DETECTION FUNCTION USING SIMULTANEOUS DRONE VIDEOS AND ACOUSTIC RECORDINGS

Scientific Report from DCE – Danish Centre for Environment and Energy No. 566 2023

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Data sheet

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Abstract: Passive acoustic monitoring (PAM) can be used to estimate density of wide-ranging species, like the harbour porpoise. The probability of detection as a function of distance, the so-called detection function must be known. Here, we combined drone footage with acoustic recorders to estimate the detection function using a standalone application fine-tuned to track wild porpoises.

Keywords: Harbour porpoise, passive acoustic monitoring, abundance, distance sampling

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Contents

Preface

This report describes progress towards establishing a detection function for passive acoustic dataloggers (SoundTraps and F-PODs), as an important requirement for obtaining an abundance estimate for harbour porpoises in the Baltic Proper (SAMBAH II). This study was carried out for the Danish Environmental Protection Agency (EPA), by Aarhus University, Section for Marine Mammal Research. The project is a fortuitous expansion to the PAL project, funded by the German Agency for Nature Protection (BfN) and conducted in a cooperation between Aarhus University and Deutsches Meeresmuseum. The objective of the PAL project is field-testing of an acoustic alarm for gillnets to reduce porpoise bycatch and was tested in coastal waters off Fyns Hoved in the summer of 2022. For that purpose, porpoises were tracked both acoustically – by SoundTraps and F-PODs, and visually – by drones. This type of data, however, is also ideal for establishing the detection function and the analysis of the data with that objective was made possible by additional funding by the Danish EPA.

Michael Dähne, from the Deutsches Meeresmuseum, coordinated data collection and organisation and developed the first version of the analytical tool used in this study. We thank all the observers in the fieldwork for their devoted assistance: Ann-Kristin Craul, Benedikt Rakotonirina-Hess, Bianka Knoll, Caroline Aillaud, Charlie Hamblin, Christian von Dorrien, Ciska Bakkeren, Daniel Stepputtis, Ella Meissner, Farina Reif, Julie Sofie Larsen, Kat Morin, Leon Rostock, Madeleine Berglund, Marco Warmuth, Ole Meyer-Klaeden, Sophie Tuchscherer, Thaya Dinkel, Thomas Noack, Tom Bär, Ulf Böttcher, Vivian Fischbach, and William Calow.

Sammenfatning

Marsvin (*Phocoena phocoena*) i Den indre Østersø er kritisk truet, hvilket stiller krav om overvågning som grundlag for forvaltningen af bestanden. Passiv akustisk overvågning med dataloggere gør det muligt at foretage langtidsovervågning og fra hyppigheden af detektioner på de enkelte stationer kan det samlede antal marsvin estimeres. For at gøre dette kræves det at man kender sandsynligheden for at registrere marsvins signaler i forskellig afstand fra måleudstyret, den såkaldte detektionsfunktion. I dette studie estimerede vi detektionsfunktionen for to type detektorer (SoundTrap og FPOD) ved at følge marsvin i nærheden af dataloggerne på optagelser fra en drone. Ved hjælp af til lejligheden udviklet software kunne marsvinenes geografiske position bestemmes løbende gennem videooptagelserne og dermed kunne afstanden til måleudstyret også bestemmes og sammenholdes med de akustiske registreringer. I alt 600 video-optagelser blev set igennem, 19 analyseret i detaljer og i alt 26 begivenheder, hvor marsvin kom tilstrækkeligt tæt på måleudstyret blev dokumenteret. Fra optagelserne blev det kvantificeret hvornår og ved hvilken afstand marsvin blev optaget, hvilket blev brugt til at beregne to detektionsfunktioner. Marsvinene var mellem 1.1 m og 519 m fra måleudstyret under optagelserne og den maksimale detektionsafstand var 105 m. FPOD'en viste sig mindre følsom end Soundtrapen og der var ikke tilstrækkeligt med detektioner til en robust bestemmelse af detektionsfunktionen for dette instrument.

Summary

The harbour porpoise (*Phocoena phocoena*) population in the Baltic Proper is red-listed as Critically Endangered. The use of passive acoustic monitoring (PAM) with underwater recorders allows for the estimation of detection rates, from which density can be derived. For density estimates, the probability of detection as a function of distance, the so-called detection function must be known. Here, we used drone footage to estimate the detection function of two acoustic recorders (SoundTrap and F-PODs). Two comparisons were made: SoundTrap vs F-POD in the same location, and F-POD vs F-POD 60 m from each other. A standalone application was fine-tuned to track porpoises from drone footage and estimate their geographic location. With this, the distance to the recorder was estimated throughout the track. Over 600 videos were screened, 19 analysed, and 26 tracks identified. From the recordings porpoise detections were identified within the periods with porpoise tracks and the distance to the recorders calculated. The animals were between 1.1 m and 519 m from a given recorder during tracking events, with a maximum detection range of just over 105m for both devices. The FPOD turned out to be significantly less sensitive than the SoundTrap and the performance of individual devices seems to be different.

1 Background

The harbour porpoise (*Phocoena phocoena*) is an abundant species in the North East Atlantic, especially in the Danish straits. In the Baltic Proper, however, the local population is red-listed as Critically Endangered with an estimated population size of only a few hundred animals (Amundin et al., 2022). Due to their small size and cryptic behaviour, porpoises are difficult to monitor using visual methods, especially in low-density areas such as the Baltic Proper. On the other hand, passive acoustic monitoring (PAM) using underwater recorders that can be deployed for long periods are optimal for porpoises, which are very vocal and produce highly stereotyped sounds well suited for automatic detection.

The use of PAM allows for the estimation of detection rates, quantified as for example as number of click-positive seconds per hour of monitoring. For density estimates, the probability of detecting a porpoise in a given second should be estimated first, specifically, the probability of detection as a function of distance, the so-called detection function. With this detection function, it is possible to estimate the surveyed area around the PAM device and ultimately, when combined with information about click rate (how often porpoises produce clicks), estimate the absolute density of porpoises. The detection function is crucial for monitoring the Baltic Proper harbour porpoise population, aiding in the completion of most actions proposed in the SAMBAH II project.

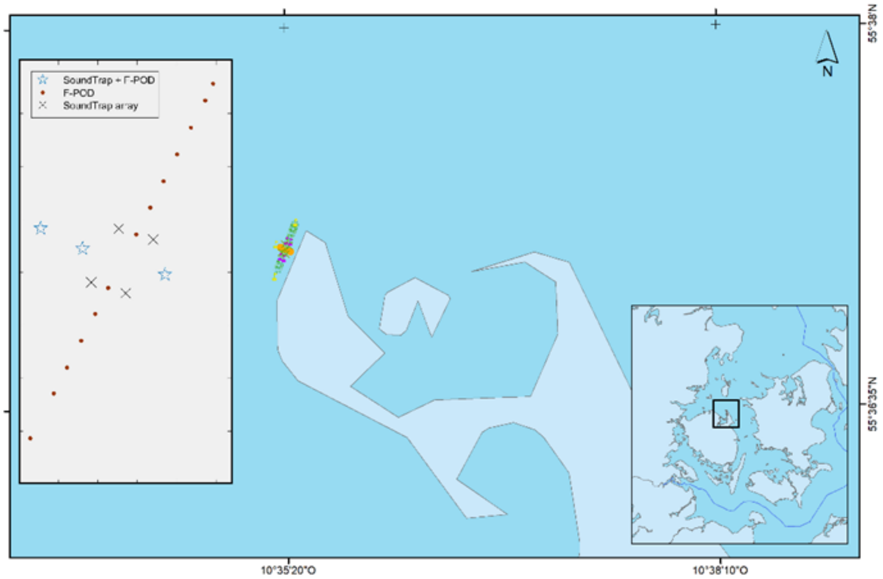
There are several ways to estimate the detection function. The most direct and accurate method is to measure the detection probability at different distances by tracking the location of an animal within a monitored area and determine for each second whether clicks were detected by the PAM device or not (Kyhn et al., 2012; Marques et al., 2013). The development of drones opened the possibility of tracking porpoises in fine scale in ways that were not possible before. This also means that the detection function can be estimated when the track can be combined with simultaneous audio recordings.

Objectives

The aim of this study was to derive accurate detection functions (probability of detection as a function of distance) for porpoises that can subsequently be used in the Baltic Sea and other waters to convert the acoustic activity (porpoise clicks per time unit) into an absolute number of porpoises per area. The detection function was estimated for one SoundTrap (Ocean Instruments, NZ) and two F-PODs (Chelonia Ltd, UK) using simultaneous drone footage and audio recordings.

2 Data collection

Simultaneous acoustic recordings and drone footage were collected from Fyns Hoved (55° 37' 09.1" N, 10° 35' 26.3" E) during the summer of 2022, as part of an ongoing project led by researchers from the German Oceanographic Museum (Deutsches Meeresmuseum). A total of 26 acoustic devices were deployed (Figure 2.1) in the area, including nine wideband recorders and 17 data loggers. The recorders used were SoundTrap 600 HF, SoundTrap 300 HF, and SoundTrap 4300 HF (Oceans Instruments, New Zealand). The first two types are single channel recorders, whereas the ST4300 is a multi-channel recorder used with an array of four hydrophones. All the data loggers were F-PODs (Chelonia Ltd, UK).



Figur 2.1. Map of the study area showing the location of the acoustic devices. The two devices (SoundTrap and F-POD) located on the area marked by the western blue star were used here.

In this study, three devices were used, to carry out two comparisons:

- Between a SoundTrap 300 HF and an F-POD deployed in the same location ('Gillnet west'), middle blue star in Fig. 2.1.

- Between two F-PODs deployed 60 m from each other ('Gillnet west' and 'Gillnet east'), eastern blue star in Fig. 2.1.

The SoundTrap was deployed nine times during the fieldwork season, recording continuously at a sampling frequency of 576 kHz. Each deployment lasted between 2 and 6 days. The F-PODs were deployed once, on the 22 of June (marking the beginning of the fieldwork season), until the 28 of August (marking the end of the fieldwork season).

Porpoises were followed using two MINI 2 (DJI, China) drones. Follows lasted for as long as possible, and the observation was terminated if the animal was lost because it went out of view or because it was necessary to return the drone to land to change batteries.

3 Data analysis

3.1 Data selection

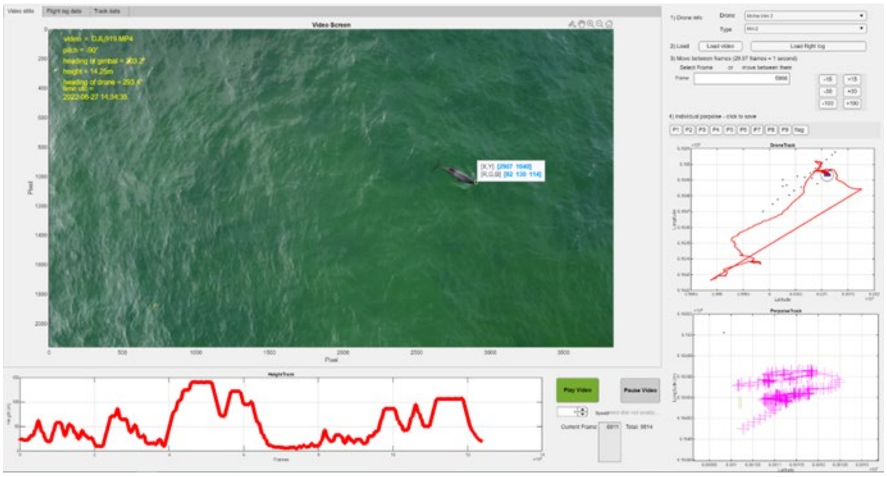
Because the data were collected during an experimental set-up to test the effect of a noise producing device (PAL) on the acoustic behaviour of harbour porpoises, only time periods where the PAL was off were used. Next, drone videos from those periods were screened to determine whether they could be used for the objectives of this study. The criteria used were:

- Only one animal in the area or a mother-calf pair moving together
- Visibility sufficient for tracking the porpoise also while underwater
- The drone actively followed the animal as it moved, rather than recording from a fixed position
- The porpoise was followed for at least 1 minute

While it was not possible to determine with certainty whether there was another animal present at a shorter distance from the recorder during a tracking event, the risk of incorrect detection at a given distance is reduced by analysing data in "snap-shots" of short duration. In this case, in bins of 1, 5, and 20 seconds.

3.2 Porpoise tracking

A dedicated software, Porpoise Tracker, was developed, specifically to estimate geographical coordinates of objects in drone footage. The algorithms use the data logged by the drone during flight: date, time, latitude, longitude, and height of the drone, direction and gimbal orientation of the camera, and number of pixels of the image (Figure 3.1).



Figur 3.1. Main display of the software used to estimate latitude and longitude of the porpoises. Main image: porpoise being tracked (text in yellow include name of video, height of the drone, and other relevant information). Right panel: options the user can select, including drone type, video to analyse, and how to move between video frames. The top graph shows the location of the recorders and the flight path of the drone. The bottom graph shows the position of the porpoise that is being tracked. Bottom panel: the graph shows the height of the drone over the flight path. To the right of the graph, the user can play or pause the video.

During the development of the software, we found unexpected and unforeseen difficulties, direct consequences of how the drones log data. The main issue for MINI 2 drones is the mismatch between the time information in the flight log of the drones and the time information in the videos. Specifically, in the flight logs generated by the drone, the time stamp of the beginning of a video recording does not match the time stamp in the video itself. The video, on the other hand, includes metadata (in the form of subtitles without a time stamp) generated every second with data from the flight logs (e.g., latitude, longitude, number of satellites used, and height). Therefore, here, we used the subtitles to match the flight log and the video frames.

The accuracy is currently within 0.5 seconds but work is underway to improve it. This, however, does not seem to be a problem in other drone models, as they generate subtitles as independent files, at smaller time intervals, and include a time stamp.

In this process, we also added new functionalities that can help us better understand porpoise behaviour (e.g., when the animal is at the surface to estimate breathing rates) as well as to understand the factors impacting detections (e.g., the direction of the animal with respect to the recorder).

Porpoises were tracked manually using the Porpoise Tracker, logging one position every 0.5s or 1s during the entire follow, depending on visibility.

The Euclidian distance between the porpoise's head (Figure 3.1) and the recorder, estimated in metres, was added to each point of the track.

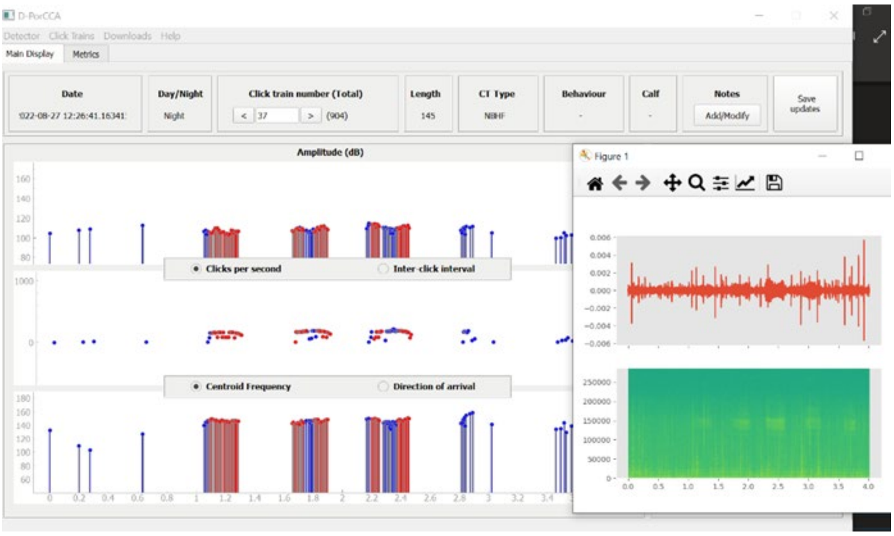
3.3 Acoustic recordings

Two devices were used to detect harbour porpoises acoustically. These devices have fundamentally different approaches to this goal. While the SoundTrap records the sounds themselves (by means of a hydrophone and an analogue-to-digital converter), the F-PODs instead stores metadata of the detected sounds, including date, time, and duration of the acoustic pulse. Because of this, the methods used to analyse the data from the two instruments were different.

3.3.1 SoundTrap

Acoustic recordings made with the SoundTrap were analysed using D-PorCCA, a recent analytical tool developed specifically to analyse porpoise sounds. It includes a transient sound detector (D. M. Gillespie et al., 2008; Parcerisas, 2021) to identify potential porpoise sounds, a porpoise click classifier (PorCC, Cosentino et al., 2019) to classify between porpoise and no-porpoise sounds, and a click train detector (Cosentino, 2020). The click train detector groups porpoise clicks into "trains", which are then classified as either high or low-quality porpoise click trains.

Figure 3.2. Main display of D-PorCCA showing information (amplitude, repetition rates, etc) of click trains emitted by one of the tracked porpoises. Bottom right: spectrogram of the click trains.



3.3.2 F-PODs

The F-POD data were analysed using a software provided by the manufacturer (fpod.exe). The raw data were classified using the KERNO classifier within the software, using the default values. The KERNO algorithm is proprietary, but it is known that it uses spectral and temporal characteristics of the clicks. These include peak frequency, duration, and number of peaks in the waveform.

The output of the KERNO classifier includes NBHF (porpoise) click trains, as well as other cetaceans, sonar, and trains of unknown origin. Porpoise click trains are further classified into four quality categories: high, moderate, low, and doubtful. Here, we used the first three categories, extracting the number of clicks per second of each category.

3.4 Synchronisation of the data

Both the track and acoustic data were organised in bins of different durations: 1s, 5s, and 20s 2-sec bins, and the resulting dataset includes the distance of the animal to the recorder(s) at any given time period as well as whether porpoises were detected in each bin. When more than one measurement was made per bin per individual, the mean distance to the recorder was used.

This allowed for the synchronisation of the detection and distance data. The final dataset, therefore, consisted of detections/no detections at all estimated distances.

3.5 Detection function

The detection functions were estimated using generalised linear models with a binomial distribution, with distance to the recorder as the only explanatory variable, detection/no detection as the response variable, and a logit link function. This model has already been shown to be appropriate to estimate the probability of detection as a function of distance to passive acoustic recorders (Kyhn et al., 2012).

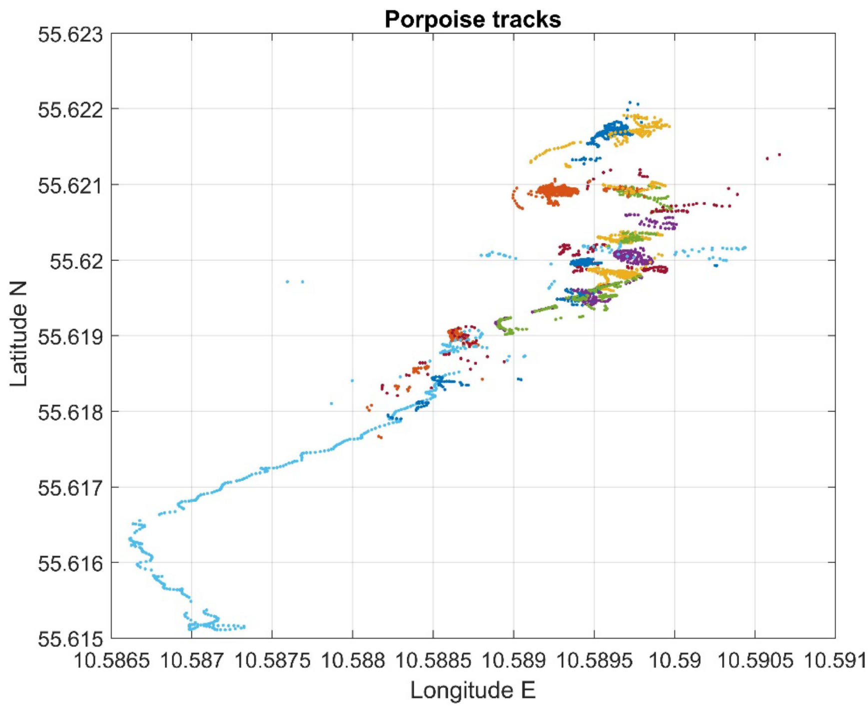
4 Results

Over 600 videos were screened to check whether they followed the criteria set for the objective of this study. Of these, 33 were pre-selected and 19 were analysed. These were recorded on the 30th of June, and the 22nd, 26th, 27th, and 28th of August 2022.

4.1 Porpoise tracks

A first version of the Porpoise Tracker is available for download here. The programme will be presented publicly via a manuscript to make it available to a wider audience in the future.

Videos where the animal(s) was tracked for less than 1 min were discarded. Porpoises were tracked between 1 and 3 minutes. The minimum distance of a tracked animal to a recorder used here was 1.1 m ('Gillnet east') and the maximum was 519 m ('Gillnet west'). All tracks are shown in Figure 4.1.



Figur 4.1. Porpoise tracks (total of 26 tracks, containing 2988 data points, representing in total approximately 39 minutes of data).

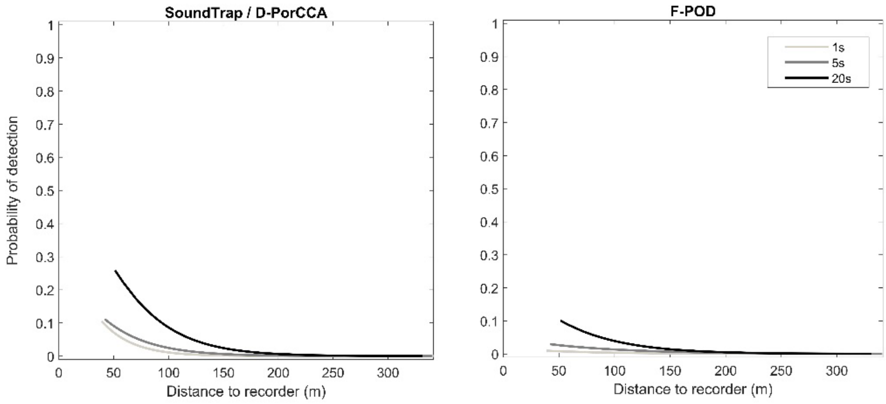
4.2 Detection function

A total of 2988 track data points were used in this study, obtained from 26 tracks of individual porpoises (including 3 cases of mother-calf pairs, tracked independently, while travelling next to each other). The same tracks were used to develop the detection functions of all three devices as the animals move in the vicinity of all of them.

The probability of detecting porpoises decreased with distance to the recorder, as expected, for all devices. Moreover, the probability of detecting a porpoise at a given distance increased when the data were grouped in periods of greater duration, as shown in Figure 4.2 and 4.4.

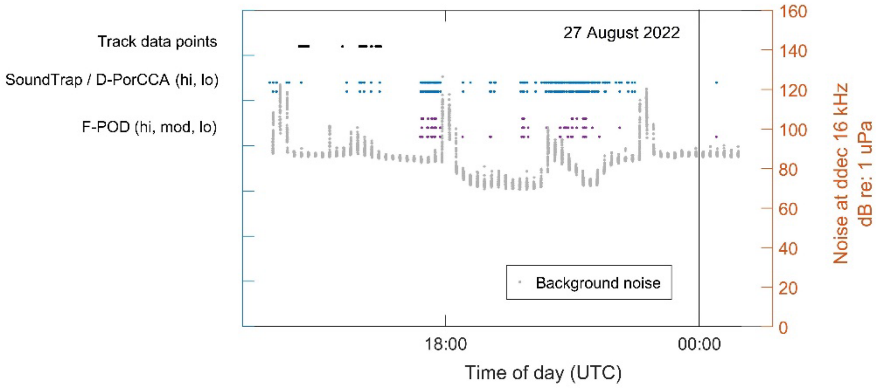
4.2.1 SoundTrap vs F-POD (Gillnet west)

The SoundTrap had more detections than the F-POD (Figure 4.2) in all bins. While the function suggest that a zero probability of detection is reached at about 200 m from the recorders, the maximum distance where a detection occur for either device was just over 105 m.



Figur 4.2. Detection function for an F-POD and a SoundTrap in the same location, estimated using 1-sec bins. Note the scale on the left panel is smaller than on the right panel.

The flat detection function for the F-POD in 1s bins led to investigate whether the device had malfunction. Preliminary analysis showed that this F-POD did detect porpoises during the deployment period, including periods before and after track periods for which no detections were made. An example is shown in Figure 4.3. Moreover, when comparing detections over time, these overlap rather well, although the SoundTrap has more detections during tracking.

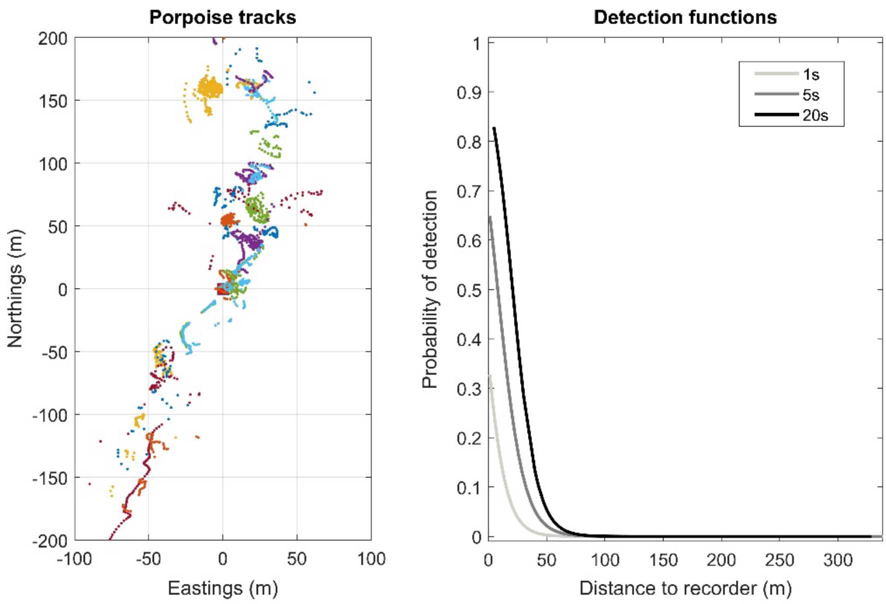


Figur 4.3. Example of detections over time of the SoundTrap and an F-POD deployed in Gillnet west.

4.2.2 F-PODs

When comparing the detection probabilities of the two F-PODs, located 60 m from each other, it is immediately clear that their performance is not the same. While the F-POD deployed at 'Gillnet west' had a probability of detecting porpoises below 10% regardless of the bin size, the F-POD in Gillnet east, reached over 80% probability of detection at short distances. On the other hand, the maximum detection distance for this device was 80m.

Figure 4.4. Detection functions of the F-POD at 'Gillnet east' (at [0,0] on the image on the left) using different bin sizes (image on the right).



5 Discussion

Despite the unforeseen difficulties we found along the way, we have shown that it is possible to use drone data to estimate the detection function of two passive acoustic monitoring devices. With these, it is possible to estimate absolute abundance of porpoises (Kyhn et al., 2012; Marques et al., 2009).

The detection function for the SoundTrap here is similar to what has been estimated in the past for other devices (T-PODs, Kyhn et al., 2012; C-PODs Amundin et al., 2022). The maximum modelled detection distance appears to be around 200m, but the probability is higher at closer distances, with up to 60 times higher than estimated for C-PODs during daytime (Amundin et al., 2022).

The detection function for the F-PODs varied significantly between devices, with one remaining below 10% regardless of the bin size used (i.e., 1s, 5s, 20s) time windows, while the other reached over 80%. This result is unexpected as previous studies with C-PODs (Chelonia Ltd), the predecessor of F-PODs have been used successfully to monitor porpoises (Carstensen et al., 2006; D. Gillespie et al., 2005; Verfuß et al., 2007) and other species that emit similar sounds around the world (Clay et al., 2018; Leeney et al., 2011). Furthermore, the C-POD has been instrumental in the monitoring of harbour porpoises in the Baltic Sea through SAMBAH, allowing for density estimates (Amundin et al., 2022; Carlén et al., 2018). On the other hand, estimated detection functions showed low probability of detections even at short distances during day time, with around 0.0001, and a maximum of 0.025 during night time (Amundin et al., 2022).

It is expected that two instruments developed by different manufacturers perform differently, however, it is yet to be understood which factors lead to varying performance for the same device. C-PODs are known to be more conservative than continuous recorders, yet F-PODs are expected to outperform them. Here, the SoundTrap was more sensitive compared to the F-POD deployed in the same location, while the two F-PODs separated from each other by 60m had a widely different result.

The difference between the two F-PODs may be explained by the fact that the tracked porpoises were closer to Gillnet east than to Gillnet west, providing more detail information about detections at closer distances. However, the instrument at Gillnet west also underperformed when comparing it against the SoundTrap deployed next to it.

We compared the overall detections during part of the deployment and there are overlaps between SoundTrap and F-POD. Further analysis and comparison of other devices also placed next to each other are needed to better understand the varied detection probabilities of the devices analysed here.

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DETECTION FUNCTION USING SIMULTANEOUS DRONE VIDEOS AND ACOUSTIC RECORDINGS

Passive acoustic monitoring (PAM) can be used to estimate density of wide-ranging species, like the harbour porpoise. The probability of detection as a function of distance, the so-called detection function must be known. Here, we combined drone footage with acoustic recorders to estimate the detection function using a standalone application fine-tuned to track wild porpoises.

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