Impulsive Sound and Offshore Wind
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Sander von Benda-Beckmann, Acoustics and Sonar Research Group,
Netherlands Organization for Applied Scientific Research (TNO)

1. **Can you please clarify the sonar sound? I'm assuming this is for navy subs/military typically. How does a typical fish finder compare, if at all?**
We will have Sander clarify what kind of SONAR was played, but different kinds of SONAR signals are engineered for different uses. The signal used will dictate the spatial resolution of the image created by the SONAR system. You can watch the previous DOSITS webinar to learn more about multibeam SONAR and the kinds of signals used here - https://dosits.org/decision-makers/webinar-series/2024-webinar-series/webinar-archive-multibeam-echosounders-mbes/

The sonar was a 1-2 kHz frequency modulated signal typically used for detecting submarines by navy sonars. Navy sonars typically operate between 1-10 kHz, but in rare cases frequencies can be lower or higher. Fish finding sonars typically operate at much higher frequencies. Although fish finding sonars may also have high source level (a measure of the source acoustic output) due to attenuation in the water the distances at which these may affect marine animals (if they are able to hear them at all) is much smaller than that of navy sonars used for anti-submarine warfare.

2. **I am working on underwater noise and which models do you recommend for data processing? Where can I learn about data processing? What steps do I need to follow?**
There are some introductory pages and videos on basic signal processing techniques on the DOSITS webpage. You may be interested in a past webinar - Signal Processing 101 with Dr. Kathlene Wage: https://dosits.org/decision-makers/webinar-series/2022-webinar/webinar-signal-soundscapes/

There is not one single source that I would recommend. There are several documents coming from larger projects, such as ADEON, JOMOPANS, or BIAS to name a few:

ADEON Soundscape Specification Deliverable v1.0 FINAL Submission.pdf
bias_standards_v5_final.pdf
wp5-final-report-measurements-guidelines.pdf

If you are interested in passive acoustic monitoring, there are some open-source programs, such as Pamguard, which may be a good start to get acquainted with passive acoustic monitoring of marine mammals.

3. **Can you explain the difference between the US and EU categorization of impulsive sound. How are these impulsive sounds defined or identified based on MSFD and Dekeling (2014) as opposed to Southall et al's US definition which defines sonar as non-impulsive**.
The main point is that Southall et al. 2019 looks at hearing impact, EU noise register is looking more at large scale behavioral disturbance, so have a slightly different perspective. Next to airguns, pile driving, sonar, and underwater explosions in the EU impulse register also other types of impulsive sources (sparkers, chirpers, boomers, etc) are reported in principle. Some of these sources are currently being reported into a general group, and grouped by source output. You can check the impulse noise register on ICES to see what's currently in there for these types of sources.
There is a 2014 report (Dekeling et al. 2014) that describes the motivation for the different source categories. The rationale was to sort out fainter sources that likely don't affect overall disturbance (note that loud ADDs are also considered in principle).

The distinction between impulse and continuous noise in the EU approach is also not as clear cut. For ambient noise, in principle all contributions are considered, also from piling, airguns, etc, although the expectation is that ship noise and ambient sound from wind/waves is the dominant and more persistent noise source present.

4. **How do the sounds generated during installation and operation of infrastructure for offshore wind compare to that for offshore oil?**
Sounds generated by impact pile driving are considered to be "impulsive" and "intermittent" and are typically high intensity sounds with short rise times. Vibratory pile driving is a lower intensity and is considered "non-impulsive" and can be "continuous" or "intermittent" depending on the installation. Similarly, drilling operations produce lower intensity, non-impulsive noise. Drilling sounds are also more tonal as a result of the mechanical nature of the noise, as opposed to the broadband noise resulting from piling operations. You can explore and compare sounds like this in the DOSITS audio gallery for anthropogenic sound: https://dosits.org/galleries/audio-gallery/anthropogenic-sounds/

Another important distinction to keep in mind is that during seismic surveys sound is made intentionally to image the seafloor, whereas for pile driving it is a side product, so there are different considerations on how much sound you can reduce. Where for pile driving you see a trend to reduce sound generated over all frequencies, for airguns there is a trend to reduce output outside the frequency band of interest (typically below 100-200 Hz, depending on application). another difference is that airguns are typically operated more continuously, but are also moving. So it is hard to compare the potential of disturbance between these sources just based on sound levels.

5. **Is there any model that we can try on predicting TTS?**
Acoustic modelling paired with a noise receptor analysis can be used to predict the extent of TTS and PTS from underwater noise sources. More complex models including the population density and behavioral responses to noise can be used to predict the number of animals who suffer a PTS or TTS for a given sound event.

Data of some seals and dolphin species exposed to impulsive sounds have been collected that could be used to test out some of the models I talked about during my presentation (kurtosis-based correction factors, or the modified power law). I expect further experiments are required to test/validate these models over a wider range of exposure conditions before adopting them in guidelines/regulations.

6. **Are bubble curtains used in those areas where behavior disturbance is being observed?**
The use of bubble curtains in commonly used in several northern European countries during pile driving, but not all. In some cases, also for clearance of old ammunitions found in offshore wind sites. These have been shown to substantially reduce noise levels, as well as degree of disturbance. Modelling suggests that the potential for hearing effects (TTS and PTS) are also substantially reduced, and in case of PTS likely avoided in the case of porpoises and seals.

7. **When pile driving ends, does foraging behavior return to the area?**
Yes, several studies have shown that animals return to the area. How fast differs between study. In some cases, it may take hours to days after piling before baseline echolocation activities are observed, in some areas it appears that the responsiveness of animals seems to be reduced throughout the construction the wind farm (for porpoises in this case). We currently don’t have a good understanding what drives these differences. Several countries are starting to monitor more broadly (including presence of prey and other environment factors) to better understand these differences.

8. **Do offshore windfarms only affect marine animals during construction or does the vibrations from their daily operation cause anthropogenic pollution issues?**
You can read more about the noise created during operation of wind farms on the Audio Gallery: https://dosits.org/galleries/audio-gallery/anthropogenic-sounds/wind-turbines/

It has been shown that vibrations can be acoustically detected underwater close to the turbines. Studies suggest so far that there is not a large-scale reduction in animal presence during the operational phase of wind farms, but it is still an active field of research.

9. **Are the noise mitigation strategies used for the pile driving cases presented here using bubble curtains or another methodology? And how effective are bubble curtains?**
Yes, the noise mitigation used in the study was both using a double big bubble curtain as well as near field mitigation (shielding of sound close to the pile), although exact measures differed between some locations (different operator building different parts of the wind farm).

Bubble screens, when deployed effectively, have been shown to reduce the sound by piling effectively, by order of 10-20 dB roughly (for a recent overview see Bellmann et al 2023). Higher frequencies are attenuated more effectively. There is ongoing research on how these can be deployed effectively in deeper waters, as the hydrostatic pressure which increases with depth influences the bubble sizes, as well as currents have a stronger effect on the stability of the screen with increasing depth.

10. **Can PAM stations that listed for MM presence also serve to monitor marine noise?**
This depends on the systems used and how loud the noise is at the location of the recorder. Harbor porpoises make ultrasonic echolocation clicks (at 120-130 kHz), for which you need dedicated hydrophones and recording systems. There are systems being used which record raw data. Because of the high data rates created by the large bandwidth required to detect harbor porpoises, researcher often use devices that automatically detect and store porpoise clicks (so called C-Pods) to reduce data storage (and expensive servicing to read out memory cards).

11. **The slide with the porpoise presence probability observed during the Gemini and Borssele wind farms is very interesting. Since EU regulations tend to develop towards habitat preservation, and e.g. Germany limits the disturbed part of the habitat to max. 10% of their North Sea EEZ, the uncertainty in the "disturbance radius" that follows from those charts is pretty impactful (disturbed area is quadratic with radius). Would you expect that this can be refined, and would you know if specific research is ongoing to reduce the uncertainty in the disturbed area?**
The effective disturbance distances are also being compared right now to the new EU guidelines. For research see reply to question 7.

12. **Are wind developers proposing to include PAM as part of their environmental mitigation plans?**
Yes, passive acoustic monitoring as well as marine mammal observations from vessel based MMO's and aerial surveys are included as part of the mitigation and monitoring strategy for wind farm development.

The exact use of passive acoustic monitoring (PAM) will differ per country though. PAM is sometimes used to monitor the mitigation zone. However, some species such as porpoises are hard to monitor both visually and with PAM, so some countries rely on acoustic deterrent devices to deter animals out of the areas of high risk of impacting the animals.

13. **What type of noise reductions are used and recommended for offshore wind projects?**
There are different noise reduction methods:

- near field noise reduction methods
- adapted hammer types
- bubble screens (1, 2 or sometimes even 3).

Alternative construction techniques are also explored and sometimes already used. these vary from floating wind, different forms of vibratory piling, suction buckets, gravity-based methods to name a few.

It is hard to make general recommendations on what are appropriate measures. The first three measures have been proven to be effective at reducing noise, but may not be usable in all locations (very deep waters). Note that noise reduction measures are very expensive, so need a careful balancing between cost and effectiveness at achieving conservation objectives.

14. **Have you ever used ADD, Acoustic deterrent devices? What do you think, do they work, any results.**
Yes, ADDs are commonly employed during construction of offshore wind. There are several studies that these may be effective for some species (porpoises, seals), but effectiveness will differ between species and type of ADD. Effectiveness of ADD for other species still needs to be demonstrated. The question is whether an avoidance response can be initiated that substantially reduces the risk mitigated for (typically PTS or TTS). Some ADD are considered too powerful in some cases (because is causes more disturbance than needed), and some countries therefore have a preference for certain systems. Such loud ADDs may be useful for extreme situations, e.g. before underwater explosions commonly found on wind farm sites in the North Sea.

15. **Is there any info available yet on how the Netherlands are interpreting LOBE? for example, what is a porpoise assessment/habitat area that is being considered?**
No, this is currently still being discussed.

16. **Can you use a key indicator species that if adequately protected would also protect all other species?**
This is a good question and difficult one to answer in general. Part of the answer that it's often a practical approach, since we lack information on effects of underwater sounds for so many species.

From our perspective in the Netherlands and offshore wind farm sites in the North Sea, I think it is a reasonable assumption to use porpoises an indicator species for several reasons: as they are known to be very sensitive to underwater noise, we are seeing large scale disturbance with these animals (if not mitigated for), they are also abundant in the North Sea, and there is a large overlap with their habitat. Although the noise regulation in the Netherlands is currently based on harbor porpoises, I want to note that we are also looking at other species, for instance harbor and gray seals, but although they also can be disturbed at equally large distances as porpoises, there is less overlap of their habitats. As wind farm activities move further offshore, we will also have to look into rarer species that also inhabit the North Sea.

There are several monitoring projects looking at impacts of piling and wind farm operation on fish species, so we are definitely looking what comes out of these studies. That may be relevant for some species that are less mobile. In the past we also investigated the potential impacts of piling on fish larvae but they turned out to be robust to piling noise.

Note that the current noise reductions currently required, are substantial, reduce sound over a wide range of frequencies, and thus most species will benefit from these.