Comparison of the performance of CPODs and FPODs to describe harbour porpoise occurrence

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Contents

Summary

This study compares the performance of two acoustic monitoring devices for harbour porpoises: the Cetacean Porpoise Detector (CPOD) and its successor, the Full waveform capture POD (FPOD). The research was conducted as part of a multi-year project initiated in 2019 to assess the impact of offshore wind farm development on harbour porpoise in Dutch coastal waters. The availability and support for CPODs are expected to decrease in the coming years as a transition is made to the newer FPODs. To enable comparisons between current and future studies using either CPODs, FPODs, or both types of PAM devices, FPODs were co-deployed with CPODs at some locations in the Harbour Porpoise Network Borssele (HPNB) in 2022. In line with expectations, preliminary findings indicate that while both devices detect porpoise activity, FPODs show higher detection rates due to their technological advancements compared to CPODs. Temporal patterns in porpoise detections are similar between both devices, but detection rates differ significantly, particularly at finer temporal scales. A universal scale factor for comparing data from CPODs and FPODs is challenging due to varying detection probabilities influenced by environmental conditions. The study underscores the need for further research to quantify the relationship between acoustic detections and environmental conditions.

1 Introduction

The Dutch government has set ambitious targets for the development of offshore wind energy, with a planned capacity of 21GW of offshore wind farms by 2030. The development of these various offshore wind farms has an impact on the marine ecosystem, which is being closely monitored by the Dutch government.

In 2016, the Ministry of Economic Affairs and Climate (EZK) commissioned Rijkswaterstaat (RWS) to carry out an integrated research program to reduce the knowledge gaps regarding the effects of offshore wind farms on the North Sea ecosystem. This *Wind op Zee Ecologisch Programma* (Wozep) started in 2016 and the results of the studies that are carried out are used in the Ecology and Cumulation Framework (KEC) in which the cumulative effects of current and planned wind farms on protected species are determined.

To date, Cetacean Porpoise Detectors (CPODs) and its predecessors (Chelonia Ltd., 2024) have been used in the Netherlands for passive acoustic monitoring (PAM) of harbour porpoises as well as their responses to anthropogenic activities in numerous settings including pile driving, seismic surveys, and acoustic deterrent devices (e.g., Omeyer et al., 2020; Philpott et al., 2007; Thompson et al., 2013; Todd et al., 2020). A few years ago, Chelonia Ltd., the manufacturer of the CPOD, released a new, improved version: the Full waveform capture PODs (FPOD). One of the advantages of the FPOD is the improved detection of harbour porpoise clicks. As the production of CPODs will cease and support for CPODs may be reduced in the near future, the manufacturer recommends switching from the CPOD to the FPOD.

To compare data collected with both devices, a scale factor is required. Such a scale factor can theoretically be obtained by dividing simultaneously obtained results from FPOD and CPOD combinations. However, given the nature of harbour porpoise clicks, the effect of environmental conditions on detectability of harbour porpoise clicks, and the spatio-temporal variation in harbour porpoise acoustic activity, a generally valid scale factor will be difficult to determine (see also Todd et al, 2023).

In 2019, Wozep commissioned a multi-year project to gain insight into effects of the construction of Borssele offshore wind farms on harbour porpoises, and subsequently collect data on presence and habitat use of harbour porpoises in and around the operational wind farms. To study these topics a PAM-network containing CPODs was set up: the so-called Harbour Porpoise Network Borssele (HPNB, Brinkkemper et al., 2021). PAM is a widely recognized technique employed to study acoustically active species (Merchant et al., 2015). Currently, there is a transitional phase from CPODs to FPODs. FPODs are an upgrade of the CPOD in terms of improved sensitivity, improved train detection and a reduced false-positive rate (Todd et al., 2023). Additionally, as its name suggests the FPOD records the full waveform and other details of clicks (e.g. position of the loudest cycle, frequency range). Apart from these improvements, the availability and support for CPODs will become limited in the coming years. To facilitate a comparison between current and future studies conducted with either CPODs or FPODs or with both PAM devices, FPODs were deployed in the HPNB in 2022. In 2024 Wozep granted a proposal for an add-on project to compare data simultaneously collected with CPODs and FPODs.

The aim of this add-on project is to gain insight into the differences and similarities in acoustic detections of harbour porpoises from CPODs and FPODs. This aim can be specified in the following questions:

1. To what extent do detections of harbour porpoise clicks differ between CPODs and FPODs?
2. Is it possible to determine a scale factor to compare CPOD data with FPOD data?

If a universal scale factor cannot be determined, the following research question becomes important: At what temporal aggregation level are CPOD and FPOD data most comparable one-on-one?

2 PAM Borssele

2.1 Study area

The Borssele wind farms were built in 2019 and 2020, consisting of sites I +II (Ørsted) and III+IV (Blauwwind) located on the Southern coast of the Netherlands (see Figure 1). Since the summer of 2020, the Borssele wind farms supply electricity to the grid.

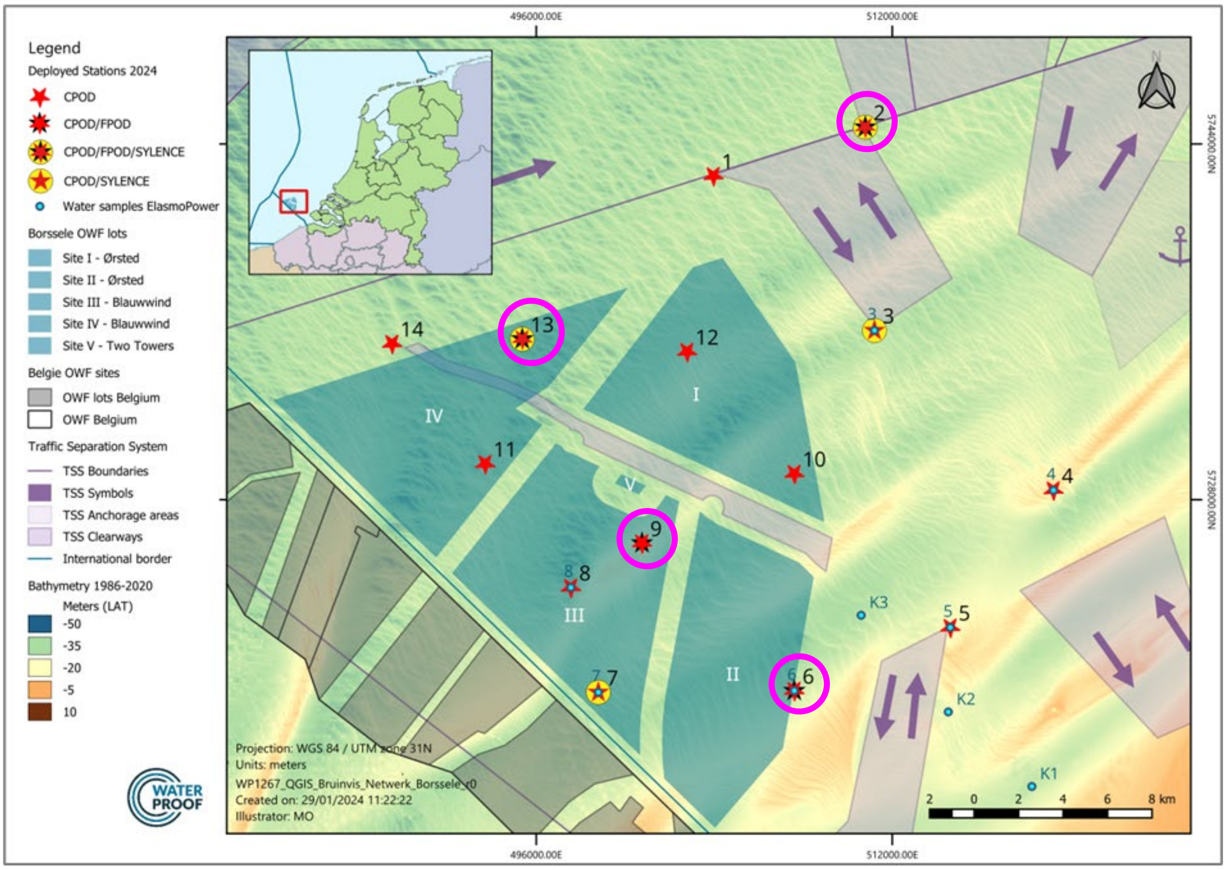

Figure 1. PAM station locations with CPODs (red stars), FPODs (black stars) and ambient sound recorders (yellow circles). Co-deployment of CPODs and FPODs illustrated by pink circles.

2.2 CPOD and FPOD

A CPOD or FPOD relies on the stereotypical nature of porpoise echolocation signals. These are distinctive in lasting about 50-150 microseconds and containing virtually no energy below 100 kHz. The main part of the energy is in a narrow band between 120-150 kHz, peaking at around 132 kHz, which makes the signals suitable for automatic detection. Harbour porpoise clicks can be detected by a comparison of the energy of the acoustic signal in a small band around a high and a low frequency, the so-called A-filter (high-frequency band ~125-150 kHz) and B-filter (low-frequency band ~90-115 kHz). Acoustic signals of harbour porpoise thus have substantially more energy in the A-filter than in the B-filter. Most other sounds in the sea, except some boat sonars, are more broadband or have more energy at lower frequencies.

Although CPODs and FPODs record more than porpoise clicks, non-porpoise clicks, as well as boat sonars and echo-sounders, are filtered out during post-processing, by analysing the time intervals between successive clicks with the dedicated software CPOD.exe and FPOD.exe respectively. Porpoise click trains are recognisable by a gradual change of click intervals and amplitudes throughout a click sequence. In comparison boat sonars and echo-sounders have highly consistent inter-click intervals. Clicks of other origins tend to occur at random with highly irregular intervals, so a probability model of a click train is used as the basis of the train filter.

For this study, the A-filter frequency was set at 100 kHz and the B-filter frequency was set to 80 kHz for both CPOD and FPODs.

2.3 Data collection

Before deploying the CPODs and FPODs the sensitivity of the devices was calibrated by the manufacturer (Chelonia Ltd.). All CPODs were recalibrated in the accredited German Meeresmuseum in Stralsund after several deployments since the HPNB project started in 2019. FPODs have not been recalibrated yet by the Meeresmuseum, since they have only been deployed as recent as 2022. See Appendix I for details on the calibration.

The mooring used for the CPODs and FPODs was similar to those used previously in Dutch studies (Brasseur *et al*., 2010). The PAM devices were secured with a mooring of two buoys. The second buoy served as an extra security measure to avoid the risk of collision with vessels (e.g. trawlers) in the area. The CPOD/FPOD floats approximately 1 m above the concrete anchoring and thus approximately 1 m above the seabed. The instruments were attached to a line between an anchor and a subsurface float. An anchor line or chain connected the anchor to a surface buoy. The set-up of the measurement stations inside and outside the Borssele wind farm is illustrated in Figure 2.

CPODs do not record the actual time, therefore the date and time of data collection needs to be assigned to the CPOD-files after retrieval of the data. During deployment of PODs the following times are recorded in UTC: activation time of the CPOD and time the CPOD hits the water surface. During recovery the time the CPOD emerges from the water is recorded, as well as the time the CPOD is deactivated. FPODs autonomously register date and time in UTC.

The HPNB consists of 14 measuring stations, of which 6 stations are located outside the Borssele wind farm and 8 stations are located within the wind farm (Figure 1). Each station contains devices to detect acoustic activity of harbour porpoises. The equipment at the measurement stations consisted only of passive acoustic monitoring devices, which means that these instruments do not emit sound, but only register sound from the environment. Harbour porpoise activity was registered based on the echolocation clicks these animals produce to navigate, find and catch prey, and communicate. These clicks were detected and stored using Chelonia CPOD and/or Chelonia FPOD devices.

During the first deployment of the monitoring of the operational Borssele wind farms in September 2021, all standard devices (CPODs and ambient sound recorders) were deployed at the measurement locations and serviced in the subsequent field visits. In Augustus 2022, four FPODs were added to the network to simultaneously monitor porpoise clicks at the same location with both a CPOD and FPOD and determine the ratio between the two devices. To partially account for variation in porpoise activity FPODs were deployed at locations that differ in porpoise detections and at locations inside and outside the wind farms. Both CPODs and FPODs were deployed at locations 2, 6, 9 and 13 (Figure 1). These four locations were characterized by relative differences in porpoise detections during the HPBN monitoring so far.

- MT 2: outside the park at the intersection of a shipping route (ambient noise variation)
- MT 6: within the park
- MT 9: centrally located in the park
- MT 13: at the edge of the park

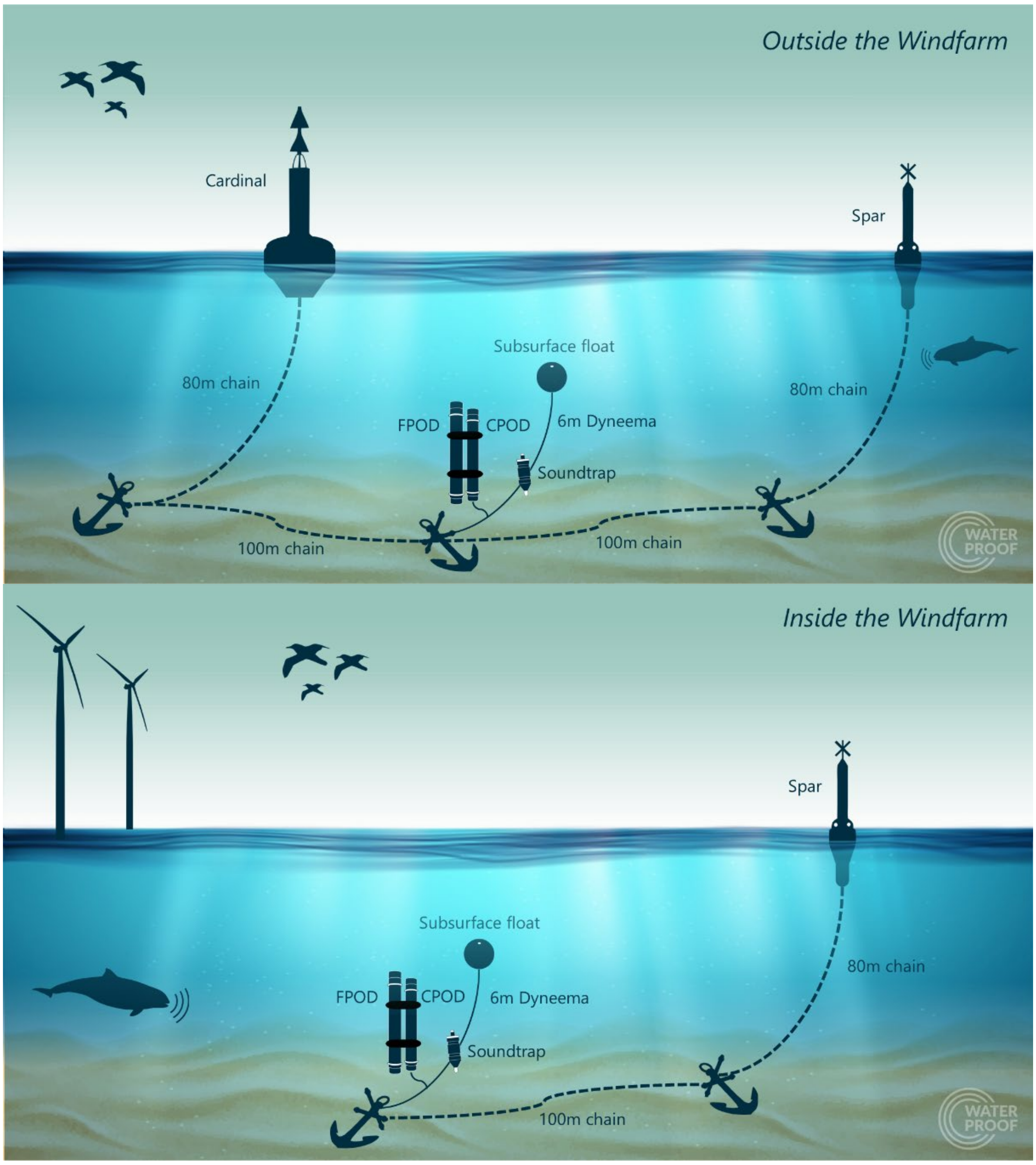

Figure 2. Mooring setup measurement stations outside and inside the Borssele windfarm.

2.4 Post-processing

After replacement of the SD cards, the data for each CPOD was separately downloaded as CP1-file using CPOD.exe software (V2.044) using a KERNO-classifier (Chelonia Ltd). FPODs were processed using the software FPOD.exe (V1.0) which stores data as FP1-file and uses the so-called KERNO-F classifier (Chelonia Ltd., 2024).

The KERNO(-F) classifier, used by the CPOD and FPOD software respectively, is designed to classify click trains produced by odontocetes, including harbour porpoises. For harbour porpoises, the classifier specifically looks for Narrow Band High Frequency (NBHF) click trains. The classifier groups individual clicks into trains, assigns these to a species and assesses the confidence level of classification. The confidence level (High, Moderate, or Low) indicates the likelihood that a detected click train originated from a single source. This helps differentiate true harbour porpoise signals from coincidental sequences, such as clicks produced from different anthropogenic sources (Ivanchikova & Tregenza, 2023).

In accordance with the WMR protocol, a quality check of the data was performed. Per file a time cross check was done by checking whether four timestamps (recorded in the field) correspond to the dates and times of the CP1-file: CPOD on, CPOD in water, CPOD out of water, CPOD off. This check revealed a few discrepancies for the CPOD data. These are probably due to the recording of local time instead of UTC during servicing; erroneous times were adjusted in the metadata. Each file was truncated at the start and end to delete ‘disturbed’ data, due to the presence of the service vessel and tilt of the CPOD. The CP1-files were converted to so-called CP3-files with the software’s detection algorithm 2.024 to identify series of harbour porpoise clicks with an integrated KERNO classifier for detecting harbour porpoise click trains. A sample of the CP3-files was screened for errors by visually checking graphs that show different parameters, like click frequency, angle of the CPOD, and temperature measured by the CPOD.

FPODs were treated similar as CPODs. Per file it was checked whether four timestamps (FPOD on, FPOD in water, FPOD out of water, FPOD off) correspond to the dates and times stored in the FP1-file. No discrepancies were found. Each file was truncated to delete erroneous data at the tails. The FP1-files were converted to so-called FP3-files with FPOD.exe’s detection algorithm 1.0 to extract series of harbour porpoise clicks with the integrated KERNO-F classifier (Chelonia Ltd., 2024). It should be noted, however, there was a time lag of almost two years between downloading the FP1-files and the whole process from post-processing to analysis.

Data analysed here concern the co-deployment of CPODs and FPODs during August 2022 and August 2023 for 4 different stations. The percentage of days that data were recorded per station ranged from 55% to 84% (Figure 3), with an average of 239 deployment days (min = 196, max = 298 days). Harbour porpoise detections were recorded >88% of days for both devices but the frequency of detections differed across locations. The data gap observed across multiple recorders at the start of 2023 is the result of a delayed service interval caused by adverse weather conditions prohibiting fieldwork.

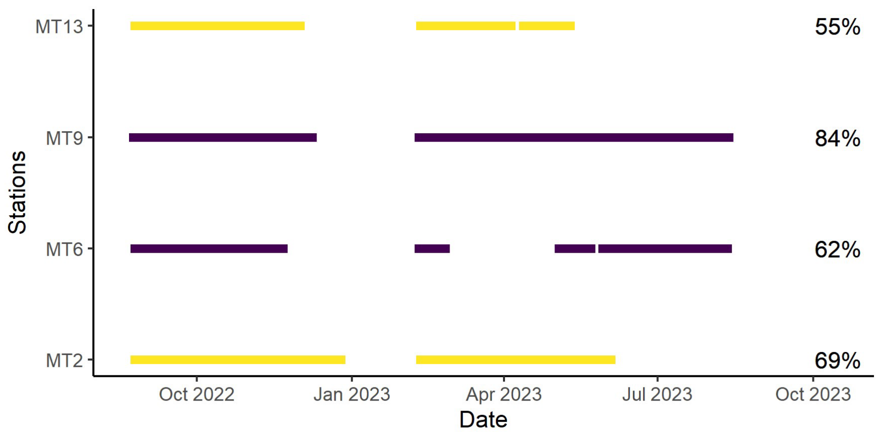

Figure 3. Periods with available data from CPODs and FPODs in and around the Borssele wind farms. Yellow bars represent stations at which both CPOD, FPOD, and ambient sound were recorded while purple bars only hold co-deployments of CPODs and FPODs. Percentage shows number of days recorded per station during the time period (August 2022-August 2023).

2.5 Methods

The principle for determining a scale factor is simple: simultaneously monitor porpoise clicks at the same location with both a CPOD and FPOD for a period of time and determine the ratio between the two, as recently described by Todd et al. (2023). However, as PAM studies, including the HPBN studies (De Jong et al., 2022) show, porpoise activity not only varies per location (depending on depth, sediment, distance to coast, etc.), but also during the day, during the tidal cycle and over the course of the year (e.g. Nuuttila et al., 2018; Schaffeld et al., 2016; Zein et al., 2019). Ideally, this variation should be taken into account when determining a scale factor, because it is unknown whether the detection probability of both measuring devices changes the same in all circumstances. Therefore, a comparison between the two must meet the following criteria: a comparison of porpoise detections per FPOD/CPOD pair on different temporal scales (minute-hour-month) and between FPOD/CPOD pairs at different locations provides insight into the ratio of the number of porpoise detections between both measuring devices and the variation therein.

2.6 Analysis

For both CPODs and FPODs the train quality filter was set to record Hi(gh) and Mod(erate) quality click trains from NHBF porpoise-like clicks. This setting filters out click trains of Lo(ow) quality and thus reduces the number of false detections. The decision to include certain quality levels depends on the question asked and balances sensitivity with the risk of false positives. It is common and recommended by the manufacturer to exclude "Lo" quality trains as it increases the rate of false positives. The inclusion of "Lo" quality click trains requires extensive time to visually validate click classification. This is usually only considered worthwhile for rare species, as the costs of missing a true detection might outweigh the cost of including a false detection.

Data were further analysed using R version 4.3.3 (Angel Food Cake) (R Development Core Team, 2024). We used click frequency as an indicator of harbour porpoise presence (Carstensen et al., 2006, Van Polanen Petel et al., 2012; Tougaard et al., 2006a & b). Click frequency is based on the fundamental unit of clicks-per-minute. This consists of many zero observations (minutes without click trains), as well as Porpoise Positive Minutes (minutes with click trains).

CPOD and FPOD pairs were compared at different temporal scales. Porpoise positive minutes were summarised at minute, hour and day level. Additionally, a comparison of aggregated porpoise detections per hour (PPM/hour) was made on a daily or monthly basis.

The R package *suntools* (Bivand et al., 2023) was used to calculate diel cycle phases (morning, day, evening, and night) with the same assignment criteria as used in Todd et al. (2009).

Following Todd et al. (2023) Kendall's rank correlation coefficients, that measures the strength and direction of correlation, were used to test the similarity in detections among CPOD-FPOD pairs. Kendell's tau values range between 1 (perfect agreement), 0 no association present, and -1 (perfect disagreement). Thus, the sign reflects the direction of the association, while the magnitude represents the strength of that association. Tests were carried out per location and among the different temporal metrics (i.e. minutes, hours, days).

3 Results

3.1 General patterns in porpoise detections

Harbour porpoise acoustic activity was detected at all locations throughout the entire study period (Figure 4). The acoustic activity varied by location and exhibited clear day-to-day fluctuations in the number of porpoise-positive minutes per day. Across all deployments, despite detection differences, results suggest similar patterns in porpoise positive minutes per day between CPOD and FPOD (Figure 4). The CPOD detections are generally lower than those recorded using the FPOD, except for station MT6 (Figure 5, Table 1). Due to the almost two-year time lag between deploying and retrieving, as well as the time required for post-processing and analysing the FPOD-data, the malfunctioning of the FPOD at this station was only discovered recently. The data of this station were omitted for statistical and further analysis.

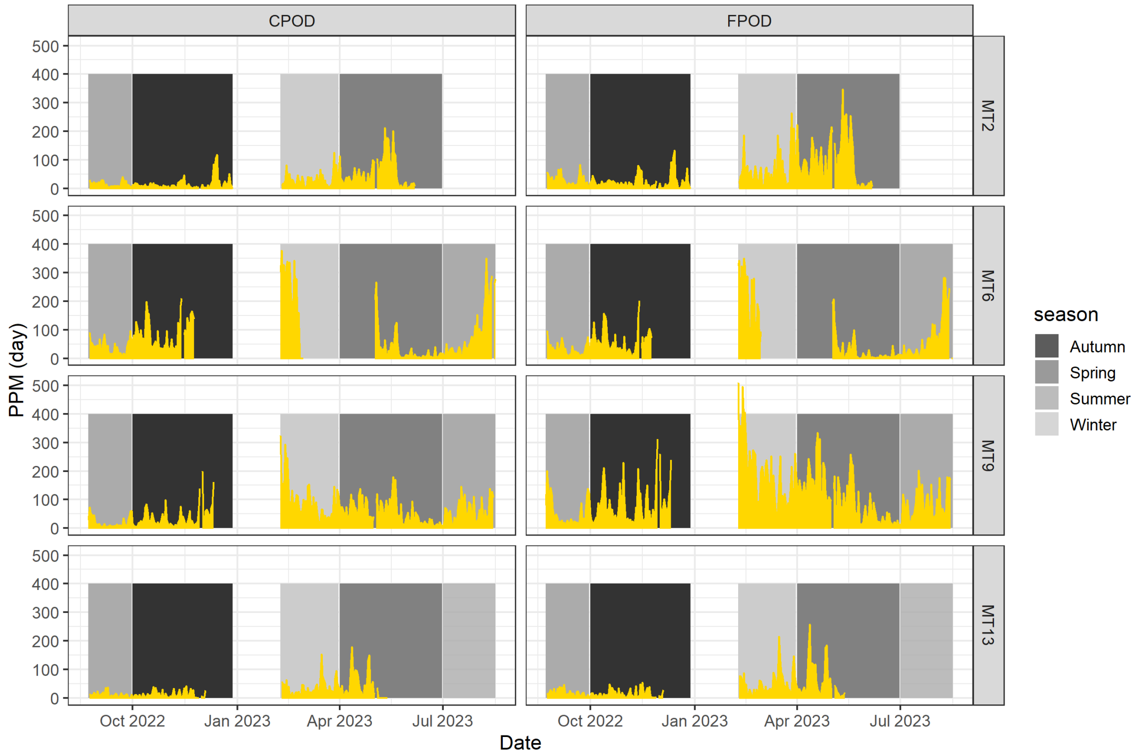

Figure 4. Porpoise acoustic activity in porpoise positive minutes per day (DPM/day) for co-deployment of CPOD (left panel) and FPOD (right panel) per location. Seasons are shown as an aid, for periods without data season is not shown.

Table 1. Summary of detection metrics (DPD = Detection positive days, DPH = Detection positive hours, DPM = Detection positive minutes) for co-deployment of CPOD and FPOD for the different measurement stations. Percentage detection of porpoise acoustic activity for CPOD or FPOD and total measurements (n) for the temporal metrics (days, hours, or minutes).

Station	MT13		MT2		MT9	
Pod type	**CPOD**	**FPOD**	**CPOD**	**FPOD**	**CPOD**	**FPOD**
DPD	91%	98%	98%	98%	100%	100%
	(n=196 days)		(n=244 days)		(n=298 days)	
DPH	24%	29%	33%	40%	44%	53%
	(n=4660 hours)		(n=5803 hours)		(n=7136 hours)	
DPM	24%	29%	34%	40%	44%	53%
	(n=279231 minutes)		(n=347875 minutes)		(n=427854 minutes)	

For all stations statistical significant correlations (p<0.001) were observed between the CPOD and the FPOD harbour porpoise detections. Increasing the temporal scale, especially from hours to days, enhanced the alignment between the measurements of the two systems. The highest similarities were found comparing PODs on the coarsest temporal scale of days (DPD; min=0.59, max=0.79) compared to the more detailed time scales of hours (DPH; min=0.15, max=0.77) and minutes (DPM; min=-0.02, max=0.77) (Table 2). The correlation coefficient showed station-specific differences. Station MT9, which was located centrally in the park, had the highest correlation values of 0.77 (DPH and DPM) to 0.79 (DPD). On the contrary, station MT2, located outside the park, had the lowest correlation values for DPH (0.15) and DPM (-0.02).

Table 2. Kendall's Tau correlation coefficient reported for the various detection metric (DPD = Detection positive days, DPH = Detection positive hours, DPM = Detection positive minutes) for co-deployment of CPOD and FPOD for the different measurement stations. All coefficients are statistically significant (p<0.001).

Station	MT13	MT2	MT9
DPD	0.59	0.67	0.79
DPH	0.47	0.15	0.77
DPM	0.51	-0.02	0.77

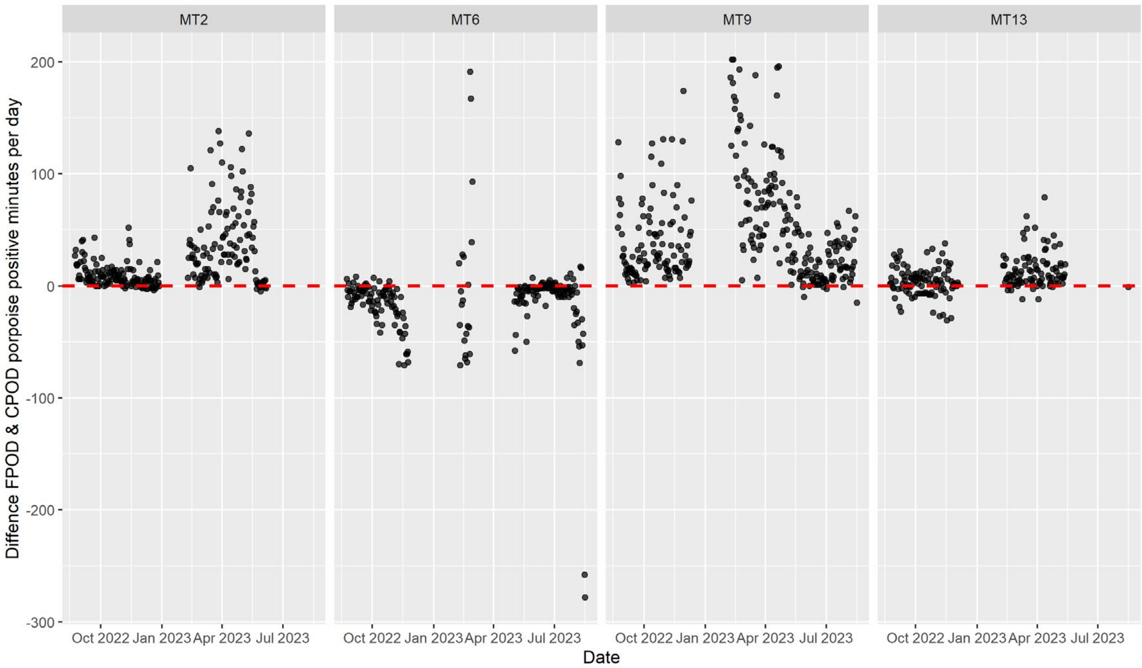

Figure 5. Absolute difference in porpoise positive minutes per day (DPM/day) between FPOD and CPODs for co-deployment of CPOD and FPOD per location.

3.2 Temporal patterns in porpoise detections

Despite the differences in porpoise acoustic detection, the PODs identified similar temporal patterns of occurrence at minute/hourly scales (DPM and DPH) per month (Figure 6-9). Seasonality in harbour porpoise detections was observed, showing high detections in the winter months from December to April (Figure 6-9).

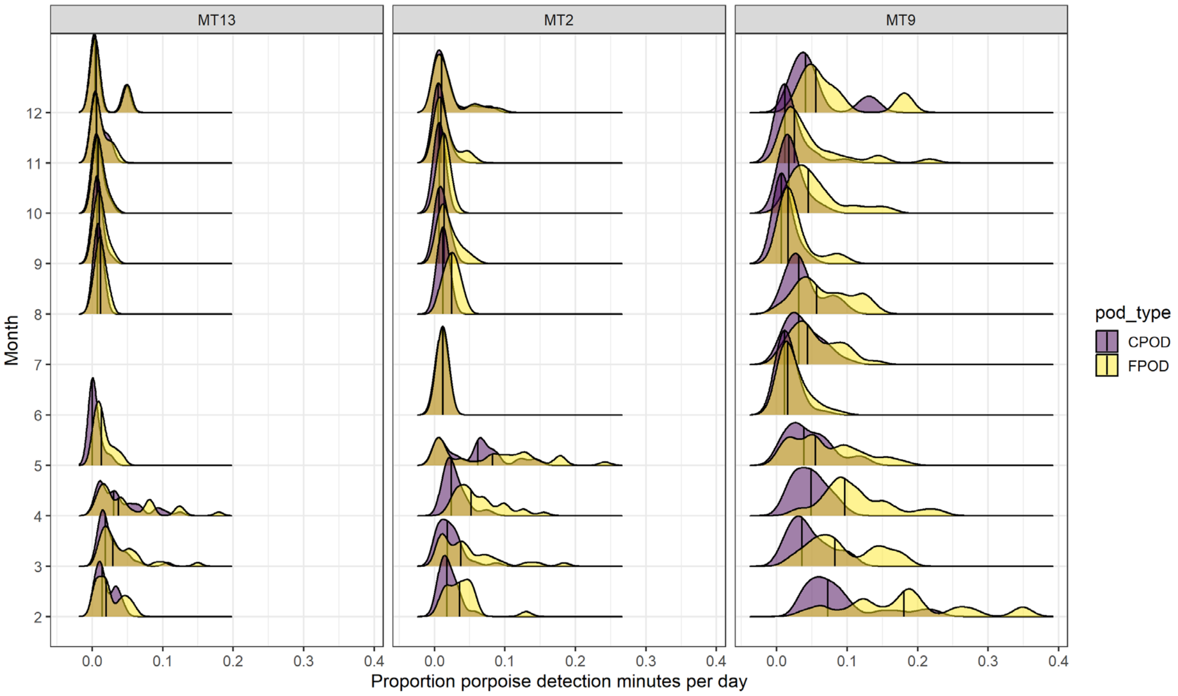

Figure 6. Distribution per month of the proportion of the day with porpoise detections for co-deployment CPOD and FPODs per location. Note that January (month 1) lacks data for all locations, and that June lacks data for MT13, whereas July lacks data for MT13 and MT2.

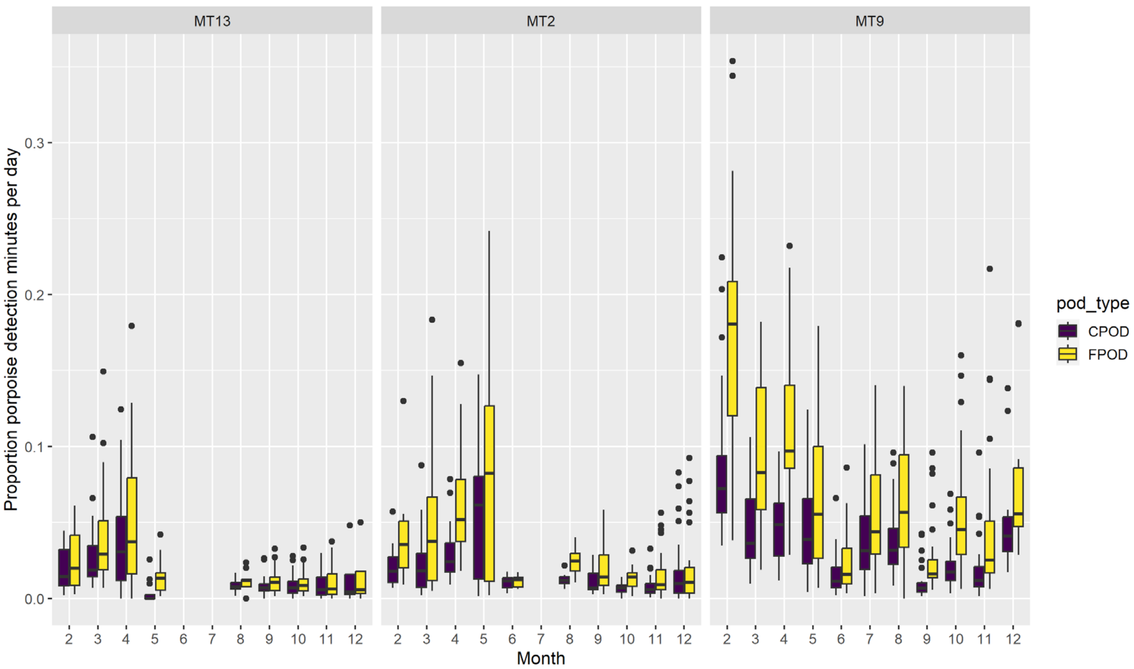

Figure 7. Boxplot per month of the proportion of the day with porpoise detections (minutes per day) for co-deployment CPOD and FPODs per location. Note that January (month 1) lacks data for all locations, and that June lacks data for MT13, whereas July lacks data for MT13 and MT2.

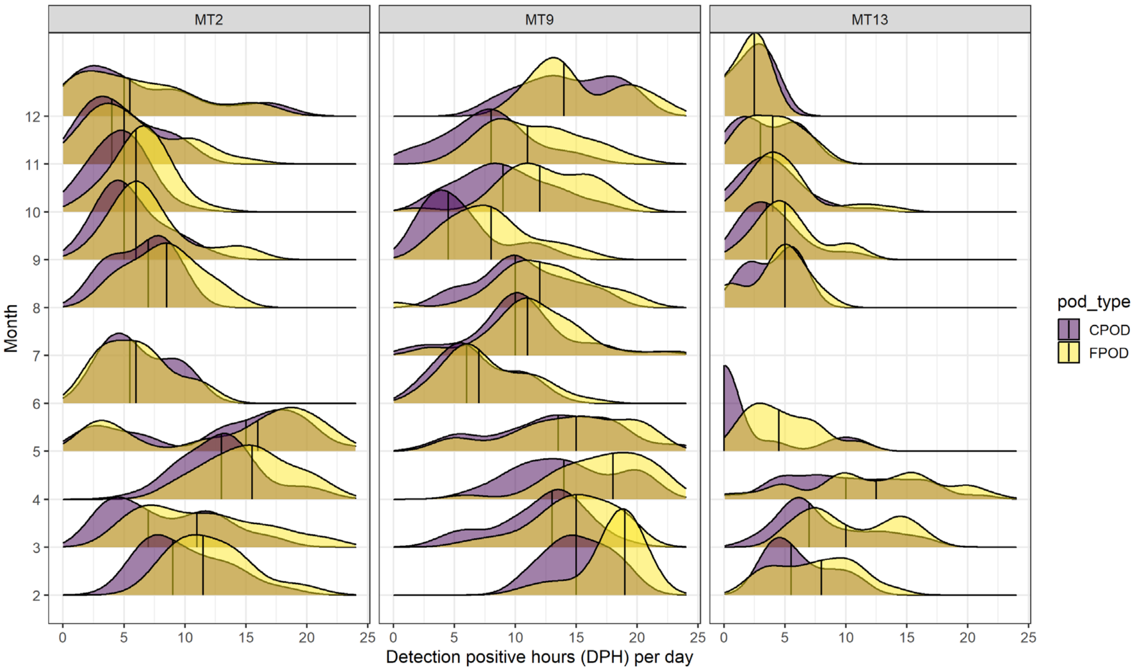

Figure 8. Distribution of monthly detections (detection-positive hours per day [DPH]) for co-deployment CPOD and FPODs per location. Note that January (month 1) lacks data for all locations, and that June lacks data for MT13, whereas July lacks data for MT13 and MT2.

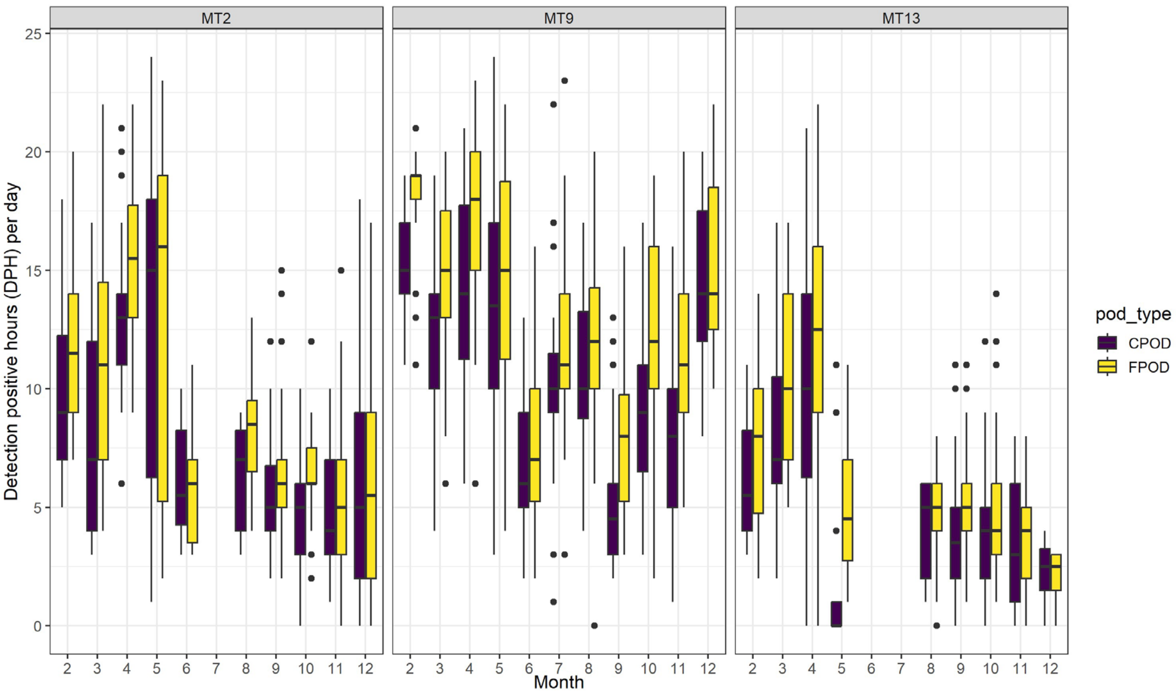

Figure 9. Boxplot of monthly detections (detection-positive hours per day [DPH]) for co-deployment CPOD and FPODs per location. Note that January (month 1) lacks data for all locations, and that June lacks data for MT13, whereas July lacks data for MT13 and MT2.

3.3 Diel patterns in porpoise detections

Similar seasonal patterns were recorded by the CPOD and FPOD in terms of harbour porpoise detections per diel category but with more clicks detected by the FPOD (Figure 10). A strong diel pattern was found with overall less detections during the day and more detections during the night. However, during spring a relatively high numbers of acoustic detections were recorded during daylight hours.

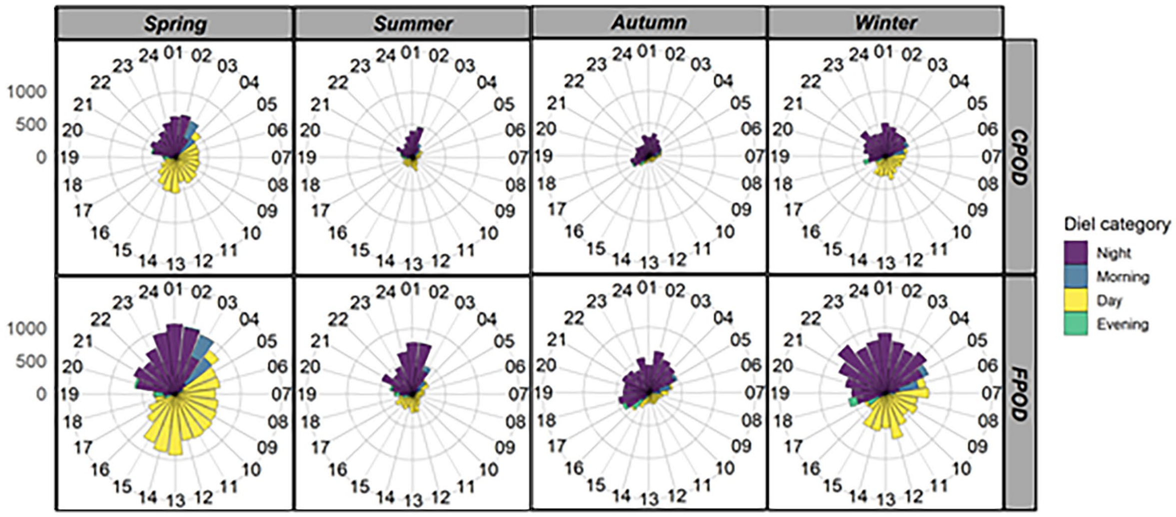

Figure 40. Total amount of harbour porpoise acoustic detections minutes (DPM) per hour of the day, diel category, and season for co-deployment CPOD and FPODs. Morning and evening are defined by the civil twilight and respectively sunrise and sunset.

4 Discussion

Our results show that patterns in harbour porpoise acoustic detections are similar between CPODs and FPODs, when used at suitable temporal scales and with specific considerations.

As expected, given the advancements in FPOD electronics and software, the FPOD has an improved detection of harbour porpoise clicks compared to the CPOD, resulting in lower detection rates for harbour porpoise echolocation clicks when using CPODs (Chelonia Ltd., 2024; Todd et al., 2023). However, the differences between the performance of CPODs and FPODs was not the same for all temporal metrics used. Similar to Todd et al. (2023), we found the highest similarity between CPOD and FPOD data at the coarsest temporal metric DPD (day) compared to more detailed scales DPM and DPH (minute, hour). The DPD data are highly correlated between CPODs and FPODs. For ecological questions that address long-term changes in harbour porpoise acoustic activity, using DPD alone may be sufficient, eliminating the need for a scaling or correction factor to account for differences between CPODs and FPODs. However, for analyses requiring finer temporal resolution, e.g. effect of pile driving on harbour porpoise presence, applying a scaling or correcting factor based on the type of PAM-device becomes necessary.

Based on Kendall's Tau correlation coefficients, we found differences in the similarity between FPOD and CPOD data among stations (Table 2). The best alignment was found for the location inside the windfarm (i.c. MT9), medium for the location (i.c. MT13) at the edge of the park, while the lowest was found at the location (i.c. MT2) outside the park near a shipping route. These differences may be attributed to variations in detections at each location, which influence the detection probabilities of CPODs and FPODs differently. Specifically, lower correlations were observed in locations and periods with reduced click activity. This could be due to the lower sensitivity of CPODs compared to FPODs, a limitation that becomes particularly pronounced in areas with low click activity or under environmental conditions that impair detectability.

As CPODs approach the end of their operational lifespan, FPODs can serve as viable replacements in current monitoring programs with higher detection probabilities. However, establishing a universal scale factor remains challenging. The difficult arises from the unique characteristics of harbour porpoise clicks (i.e. high frequency and narrow beam) combined with spatio-temporal variation in harbour porpoise acoustic activity, and differences in detectability under varying environmental conditions.

Furthermore, a scale factor would exhibit greater variation at more detailed temporal scales. As such, using a scale factor for the comparison or analysis of CPOD and FPOD data is only practical at coarse temporal scales. However, relying on the coarsest temporal metric (DPD) prevents the analysis of fine-scale temporal patterns in occurrence or behaviour (Zein et al., 2019). It also excludes the ability to explore relationships with environmental conditions, which are deemed to change within a day and influence both porpoise presence and detectability (e.g. tidal conditions, diel patterns, or acoustic conditions such as ambient sound).

To summarize, FPODs have a higher detection probability than CPODs, but the detection probability is not constant over time and space, and likely depends on environmental conditions such as the variability in ambient noise levels (Brinkkemper et al., 2021; Clausen et al., 2019; de Jong et al., 2022). Since the detection probability of CPODs and FPODs is likely to show device dependent variation, a universal scaling factor is not feasible. However, depending on the research question, when using DPD or coarser temporal metrics data from both devices can be pooled without the need for a scaling factor. When using more fine-scaled metrics the potential bias between both devices should be addressed in the analysis.

5 Recommendations

- **Quantifying detectability**

Data from PAM studies are mainly used as proxy for harbour porpoise presence. However, the relation between acoustic detections and the number of porpoises is not quantified (see Scheidat et al., 2019 for a review). To fully explore detectability a study carried out in the Baltic Sea under the SAMBAH project applied various methods to enable estimating abundance of the critically endangered Baltic Proper harbour porpoise (Amundin et al., 2022). Although the aim of the Harbour Porpoise Network Borssele is not to estimate abundance one of the key questions is being able to interpret results related to the detection probability of the passive acoustic devices (Clausen et al., 2019). This in terms of how these devices with device-specific detectability could be utilized in a single analysis or how to compare results from studies that employ different device types.

A playback experiment: artificial porpoise click trains are played over a range of distances away from the click train detector and at different source levels, which allows to determine the effective detection area (EDA) and rate as distance specific detection functions (Amundin et al., 2022; Thomas & Burt, 2016).

If such an experiment would be carried out at the Harbour Porpoise Network Borssele it would enable us to assess how detection probability at specific distances varies in relation to environmental factors (e.g. location, wind speed, ambient noise). This would potentially allow extrapolating findings from a specific location to estimate EDA for all surveyed locations and months. Data from a tracking experiment in the vicinity of a click train detector, be it CPOD or FPOD, would provide extra information to estimate EDA. We would recommend exploring the possibilities of a playback experiment in terms of experimental design and logistical, and financial feasibility.

- **Foraging behaviour**

To investigate spatio-temporal drivers of harbour porpoise occurrence and foraging activity within and outside windfarms we not only need to detect acoustic signals of porpoises, but also classification of such detection into behavioural types. POD data could be used to quantify foraging behaviour, specifically feeding buzzes (Berges et al., 2019). Feeding buzzes can be identified by analysing the inter-click interval (ICI), or the time between consecutive echolocation clicks within detected click trains (Verfuß et al., 2009) and Gaussian mixture models can be used to classify echolocation clicks according to their ICI (Berges et al., 2019; Pirotta et al., 2014; Todd et al., 2022).

Identification and quantification of foraging behaviour could aid in explaining the patterns found in and around the Borssele windfarms and could aid in answering questions about the use of windfarms by porpoises. Next to comparing feeding buzzes inside and outside the wind farms, prey abundance metrics are key to understand foraging behaviour and occurrence of harbour porpoises.

As previously mentioned FPODs have an increased detection ability compared to CPODs. This has many benefits among which an increased ability to detect foraging and or social acoustic signals. These behaviours might have been underestimated with CPOD data. Therefore, it is recommended that similar to Todd et al. (2023) and as done in this study for all detections, feeding buzz detections should be compared between CPOD and FPOD per location to better understand the differences between the devices and put results from CPOD foraging studies into perspective with the transition to FPODs.

- **GAMM analysis**

To further explore post-processing methods for comparing datasets in long-term data collections, we propose conducting a GAMM analysis. This approach would allow for the consideration of a scaling factor between CPODs and FPODs while incorporating factors that influence detection probability. It is recommended that a similar GAMM analysis as carried out to quantify effect of underwater noise on porpoises during construction of the Borssele wind farms (de Jong et al., 2023), should be done with POD type as extra co-variate. Although a general correction factor might be hard to estimate as there will be much variance among locations, certain patterns in porpoise presence and detectability among CPODs and FPODs might become evident.

6 Conclusions

This study provides a first step in comparison of CPOD and FPOD performance within Dutch waters for harbour porpoise monitoring in relation to offshore wind development. The transition from CPODs to FPODs represents a significant methodological change in data collection for long-term monitoring programs. The FPOD demonstrated superior detection capabilities compared to the CPOD. In line with Todd et al. (2023) the results indicate that switching to FPODs is unlikely to impact detecting coarse temporal patterns. The FPOD's higher detection rate of harbour porpoise clicks, however, may enhance our understanding of detailed behaviours, like foraging.

We observed the strongest similarity between correlation coefficients between CPOD and FPOD data at the coarsest temporal scale, DPD (day), compared to the finer scales of DPM (minute) and DPH (hour). Both devices showed similar overall temporal trends in porpoise detections. However, differences in detection rates were not consistent over time, making it challenging to apply a universal correction factor or directly compare results between the two devices at enough detailed resolution to answering open questions on harbour porpoise habitat use in offshore wind farms.

A logical next step would be to use GAMMs to test whether differences in detection rates by both devices can be further explained by temporal patterns and environmental drivers of harbour porpoise occurrence. This would improve data interpretation and comparison between both devices.

7 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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Appendix I: Calibration

The sensitivity of the CPODs and FPODs was calibrated by the manufacturer (Chelonia Ltd.) before shipping to Wageningen Marine Research. To check the sensitivity of each device, it is rotated in a sound field and adjusted to give a radially averaged, temperature corrected, sound pressure reading within 5 % of the standard at 130 kHz (±0.5 dB). The National Physical Laboratory in the United Kingdom performed the calibration. Only PODs that have a radial variation < ±3 dB relative to the mean sensitivity are used. On top of the manufacturer's calibration, all CPODs were recalibrated in the accredited German Meeresmuseum in Stralsund after several deployments since the HPNB project started in 2019. FPODs have not been recalibrated yet by the Meeresmuseum, since they have only been deployed as recent as 2022. The CPODs were tested in a test tank to estimate the variation in sensitivity, using calibrated hydrophones as receiver and transmitter. The transmitter sent out acoustic signals at different frequencies that were measured by a calibrated hydrophone. This hydrophone was then replaced by a CPOD for sound exposure to the same calibration signals. The same procedure was repeated on four different positions along the PODs horizontal axis in order to measure directional variation. The sensitivity of a CPOD is compared to the received levels and mean peak-to-peak pressures (Ppp) of the calibrated hydrophones. Detection thresholds and the relationship between receiving level and the corresponding Ppp-values for each CPOD were calculated with two methods: 50 % detection thresholds and linear regression models. Details of these calculations and the calibration method can be found in Verfuß *et al*. (2010).

For the calibrations, the received levels of mean peak-to-peak pressures (Ppp) emitted frequencies of 100, 110, 120, 130 and 140 kHz are examined for each individual CPOD. Since the main part of the energy of a porpoise click is around 132 kHz the differences at 130 kHz are the most applicable for comparison. The highest variation in peak-to-peak pressure at 130 kHz lies between 110 and 120 dB re µ1Pa for most PODS. This difference in peak-to-peak pressure corresponds to a difference in received sound level of less than 3 dB. Three CPODs (1884, 1744 & 1549) had Ppp-levels above 120 dB re µ1Pa, corresponding to a difference in received sound level of less than 5 dB. The results of the calibrations showed that all CPODs were operating within the maximum accepted variation recommended by the international AMPOD-project (Verfuß *et al*., 2010).

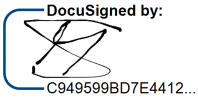
Justification

Report C087/24
Project Number: 4312100136

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: dr. Meike Scheidat
Scientific researcher

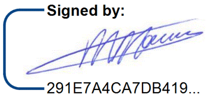
Signature:



Date: 10 December 2024

Approved: Dr. A.M. Mouissie
Business Manager Projects

Signature:



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With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

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