Protection of Marine Mammals in the Marine Environment

New Acoustic Strategies

ELAC Nautik

F³: Forschung . Fakten . Fantasie

by Matthias Conrad and Martin Meister, L-3 ELAC Nautik
Vailett Müller, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
Prof. Dr. Boris Culik, F³: Forschung . Fakten . Fantasie

Abstract

The European Directive 2008/56/EC, commonly known as Maritime Strategy Framework Directive (MSFD) defines strict guidelines for the protection and the restoration of the maritime environment with the aim of maintaining the biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive .

With the background of the intense use of the maritime environment both in the civilian and in the military sector, measures have to be taken to keep marine creatures away from dangerous maritime installations without excluding them from their habitats. On the other hand subsurface units such as submarines or autonomous underwater vehicles also need to be protected against collisions with maritime installations without producing excessive acoustic pollution.

L-3 ELAC Nautik and F³: Forschung.Fakten.Fantasie present research findings from an ongoing study, using the porpoise communication signal generator PAL (Porpoise ALarm, pat.) to alert harbor porpoises in the vicinity of e.g. marine installations or fishing gear, without scaring them out of their habitats. We discuss possible applications for PAL such as in active detectors (e.g. to be used prior to ammunitions clearance), acoustic submarine transponders for offshore wind parks and optimized alarming devices for gillnets.

Harbor Porpoise

The harbor porpoise, Phocoena phocoena (Linnaeus, 1758; Fig. 1), is the most common cetacean in the German North and Baltic Sea (Benke et al. 1998). Marine pollution, overfishing, ship traffic, military testing and the construction of offshore wind farms lay pressure on the species. Incidental bycatch of the harbor porpoise is considered to be the most important threat. The harbor porpoise is seriously depleted and threatened with extinction in the eastern Baltic Sea (Galatius et al. 2012).

Figure 1: Harbor porpoise

Echolocation enables harbor porpoises to find their prey, orientate, avoid predators and keep in contact with each other (Villadsgaard et al. 2007). Narrowband clicks series, commonly referred to as click trains, with a peak frequency centered on 130 kHz are produced (Au et al. 1999). The source level for wild animals ranges between 178-205dB re 1 µPa@1m with a peak frequency around 129-145 kHz (Villadsgaard et al. 2007). The -3dB beam width, a measure for the directionality of the echolocation beam in the horizontal and the vertical plane is only 16.5° (Au et al. 1999).

Clausen et al. (2010) studied acoustic communication sounds emitted by harbor porpoises in captivity. An 'aggressive' porpoise would suddenly turn towards the subject of aggression and emit a high repetition rate click pulse while performing a rapid scanning movement of its head. The receiving porpoise always fled after receiving this pulse. The duration of the click trains was 0.3 - 3 s, with click repetition rates as high as 1.000 /s. During aggressive interactions the porpoises expose each other to high SL, up to 180 dB re 1 µPa pp (Clausen et al. 2010). These findings form the base for the development of PAL.

Acoustic Threats

Marine noise such as maritime traffic, construction and maintenance of offshore-windpower plants, echosounder and sonar may cause masking of natural sounds, impair communication and affect prey detection negatively (Au 1993).

Underwater detonations (from e.g. ammunition clearance) have the potential for serious injuries in marine vertebrates. Peak pressures during submarine explosions of charges with a mass of only 10 kg e.g. 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 a 1 km range (Richardson et al. 1995). Finally, pile-ramming during construction of offshore wind parks (Fig. 2) generates sound exposure levels above 160 dB within the 750 m radius for all pile diameters above 1.5 m. While mitigation measures such as bubble curtains can somewhat attenuate sound exposure of marine wildlife, they have a limited effect (Koschinski 2011).

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 above 160 dB re 1 µPa pp is crucial. This would enable operators to postpone planned measures or to exclude the animals from hazardous areas prior to the onset of operations by using e.g. acoustic deterrents.

Navigational Threats

Fig. 2 shows the planned and active offshore wind parks in the North and Baltic Seas by the end of 2011. These maritime installations in combination with other offshore platforms e.g. for oil and gas exploration especially in the North Sea limit the areas for submerged submarine operations and provide the risk of collisions of submarines with these installations in case of uncertainties of the submarines inertial navigation system.

Because GPS is not usable underwater and electromagnetic waves are highly attenuated, only acoustical warning systems can be used to warn submerged submarines against these threats.

In the face of the MSFD all measures have to be taken to protect the marine environment and the maritime life from negative influences. Permanent acoustical pollution provided by continuously operated beacon pingers has been identified as a problem for marine creatures. The solution for this problem is an acoustic warning system mounted to the offshore windmill foundations working as a transponder which is activated by the operating submarine through an active acoustical transmission signal.

After reception of this signal the transponder answers with a two frequency tone sequence allowing the submarine to discriminate the bearing of the windmill by the submarines passive sonar. This method keeps the acoustic pollution of the maritime environments at a minimum.

Porpoise Detection

Harbor porpoise detection is currently conducted by observers on airplanes or ships, or via autonomous acoustic detectors such as C-PODs (Chelonia, UK). However, detection ranges and probabilities are low: 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 g(0) is between 0.7- 0.8 during extraordinarily 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. However, optimal conditions are seldom met in the German North Sea (Diederichs et al. 2010). Finally, in acoustic detection g(0) is quite low, reaching 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 g(0) in acoustic detectors is believed to be discontinuous echolocation by harbor porpoises as well as by their narrow echolocation signals not being focused on the receiver.

Figure 2: Planned and active offshore-wind farms in North Sea and Baltic Sea (http://www.4coffshore.com)

However, click detectors could have the potential of achieving a detection radius of 530 m to over 1.200 m, if they received directed porpoise clicks and if their detection sensitivity was appropriate: Clausen et al. (2010) calculated that harbor porpoises potentially communicate over such distances, depending on the source levels of their click signals. Here we show that PAL can be used to enhance click activity and thereby has the potential to improve the detection of the animals.

By-catch

Porpoises are unintentionally by-caught in a variety of fishing gear and the vast majority of this mortality occurs in bottom-set gill nets (Culik 2011). The detection distance may be negatively affected by factors such as low click intensity and high background noise levels (Kastelein et al. 2000, Mooney et al. 2007). Akamatsu et al. (2007) showed that porpoises maintain short periods of silence, during which they may be caught in nets before becoming aware of them.

To reduce by-catch in fisheries, currently employed pingers produce aversive noise resulting in disturbance of harbor porpoises: the animals maintain a safety distance of several 100 m to pinger- equipped nets (Culik et al. 2001), reduce echolocation intensity and may even become entangled between widely spaced pingers. Besides potential exclusion from fishing grounds, porpoises fail to establish a connection between noise and nets. This is another aim in the development of PAL: to alert porpoises and stimulate them to increase their echolocation intensity.

Acoustic Alerting Device PAL (Porpoise Alarm)

The newly designed omni-directional Harbor Porpoise Click Train Synthesizer PAL (Porpoise ALarm, patented, Fig. 3) is a programmable hydro-acoustic device which synthesizes communication click trains. Two versions of the PAL (differing in housing, hard- and software and generated signal) were used throughout the field experiments.

Both signals match aggressive buzzes, emitted by a female porpoise towards a male (Clausen et al. 2010). The first version, PALv1 (Fig. 3), generates a 1.39s upsweep-chirp of 700 clicks, starting with 173 c/s and ending with 959 c/s followed by a 8s pause (Fig. 4). The source level is 154db ± 2dB p-p re 1µPa @1m (133 kHz ± 0,5kHz). PALv1 operates with 6 x AA batteries and is housed in a POM housing of 370mm (length) x 66mm (diameter). This signal was tested on porpoises in captivity as well as in the field in early 2012.

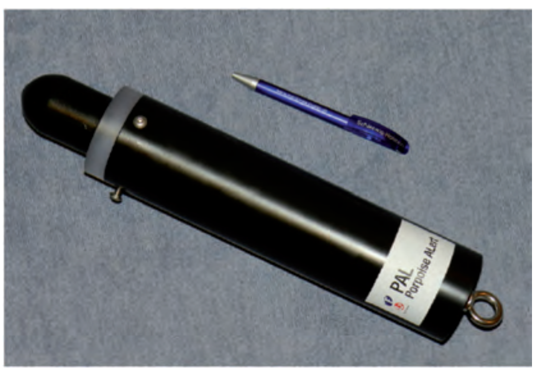


Figure 3 : Porpoise clicktrain generator PAL v1

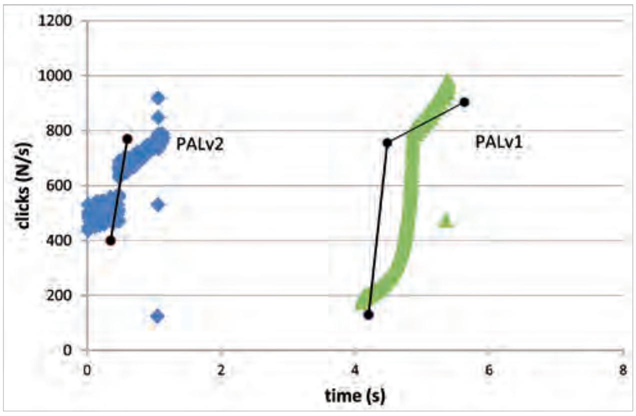


Figure 4: Clicktrains emitted by PAL

For experiments during the second half of 2012, PALv2 was used. The generated 1,13s upsweep-chirp (Fig. 4) consists of 700 clicks, starting with 437 c/s and ending with 774 c/s, followed by a 6s pause. The source level is 154db ± 2dB p-p re 1µPa @1m (133 kHz ± 0.5kHz). PALv2 operates with C-cells, size is 300 mm (length) x 90 mm (diameter). Both versions were set to transmit the signal for 15 minutes (with 7 signals per minute). After 15 minutes the PAL turned off and remained silent for 15 minutes.

Field Experiments

In an extended field study conducted in the Little Belt near Fredericia, Denmark during summer 2012, we simultaneously employed up to 5 buoys, each equipped with a PAL and an autonomous acoustic device (CPOD). We tracked porpoise surfacing positions from land via theodolite and from sea using observers on board the German RV "Clupea" (Fig.5).

Field effort during acceptable weather conditions was 197.5 h. We detected 445 porpoise groups within 300 m of individual buoys during 8.2 h or 4% of the time. Preliminary data analysis shows that porpoises are neither attracted to nor repelled by PAL-active buoys and continue on their course (Fig. 6). PAL however repeatedly stimulated the porpoise group to increase echolocation activity, e.g. from 47 clicks/min (PAL off) to 400 c/min (PAL on, Fig. 7).

Data analysis of the 2012 field season is still underway. The general picture emerging is that the PAL signal briefly stimulates harbor porpoises to increase echolocation and then to

Figure 5: Surfacing positions of harbor porpoises tracked in Little Belt (blue), PAL-buoy (red)

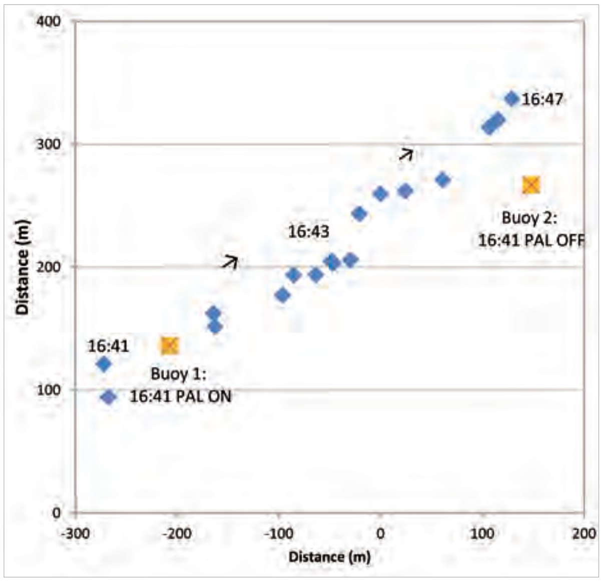


Figure 6: Porpoise group travelling in vicinity of PAL

turn away from the sender. Within 4 minutes after the signal has ended, the animals again intensively investigate the area of the transmitter acoustically (4.95 c/Min while PAL was on to 14,8 c/Min within 4 min after PAL is off. t-test, p=0,02, n=32).

This reaction of harbor porpoises has still to be confirmed during ongoing field experiments. An increase in echolocation activity would enhance acoustic detection of the animals prior to dan-

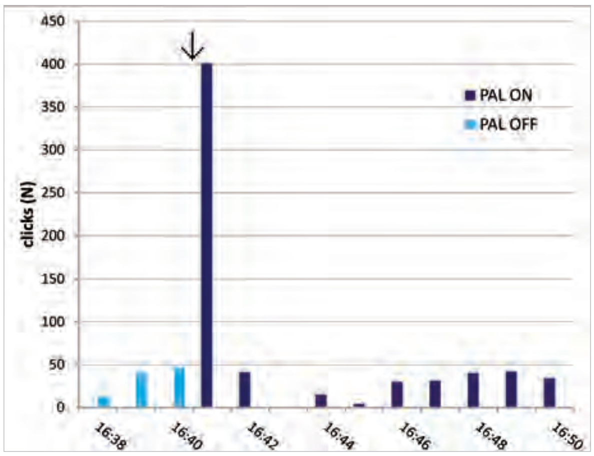


Figure 7: Increase in click activity at buoy 1 after PAL is switched on

gerous or harmful operations and would enable them to detect inconspicuous obstacles such as nets in time to avoid collision. It is planned to optimize the PAL-signal as well as the signal to pause ratios to investigate further into this interesting effect.

Conclusions

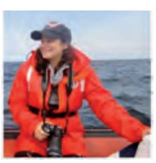
The PAL signal offers a possibility to stimulate echolocation in marine mammals without disturbing or repelling them from their habitats. This offers great perspectives for protection of these marine mammals on one hand and for specific, non-invasive acoustic monitoring on the other hand.

The ongoing intensive use of the maritime environment and the increase in maritime construction work require new strategies for protecting submerged units like AUVs or operating submarines. For these purposes only hydroacoustical devices which are in accordance with European Directive 2008/56/EC (MSFD) are useful. Such devices are currently installed in different offshore wind parks and are successfully in use.

Authors

Matthias Conrad served as an officer in the German Army and received his diploma degree in electrical engineering with specialization in electronics and communication technology from the University of Applied Sciences in Kiel, Germany in 2004. Since 2005 he is working as a system engineer in the system design department at L-3 ELAC Nautik in Kiel. His main field of work is the design of underwater communication systems and active sonar systems.

Martin Meister received his diploma degree in electrical engineering with specialization in electronics and high frequency engineering from the University of Bochum, Germany in 2001. Since 2007 he is working in Kiel for L-3 ELAC Nautik's software department. His main fields of work are active navigation and detection sonars regarding algorithms and signal processing.



Vailett Müller is enrolled in the master programme in Biological Oceanography at GEOMAR, Kiel, Germany. Currently she is working on her master thesis, focussed on the behavior of free-living harbor porpoises towards the Porpoise Alerting (PAL) device in the Little Belt, Baltic Sea, Denmark.

Boris Culik, F³: Forschung . Fakten . Fantasie (Heikendorf, Germany) has more than 30 years of experience in marine biological research. The company is currently focussed on early detection and by-catch reduction in harbour porpoises and is part of the expert team of PITAS, the piracy and terrorist aversion system for merchant ships.

Sources

Akamatsu T., Teilmann J.; Miller L.A.; Tougaard J.; Dietz R.; Wang D.; Siebert U.; Naito Y. 2007. Comparison of echolocation behaviour between coastal and riverine porpoises. 2007 Symposium on Underwater Technology and Workshop on Scientific use of Submarine Cables and related Technologies. Vol 1&2 pp 563-569.

Au u. A. (1999) Transmission beam pattern and echolocation signals of a harbour porpoise (Phocoena phocoena). J Acoust Soc Am 106 : 3699–3705.

Au W. 1993. The sonar of dolphins. Springer-Verlag New York pp 227.

Au W.; Kastelein R.; Rippe T.; Schooneman N. 1999. Transmission beam pattern and echolocation signals of a harbour propoise (Phocoena phocoena). Journal of the Acoustic Society of America. Vol 106 Iss 6 pp 3705.

Benke H.; Siebert U.; Lick R.; Bandomir B.; Weiss R. 1998. The current status of harbour porpoises (Phocoena phocoena) in German waters. Archive of Fishery and Marine Research. Vol 46 Iss 2 pp 97-123.

Clausen K.; Wahlberg M.; Beedholm K.; Deruiter S.; Teglberg Madsen P. 2010. Click communication in harbour porpoise Phocoena phocoena. Bioacoustics: The International Journal of Animal Sound and its Recording. Vol 20 Iss 1 pp 1-28.

Culik B. 2011. Odontocetes: The toothed whales. CMS Technical Series No. 24.

Culik B.; Koschinski S.; Tregenza N.; Ellis G. 2001. Reactions of harbour porpoises Phocoena phocoena and herring Clupea harengus to acoustic alarms. Marine Ecology Progress Series. Vol 211 pp 255-260.

Culik BM, Winkler S (2011) Design and Field-Test of Porpoise Alerting Device (PAL). ECS-Conference, Cádiz, Spain

Galatius A; Kinze C.C.; Teilmann J. 2012. Population structure of harbour porpoises in the Baltic region: evidence of separation based on geometric morphometric comparisons. Journal of the Marine Biological Association of the United Kingdom. Vol 92 Iss 8 pp 1669-1676.

Kastelein R.A.; Au W.; de Haan D. 2000. Detection distances of bottom-set gillnets by harbour porpoises (Phocoena phocoena) and bottlenose dolphins (Tursiops truncatus). Marine Environmental Research. Vol 49 Iss 4 pp 359-375.

Koschinski S. 2002. Current knowledge on harbour porpoises (Phocoena phocoena) in the Baltic Sea. Ophelia. Vol 55 Iss 3 pp 167-197.

Koschinski S. 2011. Underwater noise pollution from munitions clearance and disposal, possible effects on marine vertebrates, and its mitigation. Marine Technology Society Journal. Vol 45 Iss 6 pp 80-88.

Kyhn (2010) Passive acoustic monitoring of toothed whales, with implications for mitigation, manage-ment and biology. Ph. D. Thesis, Aarhus U. 170 S.

Laake JL, Calambokidis J, Osmek SD, Rugh DJ (1997) Probability of detecting harbour porpoise from aerial surveys: estimating g(0). J Wildl Manage 61: 63-75

Mooney T.; Au W.; Nachtigal P.; Trippel E. 2007. Acoustic and stiffness properties of gillnets as they relate to small cetacean bycatch. ICES Journal of Marine Science. Vol 64 Iss 7 pp 1324-1332.

Reay N (2005) Estimation of g(0) for bottlenose dolphin, grey seal, and harbour porpoise in Cardigan Bay SAC. U of Wales, Bangor. MSc Thesis, 100 pp.

Richardson et al. (1995) Marine Mammals and Noise. Academic Press, N.Y., 576 pp.

Villadsgaard A.; Wahlberg M.; Tougaard J. 2007. Echolocation signals of wild harbour porpoises, Phocoena phocoena. Journal of Experimental Biology. Vol 210 Iss 1 pp 56-64. Funded by the German Federal Ministry of Food, Agriculture and Consumer Protection through grant FKZ: 2819100612

BSH Bundesamt für seeschifffahrt und hydrographie: Nordsee: Offshore-Windparks (Pilotphasen).- 1 S.,www.bsh.de/de/Meeresnutzung/Wirtschaft/CONTIS-informationssystem/ContisKarten/NordseeOffshoreWindparksPilotgebiete.pdf; 23.09.11.

Funded by Bundesanstalt für Landwirtschaft und Ernährung | Bonn | Grant to B. Culik Nr. 313-06.01-28-1-91.006-12

L-3 Communications ELAC Nautik GmbH | Neufeldtstrasse 10 | 24118 Kiel | Germany | Tel. +49 (0)431-883 0 | Fax +49 (0)431-883 496 | elac.marketing@L-3com.com | www.elac-nautik.de

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel | Düsternbrooker Weg 20 | 24105 Kiel | Tel. +49 179 233305 | curlycee@gmail.com

F³: Forschung . Fakten . Fantasie | Am Reff 1 | 24226 Heikendorf | Tel. +49 431 2378 588 | bculik@fh3.de