Exposure and responses of harbour porpoises (*Phocoena phocoena*) to shipping noise in the Fehmarnbelt, Western Baltic Sea

HC-08

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1. Background & objectives

Most studies to date have focused on the impact of short-term impulsive noise on harbour porpoises, but little is known about how continuous vessel-related noise affects the animals. Using porpoise occurrence data from monthly digital aerial surveys (HiDef) and continuous Passive Acoustic Monitoring (PAM), coupled with high resolution noise data, this study investigates the responses of harbour porpoises to long-term exposure to shipping noise in the Fehmarnbelt, a significant maritime traffic route between Germany and Denmark.

2. Methodology

Harbour porpoise data

Monthly digital aerial surveys were flown across the study area in July 2021-August 2023 to record harbour porpoise occurrence using High Definition (HiDef) video technique (Fig. 1). Continuous Passive Acousitc Monitoring was conducted using a network of 22 C-POD stations. Data were further processed:

- HiDef data → GAM → Abundance estimates
- C-POD data → Detection rates

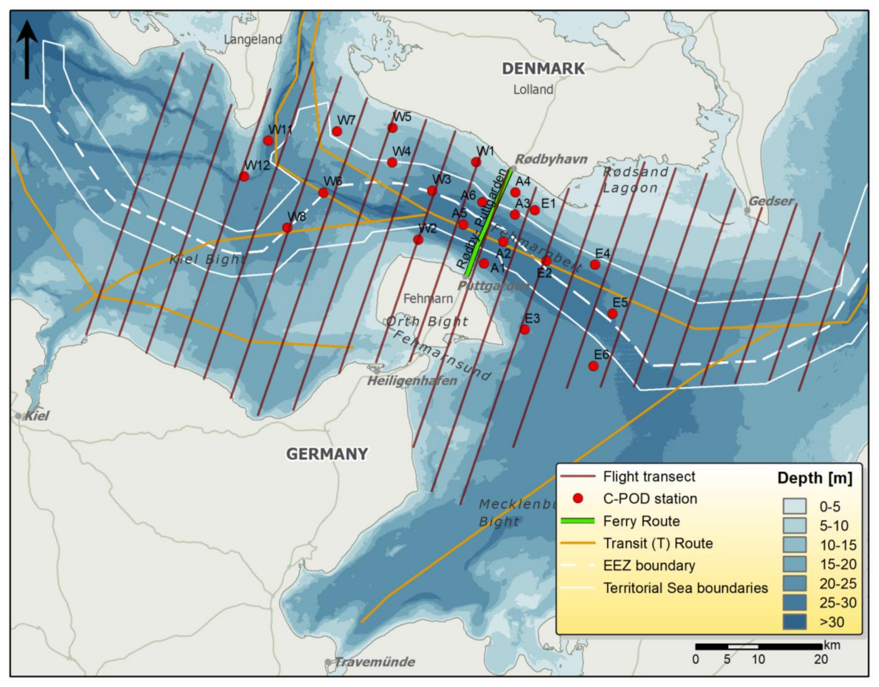


Fig. 1: The study area in Fehmarnbelt, between the German island of Fehmarn and Danish island of Lolland. For analysis, C-POD stations are categorised into subareas "W", "A", "E" depending on their locations.

Noise data

Noise data were obtained from the Quonops[1] underwater noise prediction platform which modelled the underwater soundscape of the Fehmarnbelt every quarter of the hour (hereafter "Quonops time") (Fig. 2). These 15-minute resolution noise data were then further processed to compute daily and seasonal median Sound Pressure Levels (SPL) needed for further analysis.

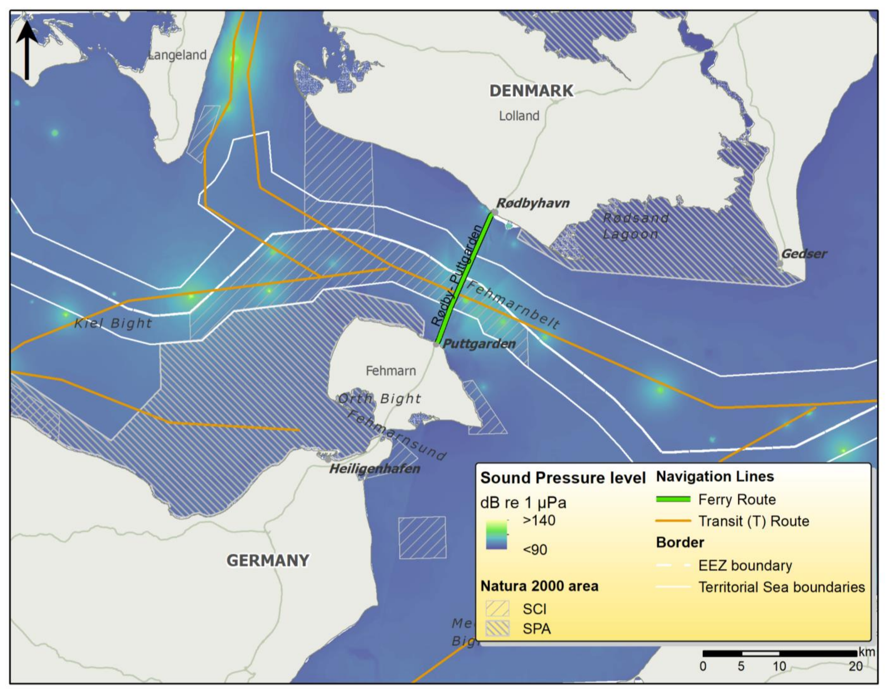


Fig. 2: An example of a noise map generated by Quonops giving a snapshot of the underwater soundscape at 22:00h on 01-12-2021.

2a. Analysis I

I. Does underwater noise influence the distribution/occurrence of harbour porpoises?

Generalized Additive Models (GAM):

HiDef (daily resolution)

Abundance estimates ~ SPLs (daily res.) + Transect ID + Shipping intensity + *

PAM-1 (daily resolution)

%Detection rates/day ~ SPLs (daily res.) + POD ID + Subarea + *

PAM-2 (15-minute resolution)

Detections (binary 'Yes'/'No') ~ SPLs (15min res.) + Detections 5 mins prior + Hour of day + POD ID + Subarea + *

*Predictors common to all models: Water depth, bottom substrate, distance to land/shipping lane/windfarms, seabed slope, current speed & direction, sea surface temperature, salinity, geographical coordinates, Julian day, year, and month.

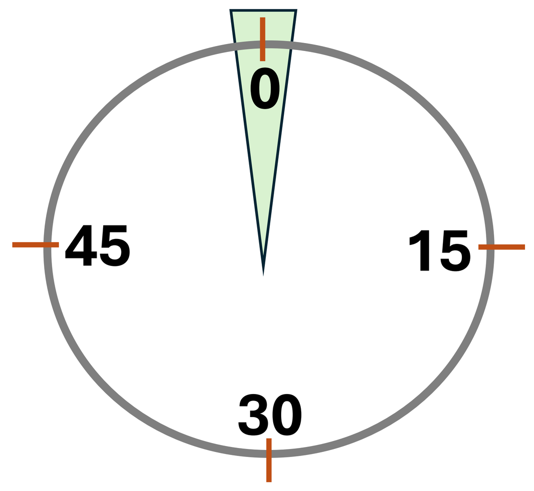
2b. Analysis II

II. Do harbour porpoise acoustic detections differ in varying noise levels?

"Quonops time" = hh:00, hh:15, hh:30, hh:45

Sound pressure level (SPL) at hh:mm = ??? dB

Porpoise detected at hh:mm ± 1 min = Yes/No?



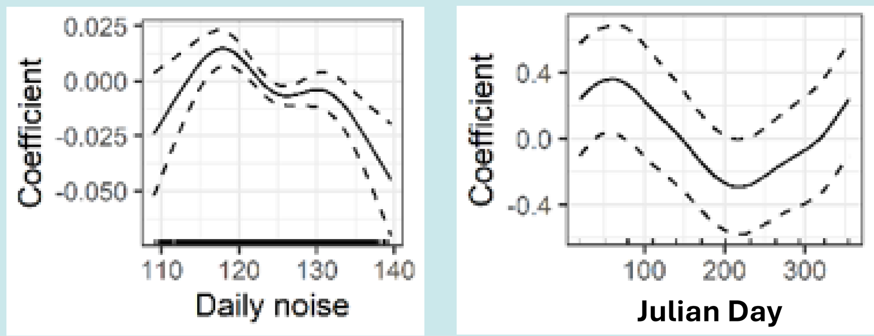
Quonops time	Station	SPL	Porpoise detected?
2021-08-05 18:00	A1	121	Yes
2021-08-05 18:15	A1	126	No
… 2022-02-12 07:45	W02	130	Yes

1. Compute number of occurrence (relative frequency):
   - All Sound Pressure Level (SPL_x)
   - Positive porpoise detection at every SPL_x
2. Visual analysis (boxplots, histograms to compare similarity of distribution)
3. Statistical tests:
   - Kolmogorov-Smirnov (K-S) test → Are there any difference between SPLs when porpoises were detected vs. when not detected?
   - Cliff's delta test[4] → Effect size, i.e., if there is a difference, how substantial is the difference?

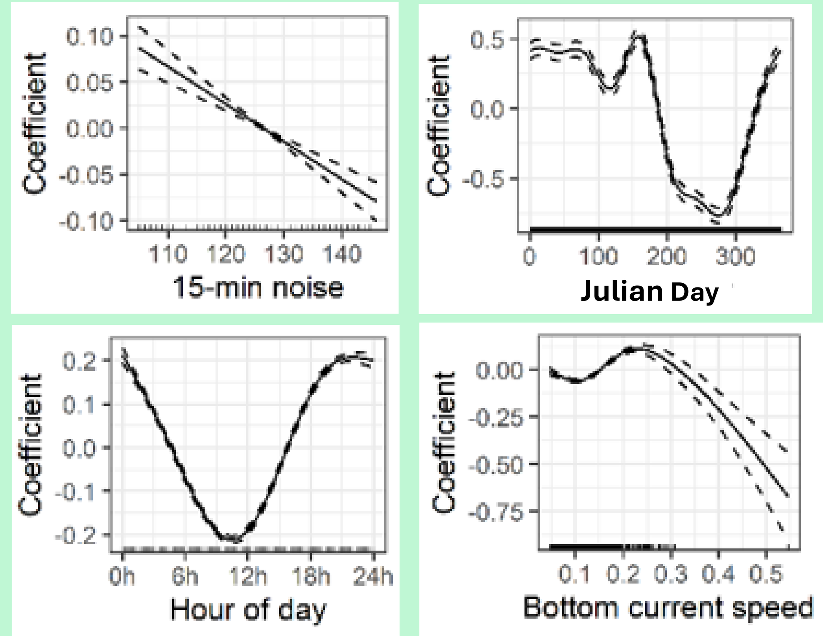
3a. Key findings I

- Noise was significant only in PAM-1 and PAM-2 models – Detections ⬇ as noise ⬆
- Distance to shipping lane was significant in the HiDef model – Porpoise abundance ⬆ as distance to shipping lane ⬆ up to 5 km away

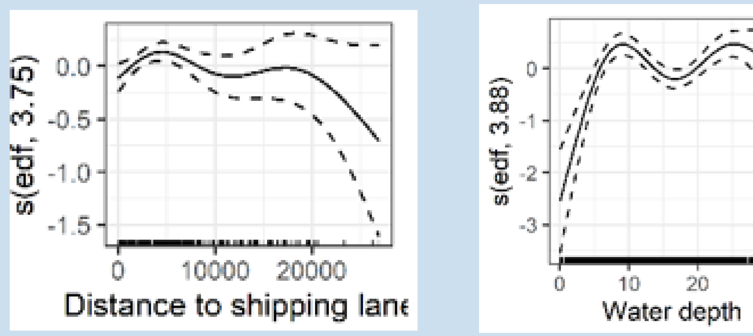
PAM-1 (daily resolution)



PAM-2 (15-minute resolution)



HiDef (daily resolution)



3b. Key findings II

- SPLs predicted at all C-POD stations ranged within 98 – 184 dB re 1 µPA
  - 1st – 3rd quartile = 120 –130 dB re 1 µPA
  - Median = 125 dB re 1 µPA
- Porpoise detections were more frequent at ≤123 dB re 1 µPA (Fig. 3 & Fig. 4).
- Two-sample K-S test: D = 0.072, P< 0.05
- Cliff's delta: δ = 0.088 (CI: 0.084 – 0.091) → negligible difference

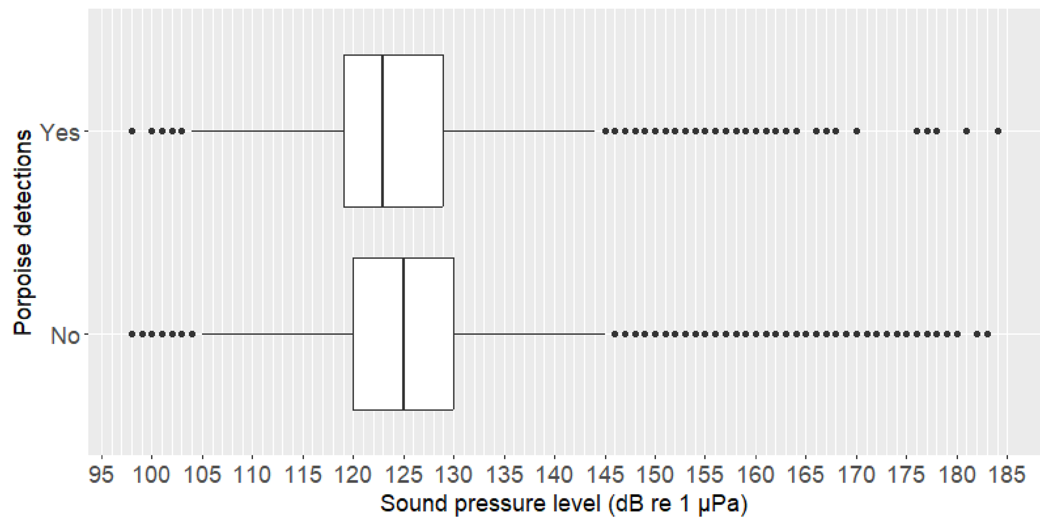


Fig. 3: Comparison of SPLs with and without porpoise detections.

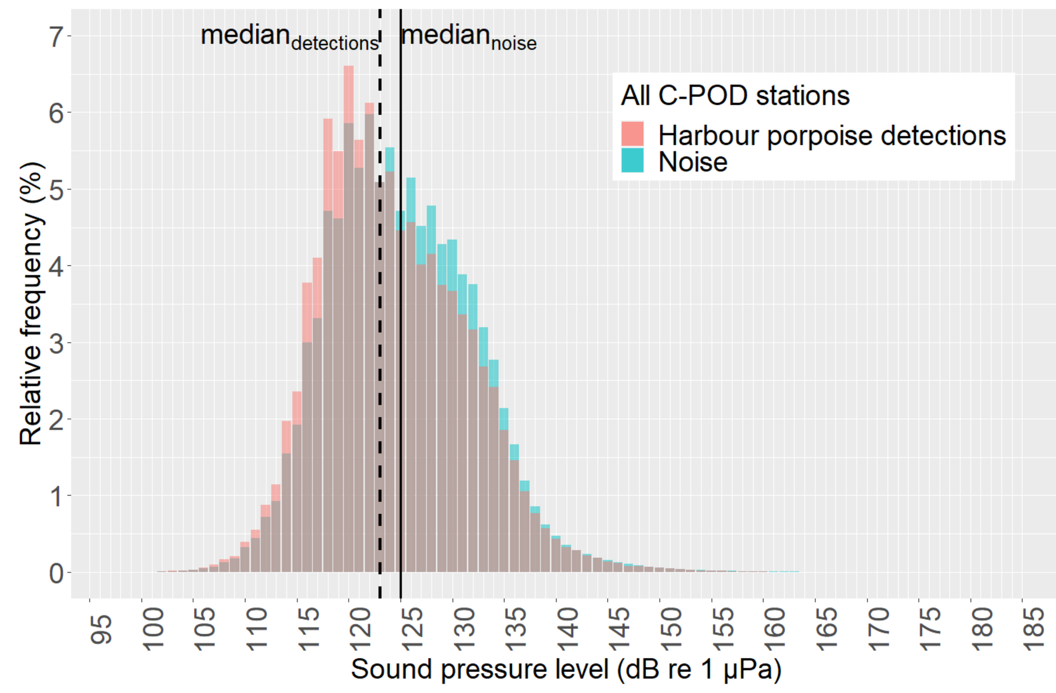


Fig. 4: Number of occurrence (expressed as relative frequencies) of SPLs predicted at all C-POD stations (blue) compared to number of harbour porpoise detections (red) at all SPLs. Note that the bars for SPLs <100 dB and >155 dB are too low to be visible here.

4. Conclusion

- Underwater noise has a significant influence on the acoustic detections of harbour porpoises, with the probability of detections decreasing as noise levels increase.
- Porpoise abundance are lower at distances closer to shipping lanes, gradually increasing with increasing distance away (up to 5 km), which may also indicate an effect of noise as it is much louder within shipping lanes than the other parts of Fehmarnbelt.
- Harbour porpoises are acoustically detected more frequently during quieter times and/or in quieter environment.
- There is a statistically significant difference (K-S test: D = 0.072, P<0.05) between the distribution of noise levels during times when porpoises were acoustically detected and when not detected.
- However, Cliff's delta indicated a negligible effect size of this difference (δ = 0.088), suggesting only that noise levels without detections were slightly higher than noise levels with detections.

References

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