JNCC guidance for the use of Passive Acoustic Monitoring in UK waters for minimising the risk of injury to marine mammals from offshore activities

JNCC

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To be read in conjunction with
JNCC's mitigation guidelines

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Contents

1. Introduction

It is recognised that sound generated from certain anthropogenic activities has the potential to cause injury and disturbance to marine mammals (cetaceans and seals). In particular, piling, geophysical surveys and explosive use (e.g. unexploded ordnance, downhole explosives) have the potential to result in an injury offence (e.g. permanent hearing damage) as defined under UK regulations for the protection of European Protected Species (EPS); for example, Regulation 45 of The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended), similar offences can be found in the corresponding regulations for territorial waters. Note Scottish regulations make it an offence to "deliberately **or recklessly** capture, injure, or kill a wild animal of a European protected species."

The Joint Nature Conservation Committee (JNCC), in collaboration with other UK Statutory Nature Conservation Bodies (SNCBs), produce a series of guidelines describing mitigation measures which will reduce the risk of injury to marine mammals from explosive use, piling and geophysical surveys to negligible levels (JNCC 2010a, 2010b, 2017). The use of Passive Acoustic Monitoring (PAM) has been included in these mitigation guidelines since their origin in 1995 (although it was not routinely used until 2002), and the guidance provided here supplements the mitigation guidelines.

1.1. Aim

This guidance aims to standardise when PAM is used to mitigate the risk of deliberate injury to marine mammals within the United Kingdom Continental Shelf (UKCS). It should be read alongside marine mammal mitigation guidelines published by JNCC.

This guidance has been developed through consultations with stakeholders at a workshop jointly hosted by JNCC and the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) (part of the Department for Business, Energy and Industry Strategy at the time of the workshop, subsequently part of the Department for Energy Security and Net Zero (DESNZ)) on 3 and 4 March 2021. This was attended by 117 stakeholders including regulators, non-governmental organisations (NGOs), SNCBs, developers, and marine mammal observers (MMOs) (see Workshop Summary for more details – Bloor *et al*. 2021).

JNCC's mitigation guidelines and this associated guidance do not directly deal with disturbance, however, measures contained may also assist in reducing a potential disturbance offence.

1.2. Scope

The focus of this guidance is the use of real-time PAM to mitigate the effect of sound generating activities on cetaceans in the UKCS. This guidance outlines best-practice for the use of PAM systems in UK waters. It does not specify what equipment or software to use or how to deploy it, or methods of sound source verification. It recognises that one size does not fit all and that PAM systems should be deployed optimally for the circumstance; alternative methods of deployment or technologies can be used. It should also be noted that

PAM is not appropriate for non-vocalising species such as basking sharks, or those that do not vocalise frequently, such as pinnipeds.

JNCC welcomes discussions on the emergence of new techniques, the potential for risk to marine species and the development of appropriate monitoring/mitigation measures.

2. Passive Acoustic Monitoring

2.1. Introduction

When used for mitigation, PAM is only one part of an overall monitoring package, but it is the only system currently available that can detect cetaceans underwater and is of particular importance for the detection of deep diving species such as beaked and sperm whales. As with visual surveys undertaken prior to a sound source being activated, the aim of PAM is to ensure no marine mammals are within a specified area (the mitigation zone) prior to a sound generating activity commencing.

Specialist trained PAM operatives are needed to set up and deploy the equipment and to interpret detected sounds. It is acknowledged that current PAM systems have limited capacity for detecting seals and some cetaceans (e.g. baleen whales) and have limited range for others (e.g. harbour porpoise). However, PAM is considered a viable monitoring method for vocalizing species during periods when effective visual monitoring is not possible (Stone 2015).

When a PAM system is used, it should achieve as much as possible of the following:

- Detect the range of frequencies of marine mammal vocalisations expected to be present in the survey area.
- Detect and identify vocalising marine mammals and establish approximate bearing and range in real time (requires a minimum of two hydrophones).
- Immediately communicate relevant information from the PAM operator (real time) so appropriate and timely mitigation measures can be undertaken (e.g. delay operation start).
- Able to be repaired on board or replaced in case of breakdown (e.g. have appropriate repair tools and back-up equipment).

2.2. When to use PAM

PAM should be used when environmental conditions prevent visual observations by the marine mammal observer (MMO); in some circumstances, it may also be needed to supplement visual observations (i.e. both methods are employed at the same time).

When conditions for doing so are optimal, visual searches are considered to be the most effective monitoring method for marine mammals. The limitations described previously mean PAM cannot completely replace a MMO visual search as it is not 100% effective at detecting all species of concern in UK waters. However, it is acknowledged it is the only method regularly used at night. Data analysis (Stone *et al*. 2023a, 2023b, 2024) suggests lower

detection rates when compared to visual observations therefore PAM should not be used as a substitute for visual observations unless the full extent of the mitigation zone cannot be seen. The two methods should be used concurrently to ensure the best possible mitigation wherever possible.

As a minimum, PAM should be utilised under the following circumstances:

- JNCC sea state category c (choppy with many white caps) or Beaufort sea state 4 (see Appendix 1) or above (note: while this sea state is above that which is recommended for sighting harbour porpoises, this sea state provides a compromise for observing other species); if possible, supplemented with visual monitoring.
- Visibility drops to a degree that the mitigation zone cannot be clearly seen in its entirety.
- Light levels drop to a point where the whole of the mitigation search zone is not clearly visible without the aid of artificial light.

When undertaking searches during bad weather or civil twilight conditions (the period of twilight when the geometric centre of the sun is less than 6 degrees below the horizon), it is beneficial to undertake both visual (if possible) and PAM searches if sufficient staff are available. Otherwise, PAM should be deployed at a point at which visual surveys are no longer possible owing to failing light, which will likely vary on a day-by-day basis. A specific amount of time after sunset/sunrise for deploying PAM should not be used as twilight length varies depending on latitude. Both the MMO and PAM operator should be aware of sunset/sunrise times and plan for when they would need to switch to between methods, and consideration should be given to the number of staff needed when planning.

While there are benefits to deploying PAM 24-hours a day, real-time monitoring of detections is only needed during the pre-activity search and soft-start (unless specified otherwise in a consent or licence).

Where PAM is not available and conditions are such that visual observations cannot be undertaken and no other form of monitoring is available, initiation of the activity should be delayed until conditions improve.

Although not always required, undertaking both visual and acoustic pre-activity searches simultaneously increase the probability of detecting cetaceans thereby strengthening the effectiveness of mitigation measures. Furthermore, having simultaneous visual and acoustic detections can help validate the PAMs estimation of the range at which a cetacean is from the sound source. Where supplementing visual surveys with PAM is a consent or licence condition (in addition to requiring PAM at night or in low visibility), insufficient PAM operators is not a viable excuse for non-compliance with that consent, licence or the JNCC guidelines. In some circumstances, remote PAM operators could be an option; however, this should be discussed and agreed with the regulator and included in the mitigation plan.

2.3. Areas of importance

One example of when PAM may be required to supplement visual observations is when operations occur within areas considered important to marine mammals. Areas of

importance can be defined as discrete areas of important habitat for marine mammal species and may comprise, but are not limited to, areas designated as Marine Protected Areas (MPAs).

UK MPAs include:

- Special Areas of Conservation (SAC): designated under legislation that previously transposed the EC Habitats Directive for habitats and species into UK law, with habitats/species that require designation identified in Annexes I and II respectively.
- Marine Conservation Zones (MCZs): created under the Marine and Coastal Access Act (MCAA) 2009 with the aim of protecting nationally important marine wildlife, habitats, geology and geomorphology in English and Welsh inshore waters and UK offshore waters adjacent to England and Wales.
- Nature Conservation Marine Protected Areas (NCMPAs): created in Scottish seas under the Marine (Scotland) Act 2010 (inshore) and the MCAA (offshore) to conserve Scotland's most important marine wildlife, habitats, and geodiversity.
- Highly Protected Marine Areas (HMPAs): areas of the sea designated for the protection and recovery of marine ecosystems; they prohibit extractive, destructive, and depositional uses allowing only non-damaging levels of other activities.

All MPAs with a marine mammal species as a qualifying feature are considered an area of importance within the context of this guidance. Consultation with the appropriate Regulator and SNCB(s) at the earliest opportunity is recommended when considering operations within or near these areas. Additional mitigation requirements for operations in these areas may be recommended (e.g. PAM in addition to visual monitoring), and any requirement will consider (as a minimum) the size, duration and timing of the operation and the species most likely to be impacted.

All proposed, possible and candidate MPAs are a material consideration within the licensing process and considered areas of importance.

2.3.1. Other important areas

In addition to MPAs, the deep waters to the west of Shetland and areas to the south-west of England are considered areas of importance under this guidance. Although these areas do not currently have legal protection, they are considered important for a variety of cetacean species which are protected under UK law, including some which do not occur elsewhere in UK waters (e.g. deep diving species such as beaked and sperm whales). As such, additional requirements to standard mitigation such as the use of PAM to supplement all visual monitoring to maximise detection potential may be required, as, for example, deep diving species are difficult to detect by visual mitigation methods alone.

Currently no Important Marine Mammal Areas (IMMAS) have been approved in UK waters, however several candidate areas were announced in 2023. While these sites have no legal status, they may be considered areas of importance under these guidelines should they be approved.

2.4. PAM Operator Training and Experience

All PAM operatives undertaking marine mammal mitigation are required to be trained on how to implement the JNCC mitigation guidelines (i.e. the individual must have undertaken formal training on a JNCC approved course). Further information on recognised courses is available on the JNCC website.

Additionally, specialist training in the use of PAM is required, however, JNCC does not review or approve these courses. Specialist training of PAM operators is recognised to be an important component in ensuring that PAM is deployed and operated effectively. It should ensure the PAM operator is capable of meeting certain competences, including the ability to configure the PAM system and any associated modules, being able to detect marine mammal vocalisations and the location of the animals detected. Practical experience on the deployment of the cable, installing equipment and real time monitoring is also important. At a minimum, a PAM operative should be able to assemble and deploy PAM equipment, configure the software, identify acoustic signals, and interpret bearing and range information.

JNCC strongly recommends newly qualified PAM operatives do not work in isolation for at least their first five PAM jobs (i.e. they are not the sole PAM operative on board a vessel). Rather they should work alongside experienced personnel (ideally with a minimum of 20 weeks of experience) who can act as mentors while they gain experience of deploying PAM and implementing the guidelines.

Most PAM operators will work alone when covering night-time operations, usually on 12-hour shifts. Fatigue can result in missed detections, and so consideration should be given to the number of PAM operators (and their experience) in a mitigation team. If only one trained PAM operator is employed, PAM will consequently not be available during the day should weather conditions deteriorate. Having MMOs that are also trained as PAM operators can be beneficial, enabling more trained operators on a single operation, although numbers must be sufficient to cover both visual and acoustic mitigation plus rest breaks. One individual must not carry out both roles at the same time.

2.4.1. Experienced PAM operators

An experienced PAM operator should have a minimum of 20 weeks of experience of using PAM for mitigation and implementing any of the JNCC noise mitigation guidelines (noting the principles are the same regardless of the activity) in UK waters over the previous five to ten years. Furthermore, they will be experienced at identifying individual species acoustically. Note PAM work overseas may count towards experience in the use of PAM for mitigations, however, 20 weeks of experience in implementing the UK guidelines in UK waters is still needed).

The use of experienced PAM operators is essential in areas of importance for marine mammals (Section 2.3).

3. Planning

It is important to consider potential mitigation methods early in the planning process to effectively incorporate them into the operation. As the potential risk of injury will vary for each operation, it is recommended that the generic guidance provided here is customised as appropriate and incorporated into the application, and/or the Marine Mammal Mitigation Plan (MMMP) as applicable. Mitigation requirements should be developed in consultation with the relevant Regulator and SNCB(s) and submitting details alongside consent or licence applications can help prevent delays in the consenting process.

Things to consider for PAM when planning sound generating activities include:

- What cetacean species are likely to be present in the area the activity is proposed, noting any seasonal considerations such as migration and breeding. Establish whether PAM is effective for these species, for example by discussing with a PAM supplier or reviewing available literature. Note any species that may show seasonal variations in their vocalisation which may hamper their detection at certain times of year. The MMMP should include information on the vocalisations of species likely to be found in the area.
- Confirm whether the activity will take place within an area identified as important for marine mammals and may require additional mitigation (e.g. the use of PAM to supplement visual observations).
- Select a PAM system most appropriate to the activity and the location where it will occur. As a minimum it must be able to detect the range of frequencies of species that may be in the area of operations. Identify the frequency bands the hydrophones will need to monitor, justified with evidence provided from published literature. Also, consider what calibration will be needed (above that undertaken by the PAM supplier prior to deploying the equipment) as this can be time consuming.
- Consider the likely required mitigation search zone for the planned activity and whether the chosen PAM system will be able to detect all sensitive species throughout this area or just part of it. Identify limitations to the range at which any of the species of concern can be detected. The radius of the mitigation zone will be confirmed at the application stage through consultation with the Regulator and SNCB(s) and considers evidenced behaviours to the activity in question and predicted injury ranges. Minimum mitigation zones can be found in JNCC's mitigation guidelines.
- Consider how the PAM system will be deployed to minimise background sound levels thereby reducing possible masking of cetacean vocalisations, and any other technical issues that may arise. Consider available tools (e.g. software modules) that can be employed to demonstrate the effectiveness of the proposed system.
- Consider how many PAM operators will be needed to ensure effective monitoring of the mitigation zone without observer fatigue, with at least one dedicated PAM operator covering night-time hours.

3.1. Information to include in applications

Consent and licence applications must demonstrate that the above planning considerations have been considered. In particular, the application must demonstrate that the chosen PAM system will be capable of detecting the species of concern (for vocalizing species) within the required mitigation zone, for example by referencing evidence provided by the chosen PAM supplier confirming this, such as the sensitivity of the hydrophones and the sample rate.

Ideally, the application should describe how the PAM system will be set up and deployed, including how it will be ensured background noise will not mask vocalizations. If known, for towed systems include the distance between the first pair of hydrophones from the stern of the vessel, and the depth they will be towed below the surface; for stationary systems include the depth below the surface at which the hydrophones will be positioned.

If the exact PAM system is not known at the application stage, the applicant must commit to ensuring the chosen system will be able to detect the required species, noting there may be a consent condition to confirm this with the Regulator/SNCB(s) post-consent (e.g. as part of a MMMP).

Well-trained PAM operators are key to effective mitigation and the minimum number of PAM operators to be employed should be stated in the application. Careful consideration should be given to the number employed to ensure sufficient coverage while avoiding operator fatigue. If they are not to be located on the operation vessel (i.e. will be monitoring from a separate vessel or onshore via a remote connection), detail must be provided regarding how this will be undertaken and consideration given to what will happen if the live connection is lost.

Note: when PAM is stipulated in a consent or licence, if PAM is the only mitigation monitoring option available at the time (e.g. at night or poor weather conditions) and live monitoring of the PAM system is not possible (e.g. due to a faulty system or the PAM operator becoming unwell), operations **must** be delayed until some form of mitigation monitoring is possible. Where PAM is not a condition of the licence and conditions are such that visual observations cannot be undertaken and no other form of monitoring is available, best practice would be to delay the initiation of the activity until conditions improve.

3.1.1. American National Standard

The Acoustical Society of America is developing an American National Standard (Thode & Guan 2019) for towed passive acoustic operations to monitor marine mammals. The fundamental goal of this is to reduce situations where background noise levels will prevent PAM from working effectively. This standard will provide requirements and recommendations for how PAM operations should be logged, reported and evaluated. Operators are welcome to use this standard (once published) when applying for licences in the UK to illustrate how their chosen PAM system will be effective at the application stage and demonstrate mitigation was effective in the post-activity mitigation report.

4. Deployment

Sounds from non-biological, biological, and anthropogenic sources all contribute to overall ambient or background sound levels that can mask marine mammal vocalisation signals of interest. Therefore, optimising the deployment configuration of the PAM system and deploying it from a position on the vessel with reduced background sound levels is important for it to operate effectively. Sound from the deployment vessel propellers is the dominant source of background sound for towed PAM systems, accounting for between 80 to 85% of sound from vessels (Hildebrand 2004). The PAM system must have a good signal to noise ratio (i.e. the ratio of signal amplitude (marine mammal vocalisation) to amplitude of ambient sound). Masking not only affects the ability to detect marine mammals, it also impacts automatic detectors and classifiers which work best on target signals with high signal to noise ratios.

There is no 'one size fits all' system, therefore PAM equipment should be appropriate to the operation, considering the length of deployment (battery life / power source), size of storage memory (if appropriate), depth of deployment and any localization requirements (Dudzinski *et al* 2011). General considerations regardless of deployment method include:

- Ensure that the computers have been pre-loaded with any necessary software prior to departure, with back-ups available should they be needed.
- Take photographs of everything prior to unpacking the equipment, to assist with repacking at the end of the project and ensuring that all equipment is accounted for.
- PAM systems work in, and should be reported in, UTC as opposed to local time, if different.

Ensuring that the PAM system is able to detect signals over the correct frequency for the target species is vital. Most hydrophones detect signals over a range of frequencies which are then filtered by the analysis software. If this is not the case, the hydrophones and recording system should be set to a suitable frequency range to detect the required species. This should be undertaken before boarding the vessel and checked before deploying in the water.

It is expected that hydrophones will have been calibrated prior to being taken offshore, usually by the manufacturer or system provider. However, prior to deployment at sea, PAM operators should ensure that all equipment is in good working order and potential detections should not be masked by background sound. A simple screen image of the spectrogram showing the background sound levels may be included in the mitigation report as evidence that masking should not occur.

4.1. Towed PAM systems

Towed PAM systems are mostly used for geophysical surveys where typically, pairs of hydrophones are installed along cables which are towed behind the survey vessel. PAM systems may also be towed around a stationary sound source (e.g. from a support vessel transiting around a pile-driving platform).

Optimising the position of the hydrophones is key to ensuring no entanglement with any other equipment (e.g. towed geophysical equipment) and that sound levels from vessel propellers are reduced as much as operationally possible to prevent interference with or masking of cetacean vocalisation signals. If possible, this should be tested before operations commence. The exact positioning of the PAM system will be vessel specific; however, the distance between the first pair of hydrophones from the stern of the vessel, and the depth they will be towed below the surface should be stated in the MMMP.

Additional considerations when deploying towed PAM include:

- Agree with the crew where the hydrophone shall be deployed from. Hydrophones should be deployed from a position where the risk of entanglement with other towed equipment is minimalised, and if line turns are required, be deployed from a position where they will not need to be brought in during line turns. Avoid deploying hydrophones from a position where entanglement is likely. Attaching the PAM cable to a streamer lead-in (e.g. the cable to which streamers are attached) and/or the use of a sliding collar which offsets the cable from the umbilical and propeller wash can help reduce the risk of entanglement. Alternatively, some PAM systems can be deployed with the source array which again reduces entanglement risk. The crew will advise which position is the safest / most appropriate, noting that on some vessels, there may only be one location from which deployment is possible.
- The route the cable will follow from the PAM monitoring station to the edge of the vessel should be planned prior to deployment of the hydrophones into the water. Assistance and advice should be sought from the crew in order to negate any risk to the equipment (e.g. avoiding sharp corners) and people (e.g. by keeping walkways clear when possible). Sharp corners beyond the flexibility of the cable should be avoided. Additionally, when installing deck leads, the cable should not be run around or near any electric cables or florescent lights as this can cause interference in the signal.
- Before the hydrophones are deployed from the vessel, each one should be tested to ensure that they are working properly. This can be done once the PAM monitoring station has been set up, simply by tapping each hydrophone and ensuring that the resulting signal is detected through the PAM system and user interface software.
- Hydrophones should be deployed far enough from the vessel as to minimise background sound levels from the vessel as much as possible, but not too far as to increase the risk of entanglement (ideally at least 200 m). This should be discussed with the crew. PAM operators should also ensure that hydrophones are not amongst airguns (where applicable).
- Hydrophones should be towed at several metres below the water’s surface to reduce background noise from surface waves; weights may be added to aid with this if required as these cables are negatively buoyant, therefore by increasing the deployment length, the depth will increase. However, adding weights can cause strain on the cable and increase risk of entanglement.
- The PAM system should ideally be left out for the duration of the works, unless there is a fault, or in severe seas (to avoid cable damage).

- The on-deck cables and connections should be checked on a regular basis (at least once a week during deployments), and anything that gives cause for concern should be immediately investigated, with the hydrophones brought back on deck if necessary.
- It is assumed a towed PAM system will have sufficient hydrophones to enable the PAM operator to determine distance and whether an animal is within the defined mitigation/search zone. See Section 5.2 if this is not possible.

4.2. Static PAM

Static activities such as piling operations, explosive use (including UXO clearance) and vertical seismic profiling may also require PAM. However, in these circumstances the system may be deployed over the side of a static vessel or rig, or held in position using anchors (e.g. attached to fishing buoys or anchored to the sea bed). Some of the points for towed systems also apply to static PAM, and the above list should be reviewed for static operations. In addition, the following should be considered.

4.2.1. Deployed from static vessel/rig

Typically, a single cable is deployed over the side of a vessel or rig with one or more hydrophones attached. As all the hydrophones are in a single vertical plain, localisation of any detected mammals is impossible (see Section 5.2 for further details on determining whether a detection is within the mitigation zone).

When a vertical PAM is deployed from a static vessel, the background sound levels can be very high, owing to the hydrophone being relatively close to the vessel, and the fact that the vessel will be operating its thrusters to remain in position. This should be taken into consideration when identifying which PAM system to use and how to deploy it in the field to ensure species of concern can still be heard over the background / vessel sound levels.

When using vertical PAM, weights might be required to ensure the hydrophone remains at a certain depth or position in the water column. It is recommended to add 5 kg of weight a couple of metres above the hydrophone.

4.2.2. Anchored

When mitigation is required in the same area for a prolonged period (for example, monitoring of tidal devices) it may be preferable to anchor PAM systems to the seabed.

Careful consideration should be given when choosing a PAM system to use, and how the detections will be monitored. Consideration should be given to local hydrographical conditions that may increase background sound levels and impede detections. Benthic conditions can also affect the placement of the hydrophones and anchoring method therefore this should be appropriate to the water depth and bottom complexity (Amundin 2016).

The hydrophones should be placed somewhere where mitigation will be effective; in particular, consider the range of the hydrophone for the species of concern. The hydrophone

should be as close to the sound source as possible whilst considering background sound levels and ensure even coverage of the mitigation zone. In shallower waters, the hydrophone(s) should be at least 5 m below the sea surface and 1–2 m from the sea floor (Browning *et al*. 2017) to reduce interference from sound wave reflections off the seabed/surface.

The use of anchor weights and a sub-surface buoy with a sinking rope helps to prevent hydrophones from changing position; however, care should be taken with soft substrates to prevent equipment from becoming buried (Dudzinski *et al*. 2011). Anchor weights should be tethered to prevent interference with background noise.

In these situations, it is likely the detections will be monitored from the shore, and if monitored live, ensuring a continuous feed is important (see Section 5).

5. PAM Monitoring

PAM operators should focus their effort on the mitigation period (i.e. the pre-activity search and post-activity if relevant). The guidelines should not be interpreted to imply that PAM operatives should continue an acoustic search during all available hours, unless specified as a licence condition. Whilst JNCC appreciates the efforts of PAM operatives to record valuable data at other times, this should be managed to ensure those observations are not detrimental to their ability to undertake duties during mitigation periods. PAM operatives should manage their time to ensure that they are available to carry out their duties to the best of their ability during the mitigation periods as outlined above.

5.1. Location of PAM operator

An adequate location must be provided for the PAM operator to monitor the detections and communication methods in place to ensure timely reporting of detections within the mitigation zone (to crew) that may require a delay in operations. PAM monitoring stations should be a comfortable temperature and should not be in a noisy environment (as much as possible). As the PAM operators will be at the station for long periods of time, a comfortable environment is advised.

Normally this monitoring will be from the vessel from which the PAM is deployed however, for some operations, remote surveillance is an option. It should be noted however that if live monitoring is undertaken from a remote location, a trained PAM operator at sea will still be needed to ensure the equipment is set up and deployed correctly and make repairs if needed.

5.2. Identifying detections within the mitigation zone

For PAM arrays that allow distance determination, PAM operators must use their acoustic knowledge to identify detections within the mitigation zone and immediately inform whether a delay in operations may be required in accordance with the activity communication protocol.

For PAM arrays that do **not** allow distance determination, generic rules should be identified and agreed between the PAM operator and the developer at the start of the operation to reduce ambiguity in decision-making. For example: if high frequency signals typical of harbour porpoise are detected, it should be assumed they are within 500 m of the hydrophone due to the rapid decay of these signals with distance. Alternatively, it could be assumed that all detections are within the mitigation zone regardless of species, depending on the distance of the hydrophones to the acoustic source. The agreed-upon rules should be clearly stated in the MMMP and post-activity report.

The following guidance is suggested to aid operators in determining whether a detection is within the mitigation zone when distance determination is not possible:

- If a signal is detected above 25 kHz and the peak for that signal is above 25 kHz, it can be assumed to be within 500 m of the hydrophones, and a delay is required if within 500 m of the acoustic source (therefore depends on the position of the hydrophone in relation to the source). Such signals are likely to be from porpoises, delphinids or beaked whales and owing to the attenuation of these frequencies in the water column, a detection is almost certain to be within 500 m. If the animal is further away, then the signal is likely to be at a lower frequency.
- If a signal is below 25 kHz but strong with clear signal definition and amplitude above background sound levels, it should first be assumed to be within 500 m unless the PAM operator is confident the mammal is further from the hydrophone based on experience. Reasonable caution should apply and mammals that might be within 500 m should be assumed to be so, on the basis of the precautionary principle.
- If a click train bearing is seen to change rapidly, the animal can be assumed to be within 500 m; this is likely to be a delphinid, beaked whale or a sperm whale.
- Due to the distance at which they can be detected, sperm whale clicks should be localised for range to animal before calling a delay; if localisation is for some reason not possible and the clicks are loud the operator should apply precaution and delay.
- Any whistle in 50 m of water should be treated as within 500 m. As sound does not travel as far in shallower water, signals will be detected at a shorter range.
- Any detection from deployment of a towed array within 150 m of the vessel should be treated as within the mitigation zone automatically. This is due to the highly unfavourable signal-noise ratio at close range to the sound source, so any signal that is loud enough to be detected is almost certainly originating from within the mitigation zone.

Factors influencing all decisions should be added to the comments' column in the sightings tab of the JNCC spreadsheet (see Section 6). If a vocalisation is detected during pre-watch, it must be recorded, and operations delayed (or a reason for **not** requiring a delay should be given). For example, if the vocalisation was below 25 kHz and only weakly detected. If vocalisations are determined to be outside the mitigation zone following consultation with visual observers, PAM operators can use this information to support a decision to not delay operations, but this must be noted in the final report and JNCC spreadsheet.

If a PAM operator demobilises mid-project, clear handover notes should be provided to the replacement operator. This should include details of the hydrophone configuration, cable layout, any issues that have occurred and details of the hydrophone frequency. Previous detections should also be included, as this may aid in correct identifications.

Throughout the survey, collected data should be constantly backed up onto a separate device (e.g. an external hard drive). This will ensure that the information required for the final report will be available and reduce the risk of data loss due to IT issues.

6. Post-survey reporting

Details of all PAM watches and detections should be recorded in the JNCC spreadsheet and screenshots of detections collated for a post-mitigation report (commonly known as an MMO report). If many detections are recorded, include a sample set of images, ensuring at least one for each species or species' group detected, and examples of low-, medium-, and high-quality detections (if available). Evidence should also be collated during operations to demonstrate the PAM system was able to detect vocalisations above background sound levels, and that the PAM system was working effectively throughout the mitigation period, (e.g. through a pre- and post-mitigation check using the PAM software). Software modules are also available that can help evaluate the efficiency of a PAM system (and the PAM operator).

The post-activity report should be provided to the Regulator once the operation has been completed, and copies sent to JNCC (via e-mail to seismic@jncc.gov.uk) along with the completed Excel spreadsheet in its original format.

The report is best written by those who undertook the mitigation role and should include both MMO and PAM mitigation (i.e. a combined report). The report should be submitted by the consent or licence holder within the timeframe specified on the consent or licence, or as soon as possible post activity.

The report should include a detailed summary of all PAM use and acoustic detections and highlight any mitigation action needed. As a minimum, the PAM section should include the following information:

- The make and model of the hydrophones, and how the array was configured. Include the frequency and range at which the hydrophone could detect different species or hearing groups (using examples from the project if available), the distance and bearing of hydrophones from the sound source, and the depth of the hydrophone below the water surface.
- The software used to identify detections and all modules applied. Confirm whether range estimation was possible and whether this was estimated by the PAM operator or by a software module.
- Confirmation that the system was able to detect all species likely to be present in the area and capable of vocalizing, with evidence to support this. For example, that the equipment chosen was capable of detecting the required frequencies (likely based on technical specifications), that is was set up correctly once at sea

(screenshots may be useful) and that background sound levels did not interfere with signal detection.

- Evidence that the PAM system was working effectively throughout the activity, noting this could be weeks or months, for example, repeated screenshots demonstrating that background sound levels were not masking vocalisation signals. Also demonstrate that mitigation decisions could be made in a timely manner, and that at no point was the system faulty or inoperative.
- If PAM and visual surveys occurred at the same time, a discussion of the differences in the data (e.g. whether visual observations coincided with acoustic detections). Including screenshots of the relevant acoustic detection can help demonstrate the effectiveness of the PAM system.
- If applicable, an explanation of how and why any of the above differed from information provided at the consent or licence application stage.

The report should clearly demonstrate that the PAM system was able to detect the required frequencies and that background sound levels would not have masked cetacean detections. Software modules are available that can help demonstrate this, and the American National Standard will also provide recommendations including a Noise Validation diagram). UK operators are welcome to use the American template in place of the above, or aspects of it to expand on the above.

The report should also include a summary table of acoustic effort and detections, containing time, date, species, length of acoustic detection and a brief description of any action taken (if any). Note, this should be a summary, as full details should be provided in the JNCC Excel spreadsheet submitted alongside the report. Full details of any shutdowns and/or delays in operations and the reasons for these should be included in both the report and Excel spreadsheet.

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Appendix 1: Wind and sea state scales

Table 1. Wind and sea state scales (for more information on the Beaufort Scale visit http://en.wikipedia.org/wiki/Beaufort_scale).

The Beaufort Scale						Sea state on JNCC recording form	
Beaufort number	**Name of wind**	**Wind speed**		**Average wave height (m)**	**Description of sea surface at this wind speed**	**Category**	**Description**
		Knots	**Km/h**				
0	Calm	< 1	< 2	0	Sea like a mirror	g	Sea is calm, glassy like a mirror
1	Light air	1–3	2–5	0–0.3	Ripples with appearance of scales are formed, without foam crests	-	-
2	Light breeze	4–6	6–11	0.3–0.6	Small wavelets still short but more pronounced; crests have a glassy appearance but do not break	s	Sea is slight with no or few white caps
3	Gentle breeze	7–10	12–19	0.6–1.2	Crests begin to break. Any foam has glassy appearance, scattered whitecaps.	-	-
4	Moderate breeze	11–16	20–28	1–2	Small waves becoming longer; fairly frequent white horses	c	Sea is choppy with many white caps

The Beaufort Scale						Sea state on JNCC recording form	
Beaufort number	**Name of wind**	**Wind speed**		**Average wave height (m)**	**Description of sea surface at this wind speed**	**Category**	**Description**
		Knots	**Km/h**				
5	Fresh breeze	17–21	29–38	2–3	Moderate waves taking a more pronounced long form; many white horses are formed; chance of some spray	-	-
6	Strong breeze	22–27	39–49	3–4	Large waves begin to form; the white foam crests are more extensive everywhere; spray is present	r	Sea is rough, with large waves, foam crests and probably some spray
7	Near gale	28–33	50–61	4–5.5	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind; spindrift begins to be seen	-	-
8	Gale	34–40	62–74	5.5–7.5	Moderately high waves of greater length; edges of crests break into spindrift; foam is blown in well-marked streaks along the direction of the wind	-	-

The Beaufort Scale						Sea state on JNCC recording form	
Beaufort number	**Name of wind**	**Wind speed**		**Average wave height (m)**	**Description of sea surface at this wind speed**	**Category**	**Description**
		Knots	**Km/h**				
9	Severe gale	41–47	75–88	7–10	High waves; dense streaks of foam along the direction of the wind; sea begins to roll; spray affects visibility	-	-
10	Storm	48–55	89–102	9–12.5	Very high waves with long overhanging crests. Large patches of foam blown in dense white streaks. Sea surface takes white appearance, tumbling of sea is heavy and shock like.	-	-