 32m
2016/17	Wikinger	70 jackets, 4 piles, Ø 2,7m	DBBC, SBC	HSD stand by	36 - 42m
2017	Nordsee One	54 MPs, Ø 6,7 m	BBC	IHC	26 - 29m
2016	Nordergründe	18 MPs, Ø 5,5 m	BBC, DBBC		4-11,5m
2016	Veja Mate	67 MPs, Ø bottom 8,1m; top 6,5m	DBBC	HSD	average 39,3m
2015/16	Sandbank	72 MPs, Ø 6,4-6,8m	BBC, DBBC	HSD	24,5-33,5m
2016	Gode Wind 01 +02	97 MPs, Ø 7,5m	BBC	IHC	max. 34m
2014/15	Amrumbank West	80 MPs, Ø 6m	BBC, DBBC	IHC, HSD	19,5-24m
2014	Borkum Riffgrd 1	77 MPs, Ø 5,9m	BBC	IHC	23-28m
2014	Butendiek	80 MPs, Ø 6 - 6,5m	BBC	IHC	17-22m
2012/14	Nordsee Ost	49 jackets, 4 piles, Ø 2,4m	BBC, DBBC, linear BBC & DBBC		22-25m
2013	Dan Tysk	80 MPs, Ø 6m	BBC, DBBC,TBBC, linear BBC		21-32m
2012/14	Global Tech 1	80 tripods, 3 piles, Ø 2,48m	BBC, linear BBC, DBBC, TBBC		38-40m
2013/14	Baltic 2	80 WTG 39 MPs, Ø 5,2-6,5m 41 jackets, Ø 3m	DBBC, TBBC		23-35m MPs, 35-44m jackets
2011/12	Meerwind Süd/ Ost	80 MPs, Ø 5,5m	DBBC		22-26m

Additionally Small Bubble Curtain (SBC) at Alpha Ventus (2009) and Bard Offshore 1 (3 locations 2010/2011)

OSS foundations up to Ø 2,5m piles used BBC or DBBC in all projects from 2016 on 5

Figure 11. Inventory of offshore windfarm projects in German waters during 2011-2018 which applied noise abatement technologies, including the technologies used and water depths.

An NGO perspective

Tania Davey (The Wildlife Trusts)

The Wildlife Trusts are supportive of renewable energy development, but it must be the right technology in the right place. The Wildlife Trusts are engaged in the development of 18 offshore windfarms and do have some concerns over:

- the cumulative impact of offshore wind farms;
- the evidence of the effectiveness of noise abatement technology;
- the effect of offshore windfarm infrastructure on benthic habitats.

UK waters are different to other seas only in the lack of legislation in place. Current regulation does not sufficiently address cumulative impacts. Outside Special Areas of Conservation, management of waters can be inconsistent: developers are not incentivised to reduce impacts, and little is done beyond managing injury. The UK should adopt a more regional seas approach through stronger links to the MSFD and OSPAR.

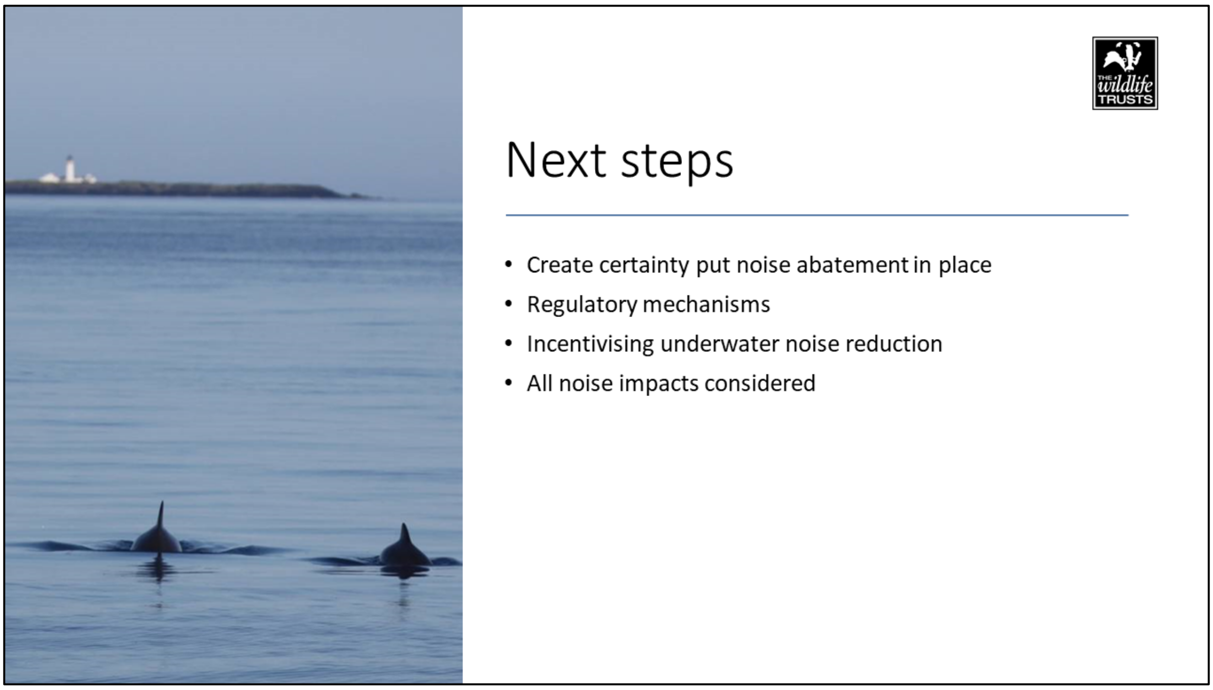


Figure 12. Recommended next steps to better manage noise pollution from offshore windfarm installation in UK waters.

Monitoring of compliance with German noise threshold regulations

Carina Juretzek (BSH)

To date, 19 offshore wind farms (OWFs) permitted by BSH in the German Exclusive Economic Zone (EEZ) are operational, and a further 6 OWFs are under construction. Environmental impact assessments reviewed by BSH predicted harm to the marine environment due to intensive impulsive noise emissions produced by pile driving during OWF construction. In accordance with the precautionary principle, the strategy followed by BSH was to reduce pile driving noise at source, with the aim of preventing impacts to the marine environment and particularly to harbour porpoise. It was also necessary for the approach to be practicable, effective and affordable.

These considerations led German regulators to develop a dual threshold (Figure 13). The foundation installation method must have low noise emissions, there are limitations on piling duration, acoustic deterrent devices must be used, and there must be reliable compliance with the thresholds. The implementation of mitigation therefore requires substantial planning (up to two years before the commencement of pile driving).

BSH now has over 10 years of experience in regulating these thresholds. Lessons learned include:

- noise emissions can be significantly reduced by noise abatement systems, up to 24 dB;
- regulation has led to unprecedented technical innovation by the industry;
- since 2014, there is reliable compliance, despite increasing pile diameters and water depths;
- the regulations offer industry the advantage of installation without temporal restrictions.

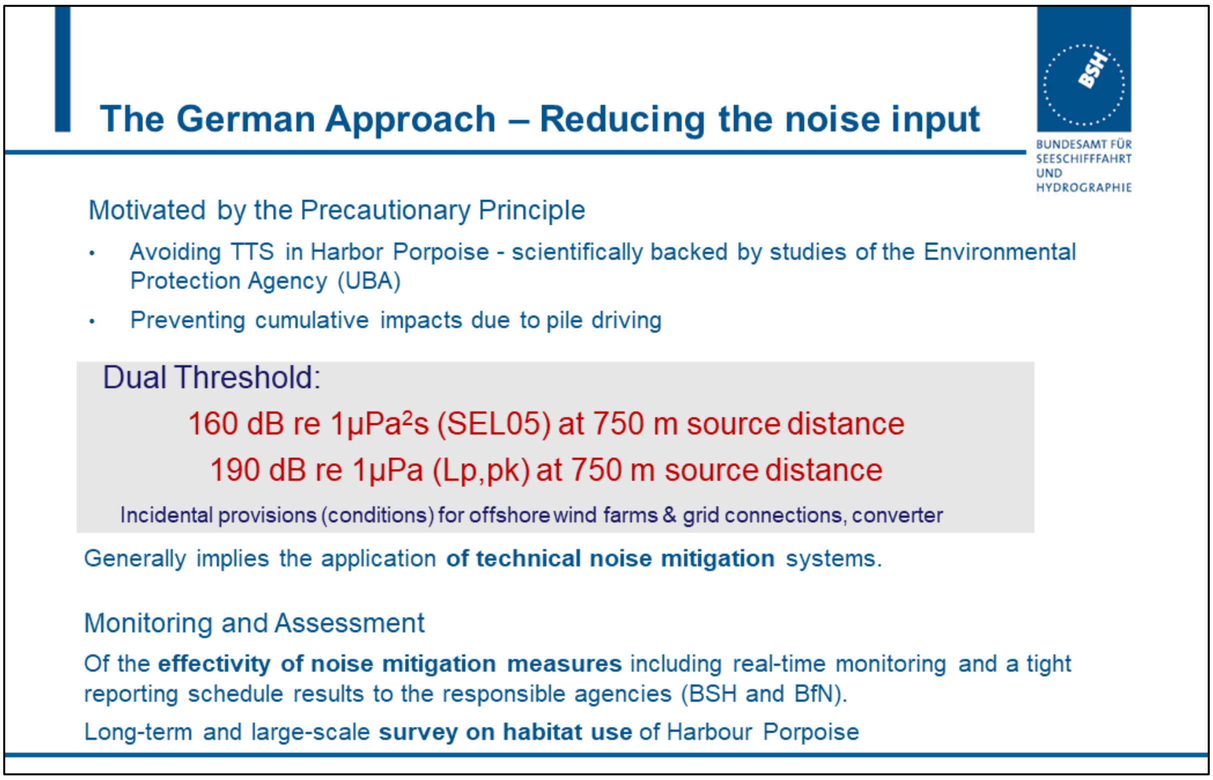


Figure 13. Summary of the German approach to regulating noise emissions from offshore pile driving.

An SNCB perspective

Rebecca Walker (Natural England) & Caroline Carter (Scottish Natural Heritage)

Natural England advise regulators and government on the impact of marine activities on marine mammals and also provide monitoring and management of Special Areas of Conservation (SACs). Rebecca reported on the Natural England position on noise abatement for offshore wind. Current conservation objectives for the southern North Sea harbour porpoise SAC allow up to 20% of the SAC to be disturbed/impacted during any particular day. For the most part, phasing of activities has allowed unabated pile driving to take place but the scale of planned windfarms and other noise-generating activities means this may not continue. Projected scenarios show that 30% or more of the SAC may be disturbed by this increase, so alternative approaches will be required. Natural England supports the development and use of noise abatement technology in this context, and encourages Government and Regulators to adopt the same position (Figure 14).

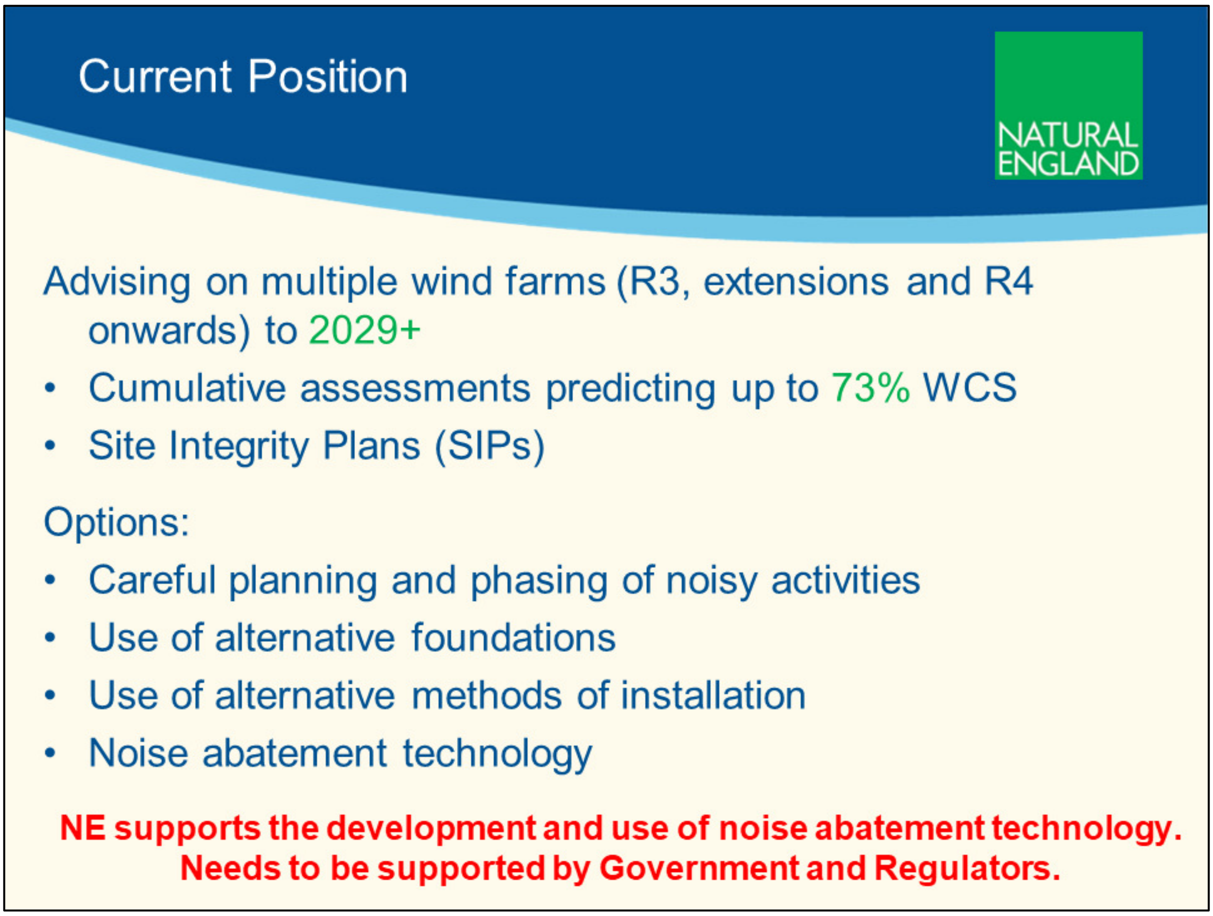


Figure 14. Slide summarising the Natural England position regarding noise in the southern North Sea SAC for harbour porpoise.

Caroline explained that the situation in Scotland is different as there are not multiple developments within an SAC. Scotland therefore has not needed to apply the same threshold approach as is proposed for English waters. Instead a regional management approach has been taken whereby developers, regulators, advisors and NGOs work together to develop case-specific mitigation strategies to minimise environmental risk (to date, this has related to piling and blasting). Noise monitoring is typically required as a consent condition and lessons learned are then used to inform the next round of assessments. Scottish Natural Heritage also supports the development and use of noise abatement where suitable and where the level of risk requires it.

A regulatory perspective

Paul Stephenson & Jessica Duffill Telsnig (MMO)

The Marine Management Organisation (MMO) is the government regulator responsible for marine and wildlife licensing around English waters. Many activities require a marine licence such as piling or UXO detonation. A marine wildlife licence is required to authorise activities which would otherwise be unlawful under wildlife legislation such as disturbing cetaceans. The criteria for the granting of the wildlife license are that:

- the likelihood of an offense occurring is high;
- it is in line with legislation;
- there is no satisfactory alternative;
- favourable conservation status is not impacted.

To inform its decisions, MMO consults a wide range of bodies including statutory nature conservation bodies, technical scientific advisors and NGOs (Figure 15). If a marine or wildlife licence is granted, MMO places conditions on the licence. These conditions may relate to matters consultees raised to ensure the activities are sustainable. As the licence is a legal document, MMO can also monitor activities post-consent and in areas of non-compliance MMO can undertake enforcement activities.

Piling and UXO detonation are two important activities authorised through marine and wildlife licences. Mitigation measures are conditioned on licences to reduce impacts of underwater noise. However, there is an ever-growing need to provide robust evidence on the effectiveness of these mitigation measures and research new techniques to abate underwater noise pollution in English waters.

Marine Licence Application (MLA) process in relation to noise issues

- Receive MLA – conduct internal checks for sufficient information & assessments e.g. Habitats Regulations Assessment, Marine Conservation Zone assessment.
- Consult with a variety of technical stakeholders e.g. JNCC, Cefas, Natural England and NGOs who will usually refer to best available and most recent evidence. If there is no evidence or data available, they will adopt a precautionary approach and offer advice accordingly.
- MMO then make final decision, and condition the licensable activity. The conditions must be necessary, related to activities, precise, reasonable, measureable and enforceable.

Figure 15. Summary of the MMO decision-making process for Marine Licence Applications.

Panel discussion: feasibility of noise abatement in a UK regulatory context

A. A number of speakers have mentioned UXO with bubble curtains and may not be aware that devices have been detonated in the North Sea and the use of the bubble curtain was very successful with the noise being quieter than expected. In fact, the scare charges were actually louder.

A. Deflagration is not unproven. It has been used by the military since the early 2000s, and it is not a "24-hour process" (the process is of similar duration to high order disposal).

Q. How do other countries manage their oil and gas and UXO activities?
A. It varies. There are no thresholds in some industry sectors and different thresholds in place in different countries. These, in turn, can vary according to season and animal activity.

Q. How are you going to get the answers to some of the questions posed in presentations in regard to bubble curtains and UXO?
A. This depends. It is problematic getting evidence from inside a bubble curtain but there is no evidence that a bubble curtain should not be used for UXO.
A. The MMO needs strategic evidence from developers to help in their decision making and this evidence will then be written in as a requirement of the license.

A. There are only a few installation vessels available at any one time and a limited amount of suppliers that can be trusted to do a good job therefore the industry desperately needs more companies and more mitigation methods to choose from.

Q. If you can't place something inside a bubble curtain to measure its efficacy what do you do?
A. You can use a half open bubble curtain.

Q. What about flexibility of testing?
A. Agree, need flexibility to test devices at short notice as you are never quite sure what you are going to encounter during the construction phase.
A. Agree. It took ages to get consent to detonate UXO whilst using a bubble curtain. Finally got consent and are currently analysing results.
A. There are so many piling time restrictions. Are these really necessary?

Session 3: Notes from breakout discussions

Group 1: Technical feasibility of noise abatement for pile driving in UK waters

Facilitator: *Michael Bellman (ITAP)*
Rapporteur: *Sophie Nedelec (University of Bristol)*

Q. **Are there any technical or logistical obstacles to implementing existing noise abatement technologies for pile driving in UK waters?**

A. No technical issues for 80% of piling planned currently which is monopiling and therefore no issues apart from obtaining vessel time and logistics, which are and continue to be an issue. Additionally, to gain 'no disturbance' is very difficult. The UK does not have a single decibel noise limit and is very reliant on modelling which can be inaccurate.

Q. **If such obstacles exist, in which areas of UK waters would they be expected to arise?**

A. This is not a UK but a global issue. As developers move into deeper water bubble curtains and jacket technology is not currently possible for these sites and again, the lack of vessels or vessel ability is an obstacle.

Q. **What development and/or testing would be required to implement noise abatement in areas of UK waters where it would currently be challenging?**

A. Need to look at mitigated and unmitigated piling. Again, the main issue is the move into deeper water and operating at different wave heights.

Questions to Group 1:

Q. Did you discuss the propagation of sound through the sea floor?

A. No. The North Sea we know. The challenge will be new areas. Different bottom types were discussed.

Group 2: Policy/regulatory feasibility of noise abatement for pile driving in UK waters

Facilitator: *Rebecca Walker (Natural England)*
Rapporteur: *Tom Stringell (Natural Resources Wales)*

Q. **Assuming no technological constraints, are there clear regulatory or policy reasons for not applying existing noise abatement technologies to pile driving in UK waters? Under what circumstances?**

A. You have to consider what is the objective? Is it injury or disturbance? What are the population level effects? There is a lot of uncertainty. Mitigation is already in place, but we could consider using the German thresholds. An issue is cost implications. The lowest price often wins in respect of noise abatement systems. However, some participants thought noise abatement systems should be a requirement. There is a lack of consistency with the use of abatement systems across the UK. There are also unintended consequences such as the amount of fuel required to run systems. This needs to be monitored.

Q. **If noise abatement of pile driving is implemented in a phased way, which areas should be considered first/have the highest priority?**

A. The Southern North Sea should be prioritised, and Site Integrity Plans should be used. Clarity is needed on what is required at an early stage. Dual thresholds are used in Germany, but their application to the UK context needs careful consideration.

Q. **If noise abatement is considered to present an appropriate regulatory/policy solution under certain circumstances, what changes to current regulatory practice would be required to ensure implementation?**

A. None. It could be added as a condition to licenses. Currently cost is the deciding factor as to whether to use noise abatements systems or not. It would not be difficult to add noise abatement systems to regulations, but the jury is out as to whether necessary.

Questions to Group 2:

Q. Looking at this from an environmental regulatory/policy angle this is quite easy but what about the economic consequences? In Germany there were huge incentives originally but no, little or low subsidies mean very hard to carry out. Also, what will happen after Brexit? We have to have a top-down push or nothing will happen.

A. Agree. Economic considerations should be a part of any conversations about noise abatement.

Group 3: Technological and regulatory feasibility of noise abatement for UXO in UK waters

Facilitator: *Paul Lepper (Loughborough University)*
Rapporteur: *Sander von Benda-Beckmann (TNO)*

Q. **Are there any technical or logistical obstacles to implementing existing noise abatement technologies for UXO detonation in UK waters?**

A. Deflagration is fairly new in civilian applications but it is ready to use. The MoD are responsible if there is a possibility of safety to the public, otherwise it is the responsibility of contractors.

Q. **If such obstacles exist, in which areas of UK waters would they be expected to arise?**

A. Not in UK waters – there will be certain obstacles if a UXO is moved to the land for detonation.

Q. **What development and/or testing would be required to implement noise abatement in areas of UK waters where it would currently be challenging?**

A. There are issues around chemical pollution (for both high and low order detonations) and the need to ensure any debris is cleared from the seabed.

Q. **Assuming no technological constraints, are there clear regulatory or policy reasons for not applying existing noise abatement technologies to UXO detonation in UK waters? Under what circumstances?**

A. No. High order detonations would require a bubble curtain. Further measurements are required.

Q. **If noise abatement is considered to present an appropriate regulatory/policy solution under certain circumstances, what changes to current regulatory practice would be required to ensure implementation?**

A. One issue is the amount of time between surveying, identifying issues and the clearing up process. There needs to be flexibility in licenses to accommodate this and a certification process for those carrying out low order detonations. This certification of experienced contractors would reduce the risk of unintended high-order detonations. The question of whether bubble curtains would still be required as a precaution also needs to be addressed.

Questions to Group 3:
There were no questions to Group 3.

Conclusions

The workshop highlighted the range of technologies now available to reduce underwater noise pollution emitted at source from pile driving activities and the disposal of UXO. It also helped to clarify the positions of key UK stakeholders with regard to the deployment of noise abatement technologies, and the steps that would be required to implement this.

The development of noise abatement technologies for pile driving is an active area, driven by requirements to meet regulations in other North Sea nations which have explicit limits on noise emissions from pile driving. The reviews of available noise abatement methods presented by international and UK scientists make clear that viable noise abatement options already exist for wind turbine installation at all locations where wind farms are expected in Scottish, Welsh, and English waters. Bubble curtains have been widely demonstrated to be effective in waters up to 45 m. They become less effective as water depth increases due to dispersion of the bubbles. Casing-based systems (e.g. IHC Noise Mitigation System) are also demonstrated up to 45 m and are constrained by the availability of large enough systems for the water depth. Encapsulated resonator systems (e.g. Hydrosound damper, AdBm Noise Abatement System) are in principle unlimited by water depth or adverse weather conditions (high current speeds and wave heights).

There are also promising options for noise abatement from the disposal of UXO. Bubble curtains have already been deployed for this purpose in UK waters, and better evidence of the efficacy of these systems would allow more robust assessment of the reduction in impact ranges achieved by this approach. The technique of low-order detonation via deflagration appears to present a viable option to avoid explosive detonation altogether, with experimental measurements presented indicating that noise levels emitted depend only on the size of the relatively small charge used to ignite the explosive. A thorough investigation of the logistical implications of deploying this method during UXO clearance at wind farm sites would help regulators to decide whether this technique can be licensed.

To implement noise abatement via these technologies, stakeholders agreed that no new policy or regulation would be required. It is at the discretion of regulators to determine whether to require noise abatement technologies as a condition of a marine licence. Such decisions are informed by the advice of Statutory Nature Conservation Bodies and scientific advisers. Although in principle economic considerations should not influence regulatory decisions over enforcement of legislation such as the Habitats Regulations, there is a perception that cost implications are a factor in the present status quo of unabated noise emissions from wind turbine installation in UK waters.

Acknowledgements

The workshop was sponsored by the UK Acoustics Network (UKAN) through funding provided by the Engineering and Physical Science Research Council (EPSRC). We thank Duncan Williams, Charlotte Swain, and Anna Romanova at UKAN for assistance with logistics and funding.

The organisers also wish to extend thanks to all the ~100 attendees who travelled to the workshop, and particularly to the international speakers for contributing their expertise and experience. We thank Prof. Peter Liss for chairing the sessions, Anne Brazier for kindly agreeing to take the minutes on which this report is based, Carol Reid (NPL) for help with the logistics, the contributing speakers, and the facilitators and rapporteurs of the breakout sessions. We also thank the workshop contributors and Rebecca Faulkner (Cefas) who provided comments on the draft report.

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Stephen Robinson leads the technical work in Underwater Acoustics metrology at the National Physical Laboratory (NPL) in Teddington. He has over 27 years' experience in underwater acoustic metrology, and serves on numerous standards committees for ISO, IEC and BSI as well as steering committees for Defra and the UK Underwater Sound Forum.

Chair

Peter Liss CBE FRS is Professor Emeritus in the School of Environmental Sciences at the University of East Anglia. He chairs the Underwater Sound Forum, a working group convened under the UK Marine Science Coordination Committee which meets biannually to discuss how the UK manages the issue of underwater sound in the science, technology, policy and legal areas.

Secretary

Anne Brazier was the UK Marine Science Co-ordination Officer until her retirement in December 2019. She was based at the National Oceanography Centre in Southampton, and served as secretary to the Underwater Sound Forum and other UK Marine Science Coordination Committee working groups.

Speakers

Michael Bellman is a Managing Director at the Institute for Technical and Applied Physics (ITAP). He has a PhD in acoustics from Oldenburg University, and has carried out extensive research on the effectiveness of various noise abatement systems for pile driving.

Caroline Carter is a marine ecology adviser at Scottish Natural Heritage. She has advised on marine renewable casework since 2012, and prior to that, completed her PhD at the Scottish Association for Marine Science on “Tidal Energy, Underwater Noise and Marine Mammals”.

Michael Dähne is Curator of Marine Mammals at the German Oceanographic Museum in Stralsund. He has researched the effects of noise on marine mammals at Aarhus University, the University of Veterinary Medicine Hanover, and the University of Kiel.

Tania Davey has a background in marine biology and has worked for The Wildlife Trusts for over 3 years, engaging across industry, Statutory Nature Conservation Bodies, regulators and government to ensure the sustainable development of offshore activities. She focuses primarily on offshore wind, mainly underwater noise impacts on marine mammals and impacts on benthic ecology.

Jessica Duffill Telsnig has a PhD in marine fish food-webs and joined the MMO as a marine licensing case officer working on a variety of cases including interconnector cables and renewables. She subsequently joined the marine conservation team where she is currently a wildlife licensing case manager.

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Henk van Vessem joined Royal IHC in 1995 and has 30 years of offshore experience. Since 2010, he has been responsible for the development and implementation of the IHC Noise Mitigation System (NMS) and Combi Lifting Tool (CLT), as well as other offshore wind related solutions. Special topics of interest are underwater sound, optimizing installation sequences, integration of functionality in equipment, offshore tools and hydraulic systems.

Carina Juretzek has an MSc degree in geophysics from the University of Hamburg. Carina joined the Assessment and Monitoring division of BSH to work on underwater noise at the beginning of 2018.

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Paul Stephenson has strong experience of project management in a marine fabrication environment including oil and gas subsea umbilicals, QE Class aircraft carriers and Astute class submarine construction. He joined the MMO two and a half years ago as a Senior Case manager and the Renewables licensing lead.

Ursula Verfuss is a Principal Scientist at SMRU Consulting and project manager for projects involving the effects of offshore industry on marine mammals. Ursula provides specialist input into environmental impact assessments and provides data and advice for mitigation studies relating to impacts on marine mammals. (Note: Ursula could not attend).

Rebecca Walker is a senior marine mammal specialist at Natural England. She has spent the last 15 years working in marine science, from working on offshore survey vessels to advising on the environmental impacts of marine developments in UK waters.

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