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Comparing the performance of C-PODs and SoundTrap/PAMGUARD in detecting the acoustic activity of harbor porpoises (*Phocoena phocoena*)

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The C-POD logger is a widely used instrument for passive acoustic monitoring of harbor porpoises, but the absence of a continuous recording in this device makes it difficult to verify its performance. An alternative but more labor-intensive approach is to use a wideband sound recorder and off-line detection software. Here we compare the performance of the C-POD with that of a HF SoundTrap recorder analysed with PAMGUARD software. Seven deployments were made with C-PODs and SoundTraps in the Danish Great and Little Belts between June and November, 2015. There was a positive but generally poor correlation between PAMGUARD and C-POD detections, with the C-PODs detecting only about 21-94% of the click trains detected by PAMGUARD based on the broadband recordings. The main explanation behind this poor correspondence is likely that PAMGUARD performs classification on single clicks, whereas the C-POD classifies groups of clicks ('trains') collectively. Such poor correlation between two common methods can have severe implications for conclusions reached in effect and abundance studies.

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1. INTRODUCTION

Passive acoustic monitoring (PAM) is used extensively for monitoring the distribution of cetaceans, measuring their density or acoustic activity and for assessing the impact of human disturbances (Zimmer, 2011). A widely-used acoustic detector for harbor porpoises (*Phocoena phocoena*) is the C-POD (Cetacean – Porpoise Detector, Chelonia Limited, UK). This devise has a passband from 20-160 kHz and detects cetaceans by classifying groups of potential echolocation signals (‘trains’) based on the intensity, duration and frequency content as well as the variation in inter-click intervals. Further data analysis is performed by the proprietary software CPOD.exe where the click trains are assigned by the KERNO classifier as originating from dolphins, porpoises or other echolocating cetaceans. CPOD.exe offers a choice of different classification filters (‘quality-classes’), each with their own detection threshold (Tregenza, 2014) but little information is available on how this software operates.

Another approach to PAM is to record sound continuously with an acoustic logger and then analyze the recordings after recovering the device with software such as PAMGUARD (Scottish Oceans Institute, Scotland), which detects and classifies marine mammal vocalizations using open-source algorithms. Here we used SoundTrap ST202HF (Ocean Instruments, New Zealand) as the acoustic logger. This device can record acoustic signals with a bandwidth of 20 Hz – 150 kHz for several days, using a 576 kHz sampling rate. The recordings were subsequently analyzed in PAMGUARD to detect porpoise clicks. This program detects potential porpoise clicks based on a comparison of energy in a narrow target band to two reference bands (Gillespie and Chappell, 2002).

In acoustic studies of porpoises and other cetaceans it is important to understand how results derived by such different analysis tools can be compared. This study compared the performance of the C-POD and SoundTrap/PAMGUARD in locations with frequent porpoise encounters. The overall objective of the study was to evaluate the effect of shipping noise on porpoise presence. Here we report on the first phase of the project in which we evaluate and compare the detection performance of the deployed devices.

2. METHODS

A. DATA COLLECTIONS

Recordings of acoustic activity of porpoises were made in the Danish Great Belt and Little Belt. Both locations are described as high-density areas for porpoises (Sveegaard et al., 2011). Moreover, they are characterized by a high number of ships passing through the straits. This is particularly the case for the Great Belt where the deep-water route into the Baltic (‘Route T’) is situated. With about 27,000 vessels passing every year, the Route T is one of the most intensively trafficked shipping lanes in the world. The deployments in the Great Belt were approximately 1 km from Route T. There is also a high level of ship traffic in the Little Belt, primarily coasters as well as a large number of pleasure boats. Here the data logger was situated about 500 m from the major shipping lane. The deployment depth at both locations was about 30 meters.

The recording setup varied somewhat between deployments, but contained an anchor, an acoustic release unit (Sonardyne, UK), a submerged buoy (trawl float), a SoundTrap and a C-POD (Figure 1).

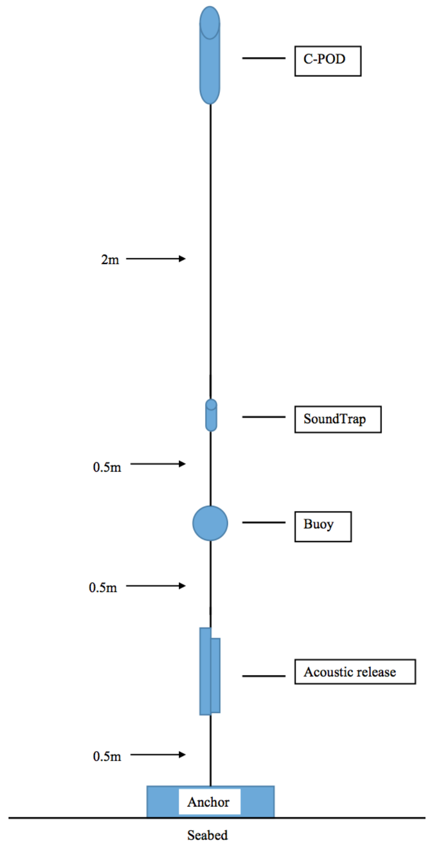

Figure 1. Schematic outline of the setup.

A total of seven deployments (named B, C, D, E, F, G and H) were made between June and November 2015: five in the Great Belt and two in the Little Belt. Each deployment lasted between 11 and 69 hours.

B. DATA ANALYSIS

Pairs of recordings were obtained from each of the deployments, consisting of one data file from the C-POD and one broad band recording from the SoundTrap.

- C-POD data

The signals detected by the C-POD are classified by the associated the software CPOD.exe (Chelonia, Ltd.) according to their frequency content, duration, amplitude and other parameters. The peak frequency of clicks, their bandwidth and other spectral parameters are determined by an analysis of zero crossings by the C-POD electronics. The C-POD thus does not store the actual acoustic signals, but stores the time stamp of each detected click as well as the duration, frequency content, amplitude etc. of each click in a data file. This data file is further analyzed by the CPOD.exe software, by means of the KERNO classifier. For click trains consisting of clicks with similar characteristics as those of harbor porpoises, the inter-click intervals within trains are used to assess the likelihood that the click train originated from a porpoise. This classification, based on trains of clicks and not individual clicks require at least five clicks per train. All clusters of clicks closely spaced in time with four clicks or less are thus left unclassified.

Each C-POD data set was analyzed by means of three different standard filter settings of the KERNO classifier. These detections were compared with the PAMGUARD detections derived from the broadband SoundTrap recordings. The three filters of the C-POD are referred to as 'High' ('Hi'), 'Moderate' ('Mod') and 'Low' ('Lo'). There is at present no information available on the design of these three filters from the manufacturer, but from the C-POD manual it is known that they reflect the likelihood that the click trains are from porpoises. The 'High' quality filter is the most restrictive filter and should thus result in the smallest number of false positive detections.

From each data file the number of porpoise clicks per minute (CPM) was extracted using each of the three filters. A moving average of 10 min were made of the CPM data before exporting it for further analysis.

- SoundTrap data

Detection of porpoise clicks from the SoundTrap was done in the PAMGUARD software. The standard settings from the PAMGUARD website (the so-called 'general configuration file – porpoise click detection') were used. This includes a pre filter (4th order digital Butterworth IIR 10 kHz high pass filter) and a trigger filter (4th order digital Chebyshev IIR 100-150 kHz band pass filter, pass band ripple 2.0). Click classification is made by comparing the 110-150 kHz test band to control bands at 40-90 kHz and 160-190 kHz, with a threshold of 6 dB. Parameter extraction was restricted to 256 samples.

The data from PAMGUARD were converted to clicks per minute (CPM) by a custom-written Matlab (Mathworks, Inc.) program, defining CPM as the number of porpoise clicks per minute. Just as the C-POD data, a moving average of 10 min were applied to the CPM data of PAMGUARD.

3. RESULTS

The detection of porpoise clicks, quantified by the number of clicks per minute, differed greatly between the C-PODs and PAMGUARD. The C-PODs recorded notably less clicks per minute than PAMGUARD, but with large differences between deployments and among filters. With the 'Hi' filter in Deployment G, the C-POD reported click counts that were only 4% of the click counts from PAMGUARD, whereas there was only a difference of 6% in deployment D with the C-POD 'Hi'+'Mod'+'Lo' filter. The mean ratio of click detections in the C-PODs and the click detections in PAMGUARD were 77%, 50% and 43% for 'Hi', 'Hi'+'Mod' and 'Hi'+'Mod'+'Lo', respectively.

Correlations between clicks per minute recorded by the C-POD and PAMGUARD were performed for all non-zero values, i.e. all minutes in at least one of the systems detected clicks. Double-zeros (no detections, neither on C-POD, nor on PAMGUARD) were removed from the analysis. In this way we could investigate how well detection counts on the C-POD correlated with detections in PAMGUARD. The results showed for 35 out of 36 cases a significant correlation between clicks per minute detected by the C-POD and PAMGUARD. Only in Deployment F, with one of the C-PODs using the 'Hi'+'Mod' filter, was there no significant correlation between detections by the C-POD and PAMGUARD.

The 'Hi'+'Mod'+'Lo' filter in the C-POD had the highest correlation with PAMGUARD among all deployments (r^2 between 0.03 and 0.76, and $r^2 \geq 0.4$ in 9 of 12 data sets; see Figure 2 for examples). The slope of the regression line with this filter ranged from 0.02 to 0.10. A slope of 0.1 indicates that for minutes where the C-POD detected porpoise clicks it detected 10% of the clicks reported by PAMGUARD.

The detections of the C-PODs with ‘Hi’ and ‘Hi’+‘Mod’ filters correlated with PAMGUARD detections to a very variable degree. The r^2 ranged between 0.002 and 0.73 and was ≥0.4 in 12 out of 24 data sets. The slopes of regression lines were small, ranging from slightly negative (-0.006) to 0.08, with 95% confidence intervals ranged from -0.02 to 0.07 and from 0.004 to 0.08.

The mean slope of the linear regression for the three filters was 0.01, 0.03 and 0.05, for ‘Hi’, ‘Hi’+’Mod’ and ‘Hi’+’Mod’+’Lo’, respectively.

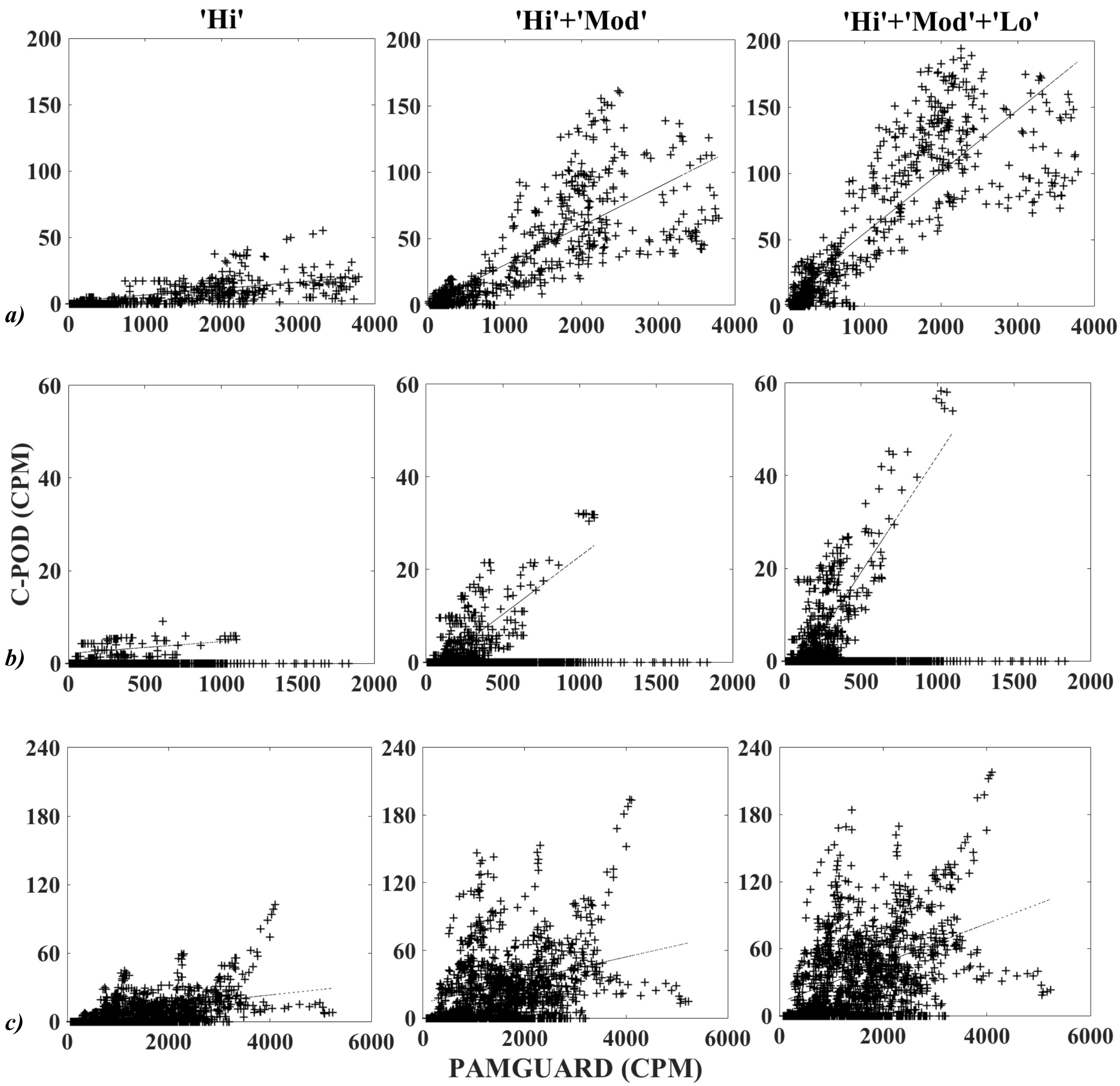

Figure 2. Comparison of clicks per minute detected by C-POD and PAMGUARD within three representative deployments: a) Little Belt, b-c) Great Belt. Clicks per minute were averaged over 10 minutes.

4. DISCUSSION

In this study, the detections of C-PODs were compared with detections by PAMGUARD from full bandwidth recordings. C-PODs reported much lower click counts than did PAMGUARD, irrespective of the filter settings of the CPOD.exe analysis software. This lower detection by the C-POD was expected, due to their different modes of operation and classification. CPOD.exe classifies clicks group-wise, based not only on parameters of the individual clicks, but also on patterns in the inter-click intervals, which is likely to be a much more restrictive classification than the classification of PAMGUARD, which is performed strictly click by click. Furthermore, the fact that all trains of four clicks or less are ignored in C-POD analysis further brings detection rate down, compared to PAMGUARD. It is thus also expected that the slope of the correlation is lowest for the most restrictive filter of the C-POD ('Hi') and highest for the least restrictive ('Hi'+'Mod'+'Lo'). The fact that the slopes in all cases are significantly less than unity is not reason for concern, as it only means that, for whatever reason(s), the sensitivity of the SoundTrap and PAMGUARD combination is higher than that of the C-POD. The low detection rate of the C-POD is thus in itself not an indication of poorer performance, rather the consequence of different design objectives.

What is worrying, however, is that the correlation between PAMGUARD and C-POD detections is extremely variable and sometimes very weak to absent. As the C-POD and SoundTrap were positioned close to each other they should have been exposed to almost exactly the same number of porpoise clicks and one should expect a robust correlation between the two detectors, but this was not the case. In some cases, such as the example in figure 2a, the overall correlation was good for all three filters, whereas in other cases, such as the example in figure 2c, the correlation was very weak. Intermediate forms were also seen, such as the example in figure 2b, where the majority of data points correlate well between the two systems, but where there nevertheless were a large number of minutes where many clicks were reported by the PAMGUARD, but zero clicks reported by the CPOD.exe software.

The deployments encompassed highly variable noise conditions as ship traffic passed by the moorings. Although the close juxtaposition of the C-PODs and SoundTraps on the moorings ensured that both devices would experience the same noise levels, the detection methods employed by each device may respond differently to fluctuating noise levels. Especially the zero-crossing analysis performed by the C-POD would be expected to be negatively affected by deterioration in the signal to noise ratio. This will be examined in a follow-on study.

Similar results to the above have been found in other studies, albeit on bottlenose dolphins. Roberts and Read (2014) observed conservative performance by C-POD in the detection of dolphins and Hansen (2011) used C-PODs to detect bottlenose dolphins together with T-PODs (a predecessor of the C-POD) and showed that the C-POD detected more clicks than the T-POD but 50 % less than a broadband hydrophone.

Another problem highlighted by this data is that when there are only a few animals in the study area, it is more likely that the C-POD will report no porpoises in the area (detection rate of zero) as compared to PAMGUARD. This may have large implications for abundance estimates and anthropogenic effect studies in such areas and may therefore affect conservations measures.

More work is needed to determine why the C-POD and SoundTrap detectors give such different and highly variable results. One possibility is that the performance of the detectors is affected by ambient noise in different ways. The performance of any detector not limited by self-noise will depend on the background noise level, but in that respect the two detectors are very different: PAMGUARD compares energy in narrow-band filters whereas the C-POD bases detection on a zero-crossing algorithm. Therefore they might be expected to be affected by ambient noise in different ways. As the dominant noise source in both locations was ship noise this relationship is important to elucidate, as it could have major implications on understanding whether ship passes impact porpoise populations.

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