Echosounders and sonars as a pressure factor

Preliminary results of a pilot project

Scientific note from DCE – Danish Centre for Environment and Energy

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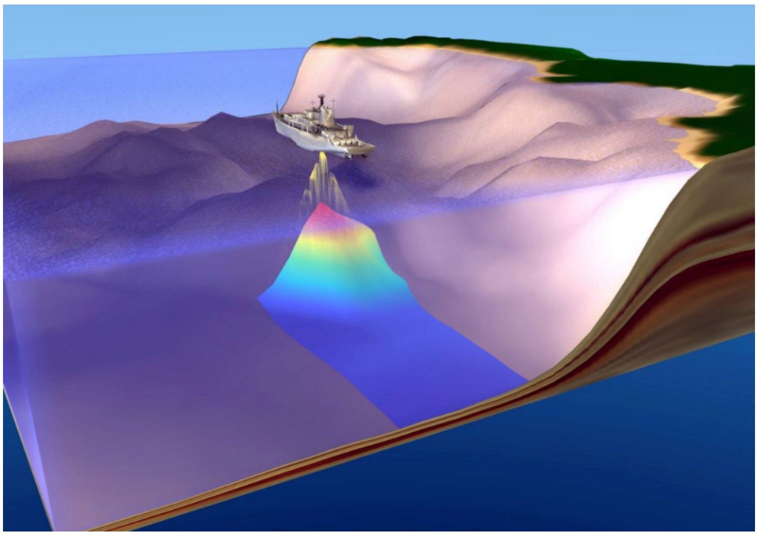

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Data sheet

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Contents

1 Background

Underwater noise is recognized as a significant pressure factor on the marine environment (European Commission, 2008). Numerous anthropogenic sources contribute to the underwater noise, and two categories are identified as particularly important with respect to negative effects on the marine environment: loud impulsive noise below 10 kHz (criterion D11C1 of the Marine Strategy Framework Directive) and continuous, low-frequency sound (criterion D11C2 of the Marine Strategy Framework Directive). A long list of other noise sources is known, and while each of these may perhaps be insignificant in isolation, they could be important when effects are cumulated across all sources due to their widespread use. One such common source is echosounders, as all larger ships and most smaller boats are equipped with at least one echosounder. In addition, for safety reasons, the echosounder is usually always operating, as the maritime rules of navigation prescribes that the crew must maintain lookout at all times *"… by* ***all means available****, suitable under the prevailing conditions ...*" (our emphasis). In practice, this means that an echosounder present on a ship must always be turned on and monitored.

Echosounders are recognized – by HELCOM, among others – to constitute a potential negative impact on the environment (see for example Lurton and DeRuiter, 2011) and that there is a need for investigating the extent of echosounders as a pressure factor and actual impact on marine organisms (HELCOM, 2021). Effects of echosounders on fish and marine mammals are poorly studied, but negative reactions has been documented in for example beaked whales (Ziphiidae; Cholewiak *et al.*, 2017) and short-finned pilot whales (*Globicephala macrorhynchus*, Quick *et al.*, 2017).

There is better documentation for negative effects for more powerful echosounders and multibeam sonars used for surveying at greater depth. Particularly noteworthy in this context is the mass-stranding of melon-headed whales (*Peponocephala electra*) on the coast of Madagascar, coinciding with – and likely caused by – a hydrographical survey with a 12 kHz multi-beam sonar system (Southall *et al.*, 2013).

Among sonars the most powerful type is military anti-submarine warfare sonars (ASW sonar). Effects of this type of sonar is well studied and very powerful reactions to ASW signals are documented from a wide range of odontocetes and mysticetes. See for example Southall *et al.* (2021) for an overview of studies and Parsons (2017) for a discussion of the possible implication for management.

Due to the knowledge gap regarding the contribution of echosounders to the anthropogenic soundscape a pilot project was developed in cooperation between Aarhus University and the Danish Ministry of Environment. The aim of the project was to study possible means to quantify the contribution from echosounders by analysing sound recordings obtained close to shipping routes. This scientific briefing reports on the findings.

2 Methods

Sound recorders for passive acoustic monitoring of odontocetes were deployed at four different positions in the Skagerrak between May and August 2021 (Griffiths *et al.*, 2023). The recorders were of the type ST600HF (Ocean Instruments, Auckland, New Zealand), programmed to record on a 50% duty cycle (30 minutes on, 30 minutes off)[1] at a sample rate of 384 ksamples/s (16 bit), yielding a bandwidth of 192 kHz. Two of the recorders (Gule Rev vest and Store Rev vest) were recording until mid-August, whereas the loggers at Gule Rev øst and Store Rev øst stopped recording prematurely – in mid-June and early July, respectively.

The four stations were placed in one of the most trafficked parts of the Danish EEZ (Figure 2.1) with about 70,000 ships passing Skagen (the Skaw) annually (Danish Maritime Authority).

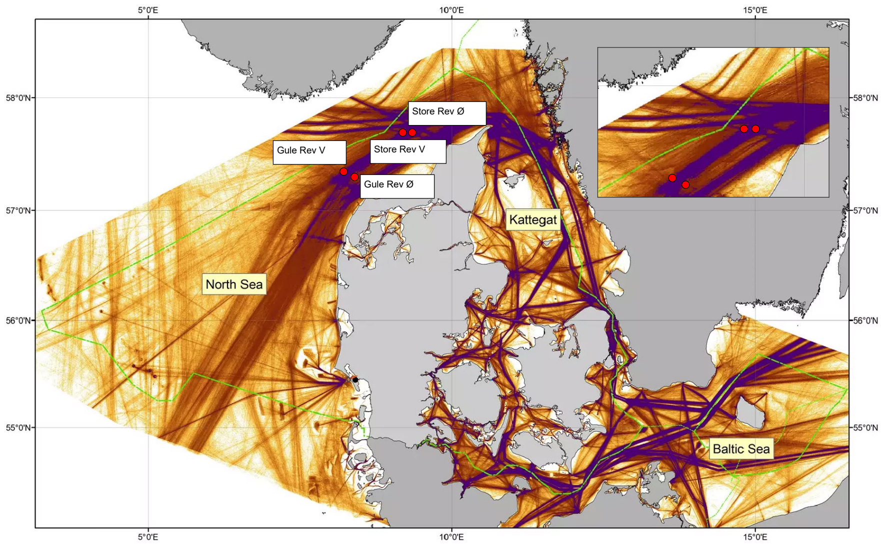

Figure 2.1. Location of the four monitoring stations on Gule Rev and Store Rev directly below the outer (south-bound) lane of the traffic separation system in the Skagerrak. The map and insert shows the traffic density in 2021 (density of AIS positions, from the Danish Maritime Authority).

2.1 Analysis

The raw recordings, stored as wav-files, were analysed with the software PAMGuard (Gillespie *et al.*, 2008). PAMGuard is a universal platform for sound analysis, allowing the user to select relevant analysis modules, each dedicated to particular tasks. The Whistle and Moan detector module (Gillespie *et al.*, 2013) was used to identify possible echosounder signals in the recordings, as this detector is well suited to find shorter pulses of pure tones and frequency modulated sweeps. Detection of tones and sweeps is based on time-frequency representation (spectrograms) of the signal and analyses the relative amplitude of the signal in time and amplitude bins. An FFT-size of 8192 was used, corresponding to a frequency resolution of 47 Hz over the 192 kHz bandwidth. This analysis resulted in numerous possible detections, each fulfilling the general criteria of the detector. A substantial amount of false positive detections, i.e. detections of sounds not from echosounders, but with similar properties, is inevitable when detectors such as the whistle and moan

[1] Duty cycle was erroneously stated to be 100% in the Danish edition of the report.

detector are used. The results were subsequently analysed for the occurrence of periodic pure tone signals, typical for echosounders.

To exclude detections unlikely to be from echosounders, results were filtered to only include detections at frequencies 13, 24, 28.5, 38, 40.5, 50, 83, 120, and 184 kHz, as these were commonly recurring frequencies in the recordings. The detections at 184 kHz were likely the aliased signals of a 200 kHz signal[2], which is a frequency commonly used by small-vessel echosounders.

After the detections were filtered a detection was only accepted as echosounders if the following two conditions were met: i) a minimum of 10 tonal signals within one minute of recording time, and ii) the peak frequency of all tonal detection were withing ±2 kHz of one of the accepted echosounder frequencies. A significant proportion of the detections were further verified by manual auditing of the spectrograms and discarded if they appeared unlikely to be from an echosounder, based for example on uneven repetition rate or pronounced amplitude variation from one pulse to the next.

The temporal occurrence of echosounder detections were quantified by counting the number of full minute intervals where the detection criteria were fulfilled (detection-positive minutes). The percentage of time detections occurred was calculated by dividing the detection-positive minutes by the total recording time, station by station. A similar calculation was made for hours and days, resulting in detection-positive hours and days, respectively.

Weak echosounder signals were commonly observed in the manual audit occurring in the minutes before and after the detection found by the Whistle and Moan detector, but too weak to fulfil the classification criteria. This led to an underestimation of the time where echosounders were detectable. To compensate for this, we also calculated the detection positive minutes in a precautionary way by assuming that echolocation signals were present 5 minutes before and 5 minutes after the actual detection, thus adding 10 minutes to the duration of each encounter. The percentage of time where echosounders could be detected were in this way reported by two numbers, of which one is certainly an underestimate (consisting only of detection-positive minutes reported by the computer algorithm) and a likely overestimate (adding 10 minutes to each encounter to include weak signals still likely to be audible to marine mammals.

[2] Aliasing occurs for signals above the Nyquist frequency, equal to half the sample rate, i.e. 192kHz in the present recordings. Due to the undersampling, the signal appears in the frequency spectrum at the frequency $2f_{Nyquist} - f_{signal} = 384kHz - 200kHz = 184kHz$.

3 Results

A large number of signals with characteristics typical of echosounder signals were identified in the recordings. Harmonic signals with fundamental frequencies between 13 kHz and 200 kHz were identified. The occurrence is listed in Table 3.1 and illustrated graphically in Figure 3.1. The most common type had a frequency of 50 kHz. Most echosounder sounds cannot be associated with specific ship types. Only exception is 38 kHz, which is the standard frequency for scientific echosounders, used by research vessels for hydroacoustic surveys of fish stocks (Jech *et al.*, 2005).

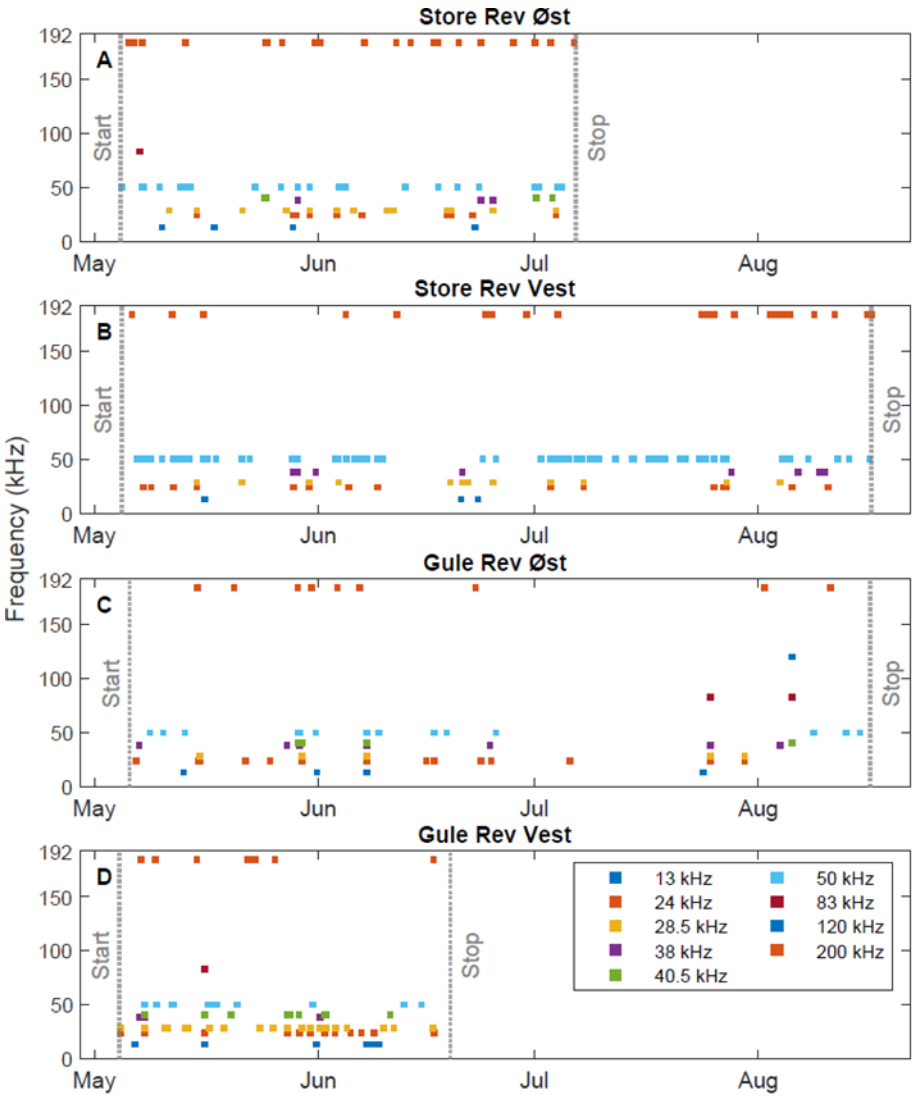

Figure 3.1. Occurrence of probable echosounder signals in the 2021 recordings from Gule Rev and Store Rev.

Detections of likely echosounder signals constituted less than 1 % of the total recording time for all four stations. Under the presumed precautionary assumption that echosounders would be audible to marine mammals 5 minutes before and 5 minutes after each detected event the estimated detection positive time increased to between 0.5% and 1.7% of the total time (Table 3.1). Detection-positive hours amounted to 2-7% of all recording hours and detections were present in between 39% and 79% of the recording days for the four stations. Echosounders are therefore to be considered a common sound source in the area but occurring in relatively short and isolated time intervals and therefore in a limited fraction of the total time.

Table 3.1. Occurrence of signals classified as echosounders in the recordings. Detections are given as number of positive minutes, hours and days, respectively, with indication of the percent of positive observations out of the total. Second column indicates an upper estimate of occurrence under the assumption that signals were audible 10 minutes longer than reported by the detector.

Station	Positive minutes	Positive minutes ±5 min	Positive hours	Positive days
Store Rev Øst	380 (0,4%)	1040 (1,1%)	79 (5,2%)	40 (63,4%)
Store Rev Vest	813 (0,5%)	1969 (1,3%)	122 (4,9%)	64 (61,6%)
Gule Rev Øst	345 (0,2%)	767 (0,5%)	46 (1,9%)	34 (33,1%)
Gule Rev Vest	556 (0,8%)	1138 (1,7%)	75 (6,8%)	36 (78,5%)

3.1 Examples of recordings of likely echosounder signals

Four typical examples of recordings of likely echosounder signals are shown in Figure 3.2.

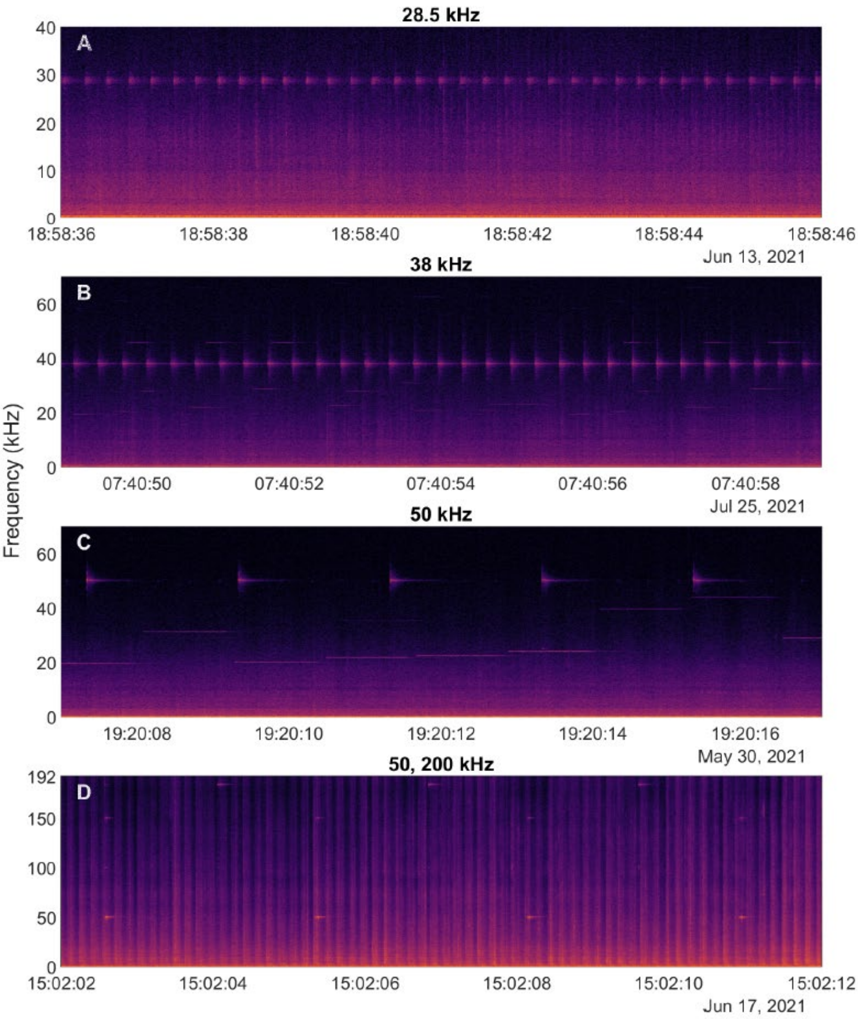

Figure 3.2. Example spectrograms showing four different types of presumed echosounders from the recordings. A) an echosounder with signals at 28.5 kHz, about 3.5 pulses per second. B) Echosounder at 38 kHz, also about 3.5 pulses per second. C) 50 kHz echosounder with 2 second pulse intervals. In addition, a series of weaker, longer pure tones, about 1 s duration, and increasing in frequency from 20 kHz, can be observed. The source of this signal is unknown. D) A 50 kHz echosounder and a 200 kHz echosounder. The latter is visible at 184 kHz in the spectrogram due to aliasing. The clearly visible vertical bands in the spectrum are amplitude modulations of the ship noise, caused by the rotation of the propeller.

3.1 Recordings of likely military sonars

Powerful pure tones (constant frequency, CF) and frequency modulated (FM) pulses below 10 kHz were identified in a number of recordings. This frequency band below 10 kHz is usually not used by echosounders, except for deep-ocean bathymetry echosounders. However, it is a frequency band typically used by many military anti-submarine warfare sonars (ASW sonar). Two typical examples are shown in Figure 3.3. Upper panel shows a type with signals several seconds long, consisting of a 1.5 kHz CF part, followed by an upward FM sweep. This type of signal matches specifications of several types of helicopter-borne dipping sonars, for example HELRAS DS100 (L-3 Ocean Systems, 2007). Lower panel shows a different type with shorter signals, with the CF-part around 6 kHz, also followed by an FM segment. These signals match specifications of some hull-mounted sonars, such as the ATLAS type ASO 713/723 (Atlas Elektronik).

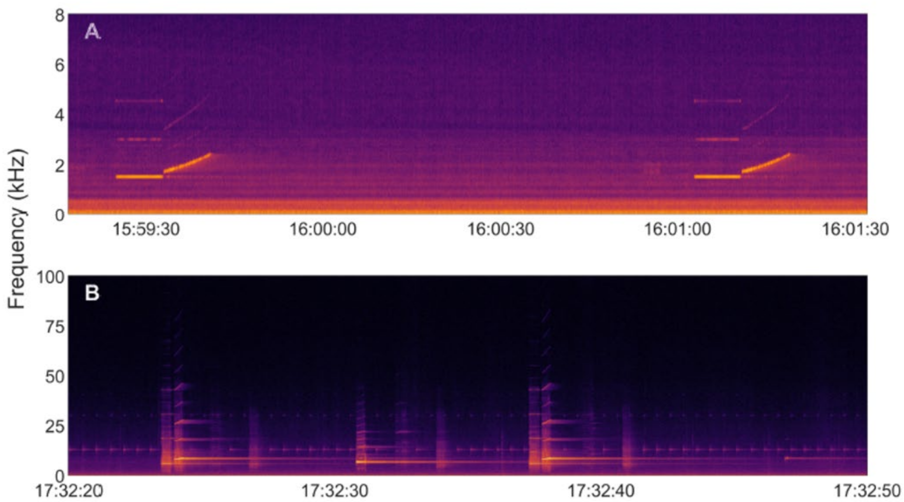

Figure 3.3. Examples of two different types of signals with characteristics matching military anti-submarine warfare sonars. Top shows a CF-FM signal in the frequency band 1.5-2.5 kHz (and harmonic overtones), bottom a CF-FM signal in the frequency band 6-9 kHz (and harmonic overtones). In this recording a 13 kHz echosounder-like signal is also visible, either from the ship that carried the sonar, or from a different ship.

4 Conclusion and further work

The preliminary analyses shows that it is possible to identify likely echosounders from passive acoustic monitoring recording systems (PAM) deployed over longer periods in the sea floor. Of particular importance is that it proved possible to identify the echosounder signals by means of semiautomatic algorithms, which required relatively minor subsequent verification by human observers. The use of this detector is a realistic possibility to screen PAM recordings routinely and therefor quantify on a larger scale the extent of echosounders in Danish waters. It is worth noting that the four recording stations used in this pilot study are located in one of the areas in Danish waters most heavily exposed to echosounders.

Our estimates of occurrence should be considered as minimum estimates for the location where the loggers were deployed, due to the conservative detection criteria. Yet, these results indicate that echosounder signals are recorded about 1% of the time at the recording stations. The short exposure duration suggests a low possible impact on marine mammals, but the occurrence of echosounders should nevertheless be regarded as high, as exposures occurred daily or almost daily throughout extended periods. Whether echosounders constitute a significant impact on marine mammals depends on the degree to which the possible reactions of the animals to the echosounders extends beyond the duration of the exposure itself.

It is planned to extend these analyses by quantifying the contribution of echosounders to the total underwater soundscape. This means providing better estimates of the percentage of the time echosounders are detectable above ambient noise, analysed separately for each station. Such a quantified metric would be useful in describing any possible the temporal trends in the anthropogenic noise pressure facture, which, in particular, is relevant for sensitive areas such as Natura2000 areas. A quantified metric will also be useful in studies of actual impact of echosounders on porpoises, where the occurrence of echosounders may be correlated with the presence/absence of porpoises monitored also by acoustic means, such as C-PODs or similarly suited detector.

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