Acoustic protection for marine mammals: new warning device PAL

Boris Culik[1], Matthias Conrad[2], Jérôme Chladek[3]

[1] *F3: Forschung . Fakten . Fantasie, Am Reff 1, D-24226 Heikendorf, Germany, Phone.: +49 431 2378 588, Email: bculik@fh3.de*

[2] *Technisches Büro Conrad, Holunderweg 4, D-24229 Schwedeneck*

[3] *Thünen Institut für Ostseefischerei, Alter Hafen Süd 2, D-18069 Rostock, Germany*

First published in German in: DAGA Proceedings, Kiel 2017, p.* 387-390. *http://www.daga2017.de/

Summary

Many whale species become entangled in gillnets and subsequently drown. Although toothed whales can rely on their sense of bioacoustic orientation, they are unable to detect these nets in time. The estimated number of marine mammals dying as by-catch is higher than the limits set by international treaties and nature protection regulations.

Fig. 1*: Harbour porpoise heading for a collision with a net*

The newly-developed, programmable warning device PAL (pat.) produces lifelike harbour porpoise communication signals. It is designed to alert the animals and to stimulate their echolocation activity, thus enhancing the acoustic 'visibility' of gillnets. The effectiveness of PAL was successfully tested with professional German and Danish fishermen in the North and the Baltic Seas.

Harbour porpoise by-catch

Too many marine mammals become entangled in gillnets (Fig. 1, 2) which they cannot perceive in time [1]. Unable to swim to the surface to breathe, the animals drown.

Their inability to detect gillnets in time is due to various reasons. The water is often murky and the nets are hard to see. However, toothed whales, just as bats, are able to orientate themselves with their biosonar: They produce clicks, whose echoes provide information on prey and obstacles. However the thin nylon yarns of the nets only reflect a weak echo at close range and only if directly ensonified. And the sonar beam, the field of "view" of harbour porpoises is very narrow, ranging from 11-13 degrees [2].

This is further aggravated by the fact that animals often are distracted by their search for food or by social interactions. Also, they may remain mute as they engage in passive acoustics in order to avoid attracting the attention of predators or aggressors, like killer whales or dolphins.

The numbers of stranded harbour porpoises along the German Baltic Sea coast shows an increasing tendency: from an average of 30-40 annual findings in the year 2000 to roughly 150 reported in 2016 [3, 4]. Up to 53% of the animals found dead are attributable to gillnet by-catch [5].

In order to allow for species conservation and regeneration of the population, total anthropogenic mortality of harbour porpoises in the Baltic Sea should not exceed 1.7% of population size [6]. According to current estimates however, this rate varies between 2.6 and 4.8%, which is far beyond this limit [7].

This leads to a controversy between the fisheries sector and nature conservation. However, demands to expand both protected areas and to establish fishery closures would strongly affect the fisheries. Moreover, gillnet-fishing is highly size-selective and sustainable in relation to its target species. Acoustic warning devices could prove to be an important immediate measure to reduce harbour porpoise by-catch.

Fig. 2*: Small cetacean drowned as by-catch in a gillnet*

At present, so-called "pingers", acoustic deterrents, are used for this purpose. They emit loud and unnerving noises to keep marine mammals at distance. But pingers may also exclude the animals from natural habitat and feeding grounds. It has also been shown that pinger noise leads to

reduction in echolocation activity in the startled harbour porpoises, [8]. The latter is especially counterproductive, as this may lead to increased by-catch in neighbouring nets or in net sections with defective pingers.

Furthermore, harbour porpoises are unable to relate between the pingers and the threat posed by the nets, as the devices keep them at a distance which exceeds the 3-6 meters at which gillnets become first 'visible' for their biosonar [9]. Several pinger types currently on the market are also disadvantageous due to their inconvenient form, high weight, low durability and transmitting power and fast battery drainage.

Newly-developed warning device PAL

How can the whales be better warned of man-made threats? Are there warning signals in their own "language"? What are other possible applications for synthetically created communication signals?

Harbour porpoises use clicks and specific click sequences, so-called click-trains, to communicate with each other. In the Fjord & Beltcenter in Kerteminde, Denmark, Clausen et al. (2010) observed that the animals use and understand certain types of click-trains (upsweep chirps) as warnings [10]. Based on these findings, we developed and patented the programmable synthetic click-generator PAL (Porpoise Alert).

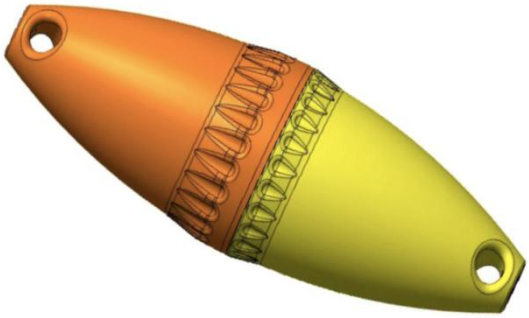

Fig. 3*: Design drawing of the acoustic warning device PAL*

PAL was optimized for the usage in fishery (Fig. 3) and its current software imitates specifically harbour porpoise alerting signals. With these, the animals are to be warned of dangers at a frequency of 133 kHz, which is the frequency they use themselves in ultrasonic orientation and communication [11].

In the development of this innovative warning device, we integrated the expert knowledge of fishermen with pingers of different manufacturers. We optimized design, source level, durability, weight, buoyancy and battery life.

In contrast to customary pingers, PAL floats and is internally shock-absorbing, reaches a very high source level of up to 152 dB and achieves a battery life of up to 1.5 years when continuously operating and a shelf life of up to 5 years. The battery is replaceable. Moreover, the PAL-hardware can be reprogrammed at any time to adjust the device for different operating requirements.

The devices are very sturdy and the 2nd generation (Fig. 3) easily withstands the rough handling on board unscathed. To that end, the mounting method of the devices to the floatline of the nets (Fig. 4) was optimized in various stages in cooperation with fishermen. PALs have to be mounted on the net float lines every 200 meters.

Fig. 4*: "PAL" v.1 on the floatline of a gillnet*

PAL fishery trials

PAL was tested between 2014 to 2016 by the Thünen Institute for Baltic Sea Fisheries, Rostock, in the professional Danish and German gillnet fishery. During this test phase, the device led to a significant by-catch reduction [12].

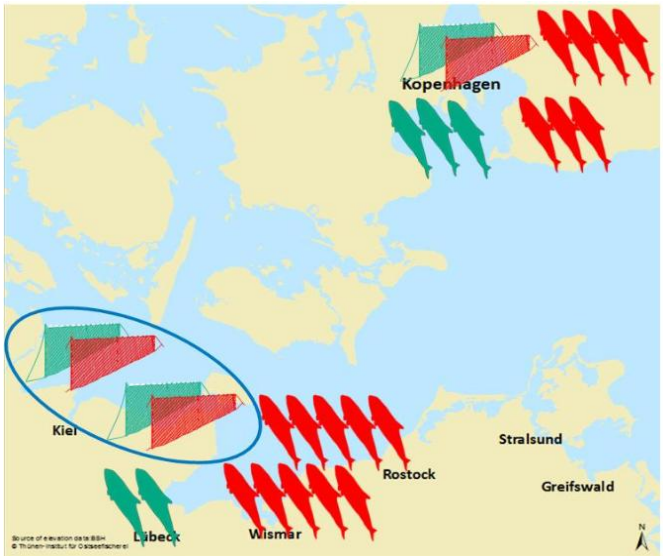

Fig. 5*: By-catches in fishery experiments in the Western Baltic Sea. Red: standard-nets, Green: PAL-nets.*

In each trial, two sets of nets, each of the same length, mesh size, height and other specs. were laid out. One of the sets was equipped with PAL, the other, standard net string served as control (Fig. 5).

In about 1.000 trials, the involved fishermen retrieved roughly 6.400 km of nets and by-caught 22 harbour por-

poises: only 5 of them in PAL-nets but 17 in nets without warning devices. The difference is statistically significant (p=0.016). The result shows that PAL can be deployed in the Baltic Sea as a means for reducing harbour porpoise by-catch by over 70%. Thus, the newly developed acoustic warning device is an important immediate mitigation measure.

At the moment, limitations concerning the usage of PAL persist with regard to the geographic location and the specific harbour porpoise population which reacts to PAL. Whereas results of tests in the Western Baltic Sea between Femahrn (East), Eckernförde (West) and the Öresund (North) show that PAL effectively protects harbour porpoises from gillnets, the results of trials in the North Sea are yet unsatisfactory. More thorough tests of the devices in these waters and research with alternative signals are required.

Reactions of harbor porpoises to PAL

During field experiments in the Danish Belt Sea we tested the reactions of harbour porpoises to PAL signals in contrast to the deterring noise emitted by customary pingers. For this purpose, 5 buoys each 100 meters from the next, were equipped with acoustic recording devices. The acoustic source to be tested was mounted at buoy number 3. Harbour porpoise behaviour was recorded visually from a cliff by means of a theodolite.

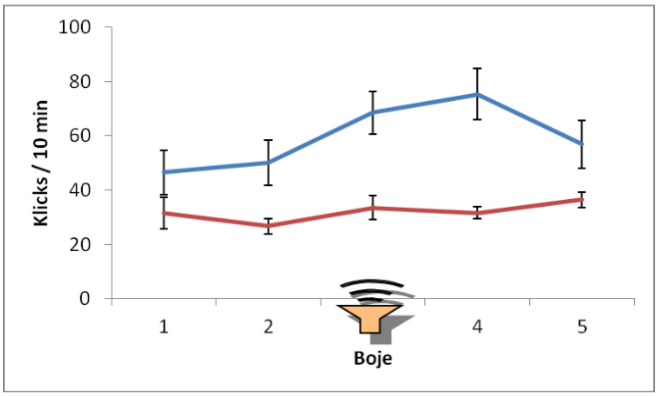

***Fig. 6**: Echolocation activity of wild harbour porpoises. The acoustic source was mounted at buoy 3. Red: standard pinger. Blue: PAL.*

The results show that harbour porpoises react to PAL most notably by increasing their echolocation activity near the sound source, while not being attracted to the PAL itself. During PAL operation, the animals click intensity was twice as high at buoy 3 and its surroundings (Fig. 6) than when the pinger model “Aquamark 100” (Aquatec, UK) was active.

The by-catch reduction observed in the fishery-tests is therefore most likely due to the increased echolocation activity of the animals. Presumably, with PAL the animals acoustically detect the threatening net and avoid collision.

Other parameters which could reduce the risk of collision during PAL operation, such as a shorter presence in the area, an increased distance or a change of swimming speed were not altered by PAL [7].

Practical relevance

With PAL as a warning device, a new path in by-catch mitigation is engaged. Within the scope of a larger validation study, the Baltic Sea Info-Center in Eckernförde is currently planning to deploy 1.680 PAL in cooperation with fishers in Schleswig-Holstein. Funding was applied for at the Schleswig-Holstein Ministry for Energy, Agriculture, Environment and Rural Areas. Further east, in Mecklenburg-Vorpommern as well as on the Danish and Swedish Baltic Sea coasts, the usage of PAL would mitigate by-catch as well and we seek cooperation with authorities there.

***Fig. 7**: Typical fishing cutter in Schleswig-Holstein*

Moreover, the PAL-Hardware is suited to conquer further market segments. The fishing fleets of the German federal states, of the EU and many more are targeted markets. According to previous experiences, a demand for 20 – 60 devices can be expected per gillnet fishing vessel, depending on the length of the net strings carried.

In the region of the Baltic Sea of Schleswig-Holstein, 220 fishermen (Fig. 7) engaged in the gillnet fishery have joined a voluntary agreement to reduce by-catch. Altogether, roughly 1,435 cutters and uncovered open boats were part of the small deep seas and coastal fishery of Germany in 2015 [13]. The fishing fleet of the EU comprises roughly 85,154 fishing vessels [14]. Most of these – 72,301 ships – are smaller than 12 metres.

Further applications

In the future, we would like to characterize, generate and test further communication signals to warn other populations and species with PAL. Our target species are harbour porpoise populations world wide, the endangered Mexican vaquita as well as species which suffer from mass strandings like sperm whales or pilot whales.

Further areas of application could be the attraction of specific whale species to focus their echolocation for scientific research. For instance, preliminary tests showed that specific signals attract harbour porpoises which subsequently focus their attention towards the acoustic detector nearby [11].

This can contribute to the improvement of acoustic whale detection in areas with low densities or high patchiness.

Furthermore, PAL can be used as a calibration device for acoustic recording- and detection devices. The latter generally operate as a “black box”. This is where PAL can be useful to provide users with synthetic test signals of their targeted species for comparison on site before and during their investigation.

***Fig. 8**: Harbour construction-site in Kiel-Schilksee*

Finally, it is conceivable to program the PAL-Hardware to use the device as a general deterrent. This is reasonable in situations in which marine mammals are to be protected from sound or explosive injuries. This concerns seismic studies of the ocean floor in the area of offshore oil and gas, military exercises during which very intense sonar devices are deployed, construction work in offshore wind power plants, for waterways and harbour installations (fig. 8) or controlled munitions’ explosions.

Acknowledgments

We thank:

- the Bundesanstalt für Landwirtschaft und Ernährung for financing (FK. 2819100612 to F3, Boris Culik and 2819100512 to TI-OF, Christian von Dorrien)

- ASCOBANS, friends of CMS and Loro Parque Fundation, for their support regarding project development

- Hans-Georg Jürgens, Guido Hillmann and Ulrich Koller, Plastimat GmbH, Oranienburg, for the injection molding of the outstanding casing

- the Crews of FS "Clupea" and all involved fishing vessels for fishery and field trials

- the wildlife-assistants: Dennis Brennecke, Anette Christensen, Charlotte and Nicolai Culik, Julian Döring, Ljudmila Gladek, Martin Grimm, Christian Hesse, Tanja Hilbig, Aline Hock, Lisa Kettemer, Regina Klapper, Christian Lieberum, Henrik Möß, Philipp Paysen, Camilla Pedersen, Vailett Müller, Daniel Österwind, Mareike Pohling, Puk Sabinsky, Fernando Sanchez, Tobias Schaffeld, Daniel Stepputis and Carola Wagner for observations

- our cooperation partners Lotte Kindt Larsen and Finn Larsen, DTU aqua, Kopenhagen, for the fishery trials

- Magnus Wahlberg, University of Southern Denmark and Peter Dam, Overstyrmand, Søfartsstyrelsen, for the authorisation of the field work.

Literature:

[1] Culik, B.M.: Odontocetes, the toothed whales. CMS Technical Series 24, 311 pp., 2011

[2] Koblitz, J.C., Wahlberg, M., Matdsen, P.T., Beedholm, C. & Schnitzler, H.U.: Asymmetry and dynamics of a narrow sonar beam in an echolocating harbor porpoise. J Acoust Soc Am 131 (2012), 2315-2324

[3] Dähne, M., Harder, K. & Benke, H.: Totfundmonitoring von Schweinswalen (*Phocoena phocoena*) an der Küste Mecklenburg-Vorpommerns von 2004 bis 2009: 17 pp.: Deutsches Meeresmuseum Stralsund, 2010

[4] Siebert U.: ITAW, Büsum, pers. Mitt., 2016

[5] Herr, H.: Vorkommen von Schweinswalen (*Phocoena phocoena*) in Nord- und Ostsee – im Konflikt mit Schifffahrt und Fischerei? Ph.D. Thesis, University Hamburg 118 pp., 2009

[6] ASCOBANS: Recovery Plan for Baltic Harbour Porpoises (Jastarnia Plan), Bonn, 2002

[7] Culik, B., Chladek, J., Conrad, M.: High echolocation intensity of harbour porpoises (*Phocoena phocoena*) towards the new acoustic alerting device PAL. Mar Mamm Sci (subm.)

[8] Culik, B.M., Koschinski, S., Tregenza, N. & Ellis G.M.: Reactions of harbor porpoises *Phocoena phocoena* and herring *Clupea harengus* to acoustic alarms. Mar. Ecol. Prog. Ser., 211 (2001), 255-260

[9] Koschinski, S., Culik, B.M., Trippel, E.A., Ginzkey, L.: Behavioral reactions of free-ranging harbor porpoises *Phocoena phocoena* encountering standard nylon and BaSO4 mesh gillnets and warning sound. Mar. Ecol. Prog. Ser. 313 (2006), 285-294

[10] Clausen, K.T., Wahlberg, M., Beedholm, K., Deruiter, S. & Madsen, P.T.: Click communication in harbour porpoises *Phocoena phocoena*. Bioacoustics 20 (2010), 1-28

[11] Culik, B., Dorrien, C., Müler, V., Conrad, M.: Synthetic communication signals influence wild harbour porpoise (*Phocoena phocoena*) behaviour. Bioacoustics 24 (2015), 201 – 221

[12] Culik, B., Dorrien, C., Conrad, M.: Porpoise Alerting Device (PAL): Synthetic harbour porpoise (*Phocoena phocoena*) communication signals influence behaviour and reduce by-catch. In Von Nordheim & Wollny- Goerke (Eds.): Progress in marine conservation in Europe 2015. Proceedings of the symposium, Stralsund, Germany. BfN-Skripten No. 451 (2016), 150-156

[13] BLE: Anlandestatistik 2015. http://www.ble.de/DE/02_Kontrolle/02_Fischerei/01_Fischwirtschaft/Fischwirtschaft_node.html

[14] Fischereiflottenregister der EU 2015 http://ec.europa.eu/fisheries/fleet/