Agenda Item 6.1 Project Funding through ASCOBANS

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Project Report: Enhanced detection of harbour porpoises prior to ramming, seismic blasts and ammunition clearance: design and construction of a PAL-porpoise detector (PPD)

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Work Report

Enhanced detection of harbour porpoises prior to ramming, seismic blasts and ammunition clearance:
design and construction of a PAL-porpoise detector (PPD)

Title **Work Report**: Enhanced detection of harbour porpoises prior to ramming, seismic blasts and ammunition clearance: design and construction of a PAL-Porpoise Detector (PPD)		**Justification:**	**Project ID:** CMS/ASCOBANS **BAL 2201**
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Introduction	**We are grateful for support by ASCOBANS for design, construction and tests of a novel prototype PAL harbour porpoise detector (PPD). Within this project, we thoroughly tested a precursor analogue detector and used the results for design and laboratory tests of a novel, real-time radio-operated porpoise detector.** Detection of harbour porpoises within a large radius is of great importance prior to the onset of activities with intensive acoustic hazard such as ammunition clearance, seismic exploration or pile-ramming, currently threatening small cetaceans world wide (Culik, 2011). The German Hydrographic Service (Bundesamt für Seeschiffahrt und Hydrographie, BSH) has limited man-made emissions within 750 m of a marine sound source at 160 dB SEL or 190 dB (peak to peak). However, peak pressures during submarine explosions of charges with a mass of 10 kg reach levels above 190 dB within a 15 km radius. Full-scale seismic arrays generate peak-peak source levels of 259 dB and received levels of more than 190 dB within 1 km (Richardson et al. 1995). Finally, pile-ramming during construction of offshore wind parks generates sound exposure levels above 160 dB within the 750 m radius for all pile diameters above 1,5 m. In order to avoid negative impacts or injury to marine mammals, real-		

	time detection within the exposure radius prior to the beginning of sound emissions is crucial. This would enable operators to postpone planned measures or to adopt adequate measures to exclude the animals from hazardous areas. Harbour porpoise detection by observers on airplanes or ships, or via autonomous, archival acoustic detectors such as C-PODs (Chelonia, UK) is frought with low detection ranges and probabilities: As quantified via g(0), the detection probability from aircraft is only 0.079 – 0.292, depending on the experience of the observers (Laake et al. 1997). Ship-based detection probability is between 0.7- 0,8 during extraordinarily (and rarely met) good weather (sea state < 1.5; Reay, 2005), with detection probabilities decreasing from 0,8 to below 0,2 within 0 - 300 m from the ship. Finally, in acoustic detection g(0) reaches only 0.1 – 0.3 for T-PODs (the precursor of the C-POD), with an effective detection range of only 22-104 m (Kyhn 2010). The reason for low detection probabilities in acoustic detectors is believed to be discontinuous echolocation by harbour porpoises as well as by their echolocation signals not being necessarily focussed on the receiver: their signals are narrow-beam with a 3-dB aperture of only 13° in the horizontal plane (Koblitz et al., 2012). Our newly developed, acoustic alerting device “PAL” (porpoise alarm, patented) synthetically generates clicktrains matching harbour porpoise alarm calls as characterised by Clausen et al. (2010). In this project, we thoroughly field tested an analogous porpoise detection buoy and established the framework for design and construction of a novel, real time porpoise detector and corresponding software, which were thoroughly tested in the laboratory. Within another project, we investigated a series of communication signals to enhance harbour porpoise echolocation. We identified one specific signal, internally named "M1" which attracts porpoises within hearing range and leads them to significantly intensify their echolocation.
Activities	<u>Design and construction of a PAL-based porpoise detector (PPD)</u>. We designed and built a laboratory version of a <u>real-time, radio-operated,</u> programmable, easy to use harbour porpoise clicktrain generator combined with a digital detector for these signals. The complexity of this design was well beyond the scope of our original ASCOBANS proposal, but became necessary after reconsidera-tion of deployment conditions in the field. The PPD will be incorporated in a buoy which can be moored at sea. The system is operated on the receiving side on land or on board a ship via a notebook PC. The software depicts detections via a specifically designed user interface and allows the user to change settings on the

PPD buoy, e.g. PAL clicktrain transmission or signal detection parameters. Furthermore, the operator can listen in via an acoustic interface operated over GSM, to hear the demodulated signal recorded by the buoy in real time. Deployment range of the buoy is within 5 nautical miles of the receiver (line of sight).

Detector-buoy

The detection buoy houses and supports 1) the PAL clicktrain generator and 2) the detection hardware consisting of a hydrophone, specific signal amplifier, digital detector and transmitter based on the XBee radio-system. Signal detection requires 12 Bit resolution for the analogue-digital converter, 600 kHz detection rate, and the 168 kHz processing speed of the 32 Bit micro controller (Fig. 1).

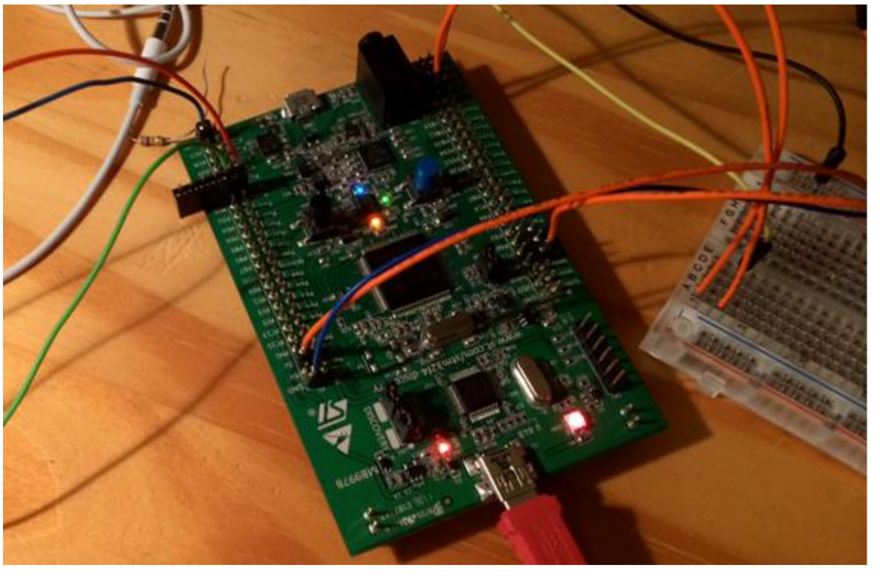

Fig. 1: Detector module for the buoy during laboratory tests

Porpoise click detection in the frequency range of 132 kHz with a band-with of 25 kHz is achieved by using Fast Fourier Transformation (FFT). All detections are stored on the buoy in real time on a SD memory card.

The porpoise click and clicktrain detector is designed to automatically filter animal signals from the surrounding acoustic environment. This is particularly important in areas with intensive marine traffic, such as e.g. during offshore wind park construction. Archival functions include click numbers, time and date which are saved on the internal SD card.

Receiver and operation module

The operation software and graphical user interface (GUI) enable the operator to modify frequency, ramp-up, click-train duration and pause intervals of the stimulating signal, to achieve rapid optimisation of these parameters and effectively enhance porpoise detection.

The GUI is arranged in a series of tabs. The control tab contains all the functions required for parameter setup on the buoy. The left half of the window shows the parameters for connecting the receiver with the buoy, as well as the buoy status information. On the top right are the settings for the PAL clicktrain generator and the detector (Fig.2). System messages are depicted on the bottom right.

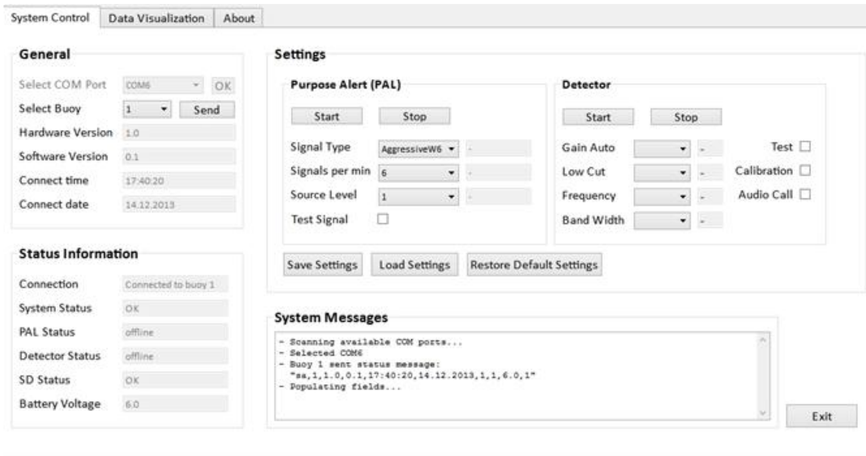

Fig. 2: Graphical user interface of PPD-receiver

Data is visualised (Fig. 3) on the receiver with the top display showing cumulated clicks per minute, starting with the connection of the receiver to the detection buoy. The bottom display shows the number of clicks cumulated per hour since the detection buoy was started: whenever the receiver is linked to the buoy, this hourly detection history is transmitted to the receiver, enabling a rapid overview of past detections (ranging 60 hours into the past).

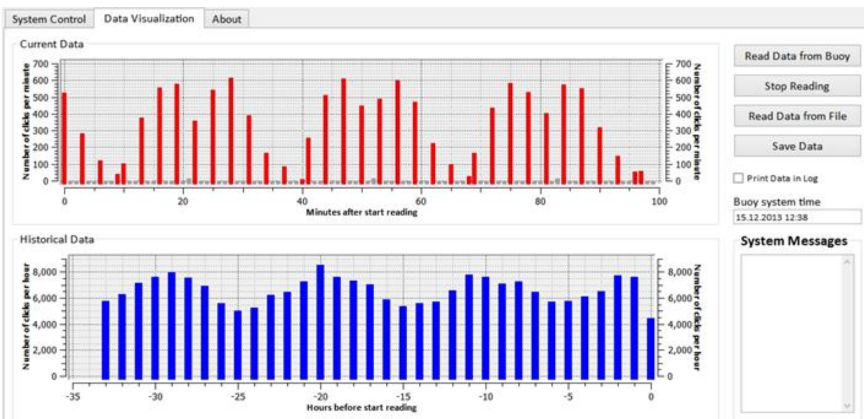

Fig. 3: Data visualisation on the receiver-PC. Red bars: minute sums of received clicks. blue bars: hourly click sums.

	Design and prototype of detection and reception were thoroughly tested in the laboratory, using a standard PAL as a synthetic harbour porpoise clicktrain generator. The underlying detection algorythm showed a 95% accuracy towards click detection in a simulated acoustic environment with background noise. Field tests requiring a hydrophone and a specific digital signal amplifier and processor are envisaged for April 2014. This will lead to the optimisation of the algorythm parameters and to extension of the detection range. Further development of a ruggedized device ready for deployment during a real ammunitions clearance situation will require additional funding. <u>Field tests:</u> In Kiel Fjord and in the Little Belt, Denmark we tested an analogous radio-buoy prototype equipped with an ETEC amplifier and envelope detector and determined the signal detection radius using a calibrated PAL clicktrain synthesiser (calibrated source level 157,5 dB at 133 kHz) by comparison to a standard detection device, the CPOD. We found that the immediately audible acoustic detection range of the buoy only reached 80 m, whereas the range of the CPOD (after retrieval of archived data) was 260 m under the same conditions. This discrepancy shows the advantage of digital over analogue signal processing and provided useful insight prior to designing the new PPD detector described above. However, the analogous buoy also showed the usefulness of providing real-time underwater sound information from the deployment site of the buoy, a feature that will be retained in the PPD. Using the PAL as a signal generator, we determined *in situ* the most appropriate function to describe transmission loss (TL in dB re. 1 µPa, 1 m) in the shallow water field areas in the Baltic Sea as being TL = 20 log R1 + 10 log (R1/R2) (Richardson et al. 1995) (R1 = distance, R2 = 1/2 Water depth; in m). We assumed a noise level NL = 67 dB (fair weather) during periods with no wind and no rain, as opposed to NL = 87 dB for winds force 7 Bft. and strong rainfall (foul weather; Richardson, 1995). The critical detection ratio of harbour porpoises is CR = 38 dB at 135 kHz and the animals have a directivity index of 11,7 dB (Kastelein et al. 2005). The CPOD is omni-directional and has a CR = 47,5 dB as shown by our own measurements and as confirmed by Dähne et al. (2013). CR of the radio-buoy as calculated from our field measurements was 60 dB. Finally, whereas the PAL is an omnidirectional transmitter with a source level of 157,5 dB, harbour porpoises transmit their clicks within a very narrow beam of only 13° in the horizontal plane (Koblitz et al. 2012). Their source level was assumed to be 178 dB when the beam hits the detector head on, but only 149,5 dB (weighed average), if animal orientation towards the detector is assumed to be random (calculated from

Villadsgaard et al. 2007, Koblitz et al. 2013, Hansen et al. 2008).

Using these values, we determined the detection range of CPODs and the analogue radio buoy under fair and foul weather conditions (Table 1): If a harbour porpoise clicks head on in fair weather, a CPOD can detect it from a distance of 650 m, while the analogue radio buoy range is only 400 m. If the animal is not facing the detector, the CPOD average detection range falls to 140 m as opposed to only 20 m in the radio buoy (in fair weather).

Table 1: Detection range as calculated from field measurements. HP: Harbour porpoise. CPOD: archival detector. RadioB: Radio Detector Buoy. PALres: research PAL emitting specific communication signals

		Detection range (m)	
		Weather conditions	
		fair	foul
HP-CPOD	**Head on**	**650**	**300**
	Average	**140**	**6**
HP-RadioB	**Head on**	**400**	**90**
	Average	**20**	**0**
PALres - HP	**Head on**	**440**	**120**
	Average	**320**	**50**

However, if a PAL were transmitting at the site of the detector, harbour porpoises would hear the signal at distances of 440 m (head on) and even at 320 m (average) if body orientation is random. In other terms: actively "calling" harbour porpoises will potentially increase the CPOD detection radius from 140 m to 320 m, and of the radio buoy from 20 to 320 m, since the head on click intensity of the positively responding porpoise is in any case strong enough to be detected by both detectors at that distance.

Having determined that, we re-analysed field data (obtained in a separate project) on harbour porpoise behaviour within a range of 300 m from the radio buoy and CPOD, both being moored at the same site. Surfacing position of the porpoises were recorded by theodolite from a field station located 14 m above the Little Belt, Denmark. The PAL at the detector site emitted signal "M 1" and was activated by a timer for 15 minutes, following a 15 minute pause (controls).

A typical example is shown in Fig. 4: whereas click intensity (red bars) of a porpoise group of 2 swimming at approx. 150 m from the detector (blue line) is at first low, this changes drastically as the PAL is activated between min. 9 and 22 (shaded blue): the porpoises approach the detector and emit a high number of clicks. After the PAL switches off, the animals linger around for another 7-8 minutes, but finally leave.

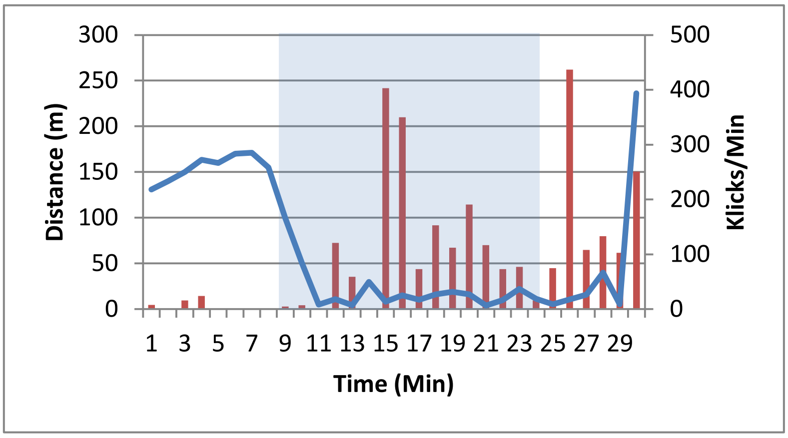

Fig 4: Effect of PAL signal M1 on porpoise behaviour

All observed surfacings of porpoise groups were used to calculate their range to the detector. We obtained 54 data points with PAL off as opposed to 63 data points with PAL on (signal M1). From this we determined the distribution of closest surfacings (Fig. 5).

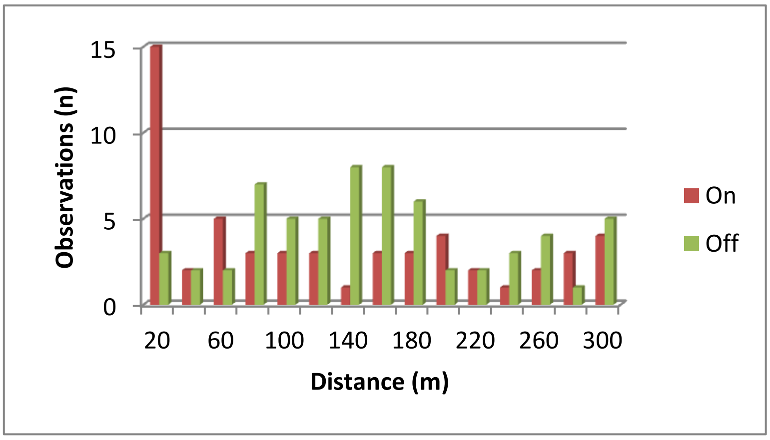

Fig. 5: Effect of PAL on porpoise range from detector

The difference between the two distributions is statistically significant (t-Test, $p<0{,}05$).These findings show clearly, that PAL signal M1 leads harbour porpoises within hearing range to close in on the detector. At the same time, the animals intensify their echolocation.

We determined the number of clicks received by CPOD per minute in the 15 minute interval before PAL was activated as compared to the 15 min during PAL transmission and 15 min when PAL was off (Fig. 6). Because porpoises vary the numbers of clicks emitted between day and night time, as well as from one approach to the next, we standardised each of the 157 approaches with respect to itself by calculating percentage click numbers. This gives every approach the same comparative significance.

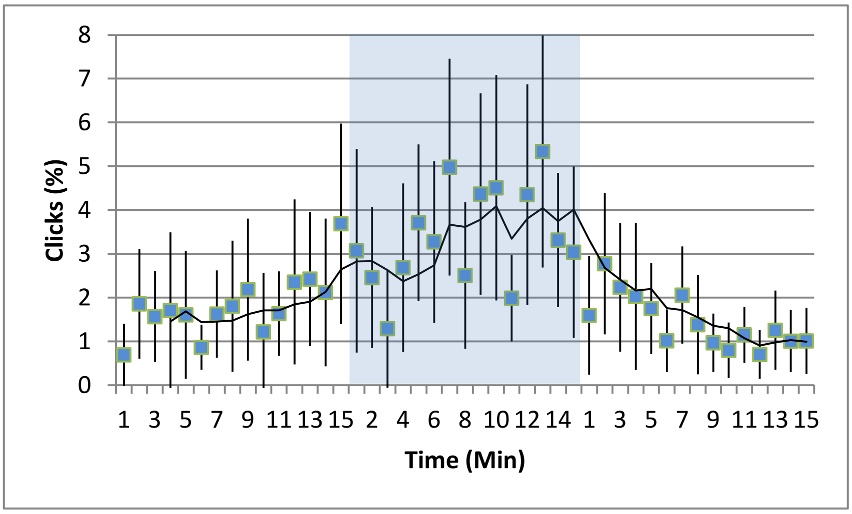

Fig. 6: Harbour porpoise click intensity before, during (shaded blue) and after PAL operation

Statistical comparison of the proportion of clicks (27%) emitted before PAL was started as opposed to when the PAL was on (51%) is highly significant (ANOVA, $p<0.0001$): with PAL on, the porpoises click about twice as often.

Conclusion

From the results presented in this work report we conclude that PAL emitting the signal M1 is a very efficient positive stimulator of harbour porpoises. The signal entices the animals to approach the detector and to significantly intensify their echolocation, thereby significantly increasing their chance of detection.

We have tested an analogous radio buoy with a detection range which is on average 20 m (irrespective of porpoise orientation). This range can be increased to 320 m by stimulating the porpoises with PAL signal M1: after hearing the signal, they turn towards the detector and thereby hit it directly with their narrow echolocation beam.

We have developed a novel PPD digital detector and the required detection and operating software, which was proven to work in a laboratory setup. Field tests of the PPD will be conducted in April 2014.

Outlook	The investigations presented here are the basis for further development aimed at : – optimising long-range detection of porpoise signals in the field with the new PPD detector – deploying a prototype PPD during ammunitions clearance or at an offshore wind park construction site

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