ECHOLOCATION ACTIVITY OF HARBOUR PORPOISES (*PHOCOENA PHOCOENA*) AROUND AN OFFSHORE GAS-PRODUCTION PLATFORM-DRILLING-RIG COMPLEX

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1 INTRODUCTION

Harbour porpoises (*Phocoena p. phocoena* L.) are vocal animals and their activity can be monitored effectively using underwater, autonomous, passive-acoustic cetacean-click detectors called T-PODs [e.g. 1, 2, 3].

The characteristics of porpoise-echolocation clicks have been described in great depth over the last forty years [4-10]; clicks can be emitted singularly or in groups known as “trains”. There is a linear correlation between porpoise-echolocation pulse intervals and target range [11, 12] with a peak in repetition rate as the animal nears the target, analogous to the “terminal buzzes” repeatedly observed in echolocating bats [13]. Determination of a successful prey-capture event in wild echolocating bats has been achieved effectively [e.g. 14] but for wild porpoises, underwater filming of prey-capture attempts is extremely tedious. Moreover, in the wild, without visual confirmation, any correlation between porpoise buzz activity and feeding success cannot be assumed *a priori* without experimental evidence, because a high buzz rate may simply be associated with increased foraging effort for the same amount of prey. Nonetheless, it is conceivable that by using acoustics alone, a proxy of feeding activity could be surmised by examining the relative incidence of increasing click rates, emitted during range-locking echolocation behaviour, and the associated decreasing interval between clicks, known as “inter-click-intervals (ICI)” [see 2]. A link between feeding and decreasing ICI has been established for foraging Blainville's beaked whales, *Mesoplodon densirostris* [15] and harbour porpoises [16].

Previous research on harbour porpoise echolocation behaviour has focused on inshore populations [e.g. 2] or on captive animals [see 17 and refs. therein] and knowledge of their offshore echolocation behaviour remains scarce. It is a well accepted tenet, however, that offshore installations may act as artificial reefs, effective in aggregating benthic, demersal, and pelagic marine species [18-20] and in the North Sea, fishing is not permitted within the 500 m exclusion zone around each installation, further enhancing the properties of these “reefs” as refuges for marine life.

World-wide rigs-to-reef studies (i.e. decommissioned rigs left *in situ* for the benefit of marine life) have focused mostly on quantifying aggregations of fish and invertebrates and there have been only a few isolated studies in the North Sea [e.g. 21, 22]. No research to date has considered the potential of these installations to serve as foraging sites for marine mammals even though the short-term activity of porpoises by routine oil-and-gas operations such as drilling, tender-boat operations, and cementing and casing [23]. We hypothesised that areas in the near vicinity and between the legs of such structures might serve as reefs for potential prey of harbour porpoises, and thus porpoises, in otherwise significantly overfished or disturbed parts of the North Sea.

Between 2004 and 2006, we gained an unusual opportunity to access a gas production platform-drilling-rig complex in the Dogger Bank region of the North Sea, in order to establish, using T-PODs, whether porpoises were present around the installations. The T-POD is an autonomous acoustic recorder designed to detect and record porpoise echolocation clicks We were not able to undertake replicated work, although this was not a comparative study, and we made no assumptions on whether porpoises were attracted to installations. The objectives of the T-POD study described here were to (i) determine whether porpoises were present around the installation, (ii) examine any diel patterns in echolocation activity, and (iii) use the inter-click interval as a proxy indicator of feeding.

2 MATERIALS AND METHODS

2.1 STUDY LOCATION AND TIMING

Monitoring was performed from the A6-A gas production platform operating under the auspices of the North Sea oil-and-gas branch of BASF (Wintershall AG) in the Northeast German Sector of the Dogger Bank (Figure 1.). The A6–A platform has been in position (55°47′28.895″N, 003°59′39.584″E) in natural-gas field sector A6–B4 since July 1999. During the monitoring period, the *Noble Kolskaya* “jackup” drilling rig was positioned and fixed alongside A6–A at its southern end. Monitoring at the A6–A-*Kolskaya* complex took place over a six-month period from 30 July 2005 to 27 January 2006.

2.2 INSTALLTION AND SITE DESCRIPTION

The A6–A-*Kolskaya* complex was situated in a mean? water depth of 47.80 m with a x tidal range on a seabed of very soft clay and sand on a heading of 180.30°. The A6-A had a typical six-legged steel construction with a base area of 1015 m^2, a length of 52 m long and width of 33 m. The *Noble Kolskaya* had a typical triangular-shaped barge hull, with a deck area of 1765 m^2 and three legs at 53.95 m spacing. The hull length was 69.25 m, with a maximum centre-depth of 8.55 m.

Detailed empirical and hindcast modelled weather and hydrographical data such as tidal height, significant wave height, current speed, conductivity temperature depth (CTD) and turbidity profiles etc. were also taken but analysis of these data are not presented here.

2.3 LOGGING PORPOISE ACTIVITY

A manual for T-POD data acquisition and analysis and a detailed description of associated software can be found at http://www.chelonia.co.uk. T-POD functionality and settings have been described, in detail, elsewhere [24-27]. In brief, T-PODs comprise a hydrophone, an analogue processor, a digital timing/logging system, and analysis software (TPOD.exe) that filters the data for porpoise clicks, after they have been transferred to a PC. T-PODs log the time and duration of porpoise-clicks to 10 μs resolution, distinguishing between other sources of energy in the same frequency band, such as boat sonar., T-POD settings are given in Table 1. All T-PODs were set to exclude logging click durations of <10 μs.

2.4 T-POD DEPLOYMENT

Following three days trial and optimisation, three T-PODs were deployed from the A6-A-*Kolskaya* complex from custom-made hand-winches to depths of 10 m, 25 m and 35 m. The T-PODs were permutations of V3s (identification numbers 406, 407, and 408 and a V4 (identification number 516). T-POD memories were updated from industry standard to 128 MB RAM and ran on 12 × 3.4 V D-cell alkaline batteries. Every 4–5 weeks, T-PODs were retrieved, the logged data downloaded onto a laptop PC (Sony Vaio VGN-S1XP, PGC-6C1M, Tokyo, Japan), the D-cells replaced and T-PODs re-deployed. At no point were all T-PODs recovered simultaneously, ensuring a continuous monitoring dataset.

2.5 INDICATORS OF PORPOISE ACTIVITY

Data were analysed through T-POD.exe v. 8.17.Trians using the CetHi setting only were analysed. This setting allows only data with the higher degree of certainty positive detection of the target species to be recorded. Data for each porpoise train were exported using T-POD.exe software into Microsoft Excel™ for analysis. We used two indicators of porpoise echolocation behaviour that each measured different aspects of activity, Encounter Rate and Minimum Inter-click Interval (MICI) .

2.5.1 Encounter Rate

An encounter is defined as a group of trains that are separated by periods of silence with a minimum duration of 10 min, after [2]. The encounter rate (encounters per h) was calculated as the number of porpoise encounters divided by the mean duration of each diel phase multiplied by the number of recording days. See Section 2.6 for diel phase determination.

2.5.2 Minimum Inter-click Interval

A description of the minimum inter-click-interval (MICI) per train is given in [2] and [26]. An MICI of <10 ms was used as a proxy indication of porpoise-feeding activity, as per [2].

2.6 DIEL CLASSIFICATION

A custom-written computer algorithm categorised porpoise trains into four diel phases: morning, day, evening or night (Table 2.), by comparison with civil twilight and sun-state tables from the US Naval Observatory (http://www.usno.navy.mil/). Technical definitions for precise rise, set, and twilight are explained on the USNO site at http://www.usno.navy.mil/USNO/astronomical-applications/astronomical-information-center/rise-set-twi-defs. The effects of the lunar cycle were not considered. The algorithm revealed the diel phase in which a train was detected and sorted the trains by whether they had a MICI of less than 10 ms, a proxy indicator of feeding behaviour.

2.7 STATISTICAL ANALYSIS

Statistical tests were performed using SigmaStat v.3.1 (Systat software Inc., California, USA). Data from each T-POD were analysed separately for calculations. Data were non-normally distributed (Kolmogorov–Smirnov tests $p < 0.05$); logarithmic and arcsine transformations failed to normalise data. Non-parametric Kruskal–Wallis, one-way ANOVAs, with the appropriate *post hoc* tests, were thus employed to assess significant differences for the indicators of porpoise activity.

3 RESULTS

Tidal heights and currents at all three locations were minimal (0.5 m, and 0.51–1.03 ms^{-1}, respectively), because of the installations' proximity to an amphidromic point, i.e. a position within a tidal system where the tidal range is almost zero, in the German Bight.

Data from the 10 m T-POD 406 were excluded because of its proximity to a previously unseen cooling-water vent, which generated high levels of high-frequency tonal noise in the porpoise band. All other T-PODs logged 2479 porpoise encounters during a total of 756 369 monitoring minutes (525.26 d).

3.1 ENCOUNTER RATE

Significantly more porpoise encounters were recorded at night (Kruskal–Wallis, one-way ANOVA on ranks, d.f. = 3, $H = 8.638$, $p = 0.035$). All *post hoc,* pairwise, multiple-comparison procedures (Tukey method) revealed this difference to exist between night and day ($p < 0.05$).

3.2 MINIMUM INTER-CLICK INTERVAL

The median MICI was shorter at night (Figure 2.). This result was significant throughout all T-POD deployments (Kruskal–Wallis, one-way ANOVA, $p < 0.001$; all *post hoc,* pairwise, multiple-comparison procedures, Holm–Sidak method, are illustrated in Figure 2). The shortest ICI in the entire dataset was 0.74 ms.

4 DISCUSSION

Overall results sustain the hypotheses that (i) porpoises are present at the offshore installation or, at least, within a few hundred metres of them, and (ii) there is a marked diel pattern in echolocation activity, and (iii) an equitable interpretation of this pattern is that porpoises are probably feeding at night below or around the platform complex.

Although a correlation between low Inter-click Click Intervals (ICI’s) on T-POD recordings and feeding behaviour has not been verified experimentally (and this research cannot prove *per se* that the MICI is a reliable indicator of feeding behaviour in porpoises), we can conclude at the very least that it is a useful indicator of the presence of a certain type of trains, though further evidence involving independent studies on the behaviour of porpoises, from cameras, time-depth recorders or similar instruments, is needed to establish the link to feeding.

Diurnal/diel patterns in Cetacean are common [see review by 28], but it is not clear whether these patterns are related to circadian rhythms, external cues (e.g. light/lunar cycles), diel activity in their prey species, or to some combinations of all three. There are no *a priori* reasons to expect diel patterns to be the same for all porpoises around the world and at all times of the year and in different tidal regimes. The results presented here, however, agree fundamentally with those of [2] who reported that using one POD only, the rate of Scottish harbour porpoise echolocation encounters and the proportion of trains with MICI <10 ms all peaked at night and were at their minima by day. Similar diel patterns have also been reported for a single POD study of wild porpoises in the Bay of Fundy, Canada [29].

Porpoises may produce more click trains and click bursts (inferred feeding attempts) at night to compensate of lack of light, though porpoise studies so far have been inconclusive or based on small sample sizes [e.g. 30, 31]. It is more probable that the nocturnal increase in proxy feeding behaviour is related to the concurrent increase in the availability of their prey. Porpoises use click bursts to investigate specific objects at close range, but also during the pursuit of live fish [30]. While in our study, we have no empirical evidence on fish species diversity, distribution and behaviour, or the prey-preferences of porpoises around installations, North Sea porpoises are known to feed on sandeels (Ammodytidae) and herring (*Clupea harengus*; [32, 33], both of are present in the Dogger Bank region [33, 34], and both exhibit diel patterns in behaviour [35 cited in, 36, 37]. Diel periodicity in fish species has also been found around installations [21]. Detailed discussions on prey behaviour are beyond the scope of this paper, however.

In conclusion, harbour porpoises frequented the offshore installation, possibly to feed, mainly at night. Replicated and controlled experiments should be carried out to explore the possibility that installations are important foraging areas, which has implications for rig-decommissioning decisions. If porpoises regularly cluster around installations within the 500-m exclusion zones, then they may historically have been omitted from population surveys, resulting in potentially significant underestimations of their true population status in the North Sea and other areas.

5 FIGURES AND TABLES

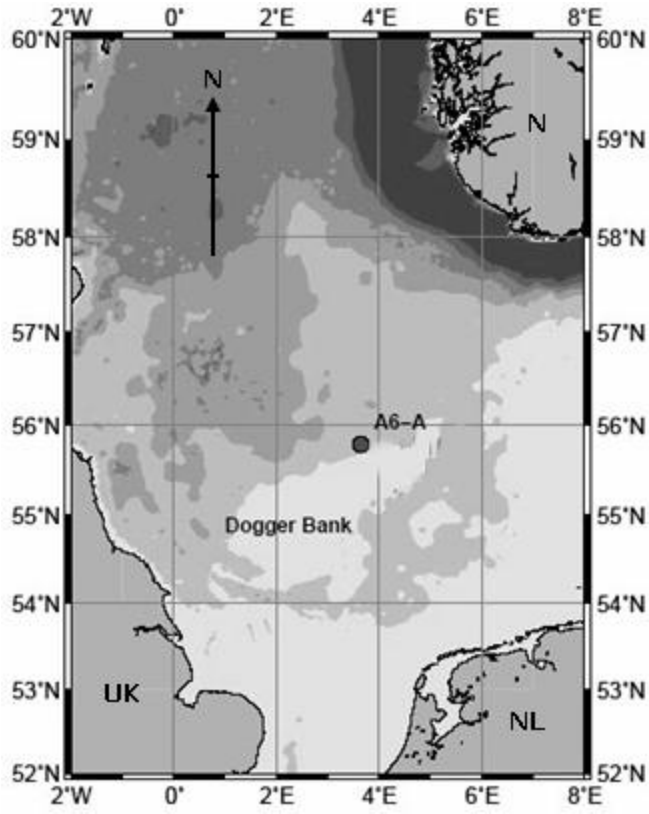

Figure 1: Location of A6-A-*Kolskaya* complex in the German Sector of the North Sea. Lightest grey bathymetry region delineates 30 m contours. Map projection: Mercator.

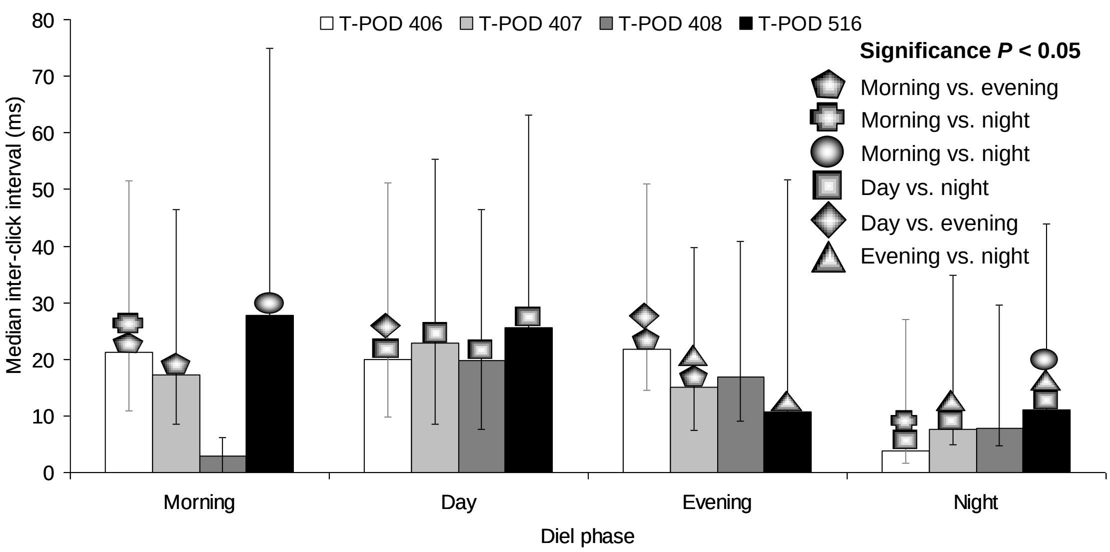

Figure 2. Minimum inter-click intervals (MICI) and inter-quartile ranges. The shapes refer to *post hoc* Dunn's tests that gave significant results at the level $p < 0.05$.

Version 3 T-PODs (identification numbers 406, 407 & 408)						
Scan	1	2	3	4	5	6
Target A filter frequency (kHz)	130	130	130	130	130	130
Ref. B filter frequency (kHz)	90	90	90	90	90	90
Selectivity ratio (A/B)	5	5	5	5	5	5
A integration period	Short	Short	Short	Short	Short	Short
B integration period	Long	Long	Long	Long	Long	Long
Minimum intensity	6	6	6	6	6	6
Scan limit no. clicks logged	160	160	160	160	160	160
Version 4 T-POD (identification number 516)						
Scan	1	2	3	4	5	6
Target A filter frequency (kHz)	130	130	130	130	130	130
Ref. B filter frequency (kHz)	92	92	92	92	92	92
Click bandwidth	4	4	4	4	4	4
Noise adaptation	++	++	++	++	++	++
Sensitivity	6	6	6	6	6	6
Scan limit no. clicks logged	240	240	240	240	240	240

Table 1: T-POD settings used throughout study.

(a)

T_1	T_2	T_3	T_4
Civil twilight start	(2 x sunrise) – (civil twilight start)	(2 x sunset) – (civil twilight end)	Civil twilight end

(b)

Diel phase	Time of day
Morning	From T_1 to T_2
Day	From T_2 to T_3
Evening	From T_3 to T_4
Night	From T_4 to T_1 the following day

Table 2: (a) Calculation of the four diel phases for input into the diel phase algorithm. T = start time. (b) Explanation of diel phases intervals.

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