Arctic diel and circadian acoustic pattern of orcas, fin, and humpback whales revealed by two months of continuous recordings

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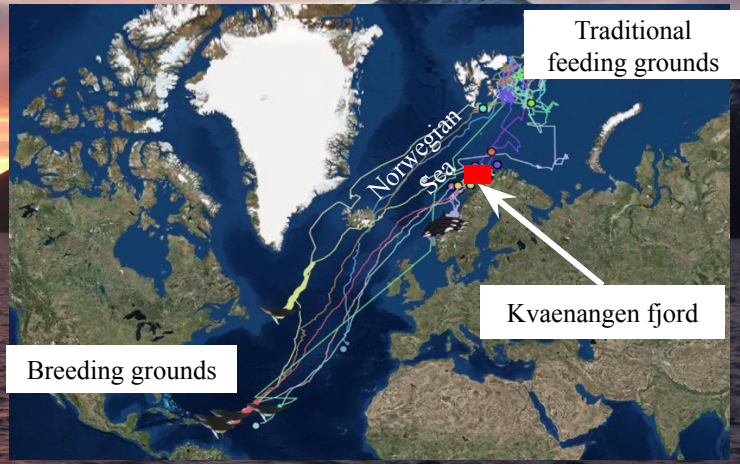


Migratory map of humpback whales
WhaleTrack/UiT the arctic University of Norway

HERRING : IMPORTANT RESSOURCES

- Aggregate in fjord in winter
- Attract many predators
- Orcas, specialized herring hunters

- Recent northward shift of wintering grounds
- New feeding grounds for humpback and fin whales
- First observation in 2010 since a century

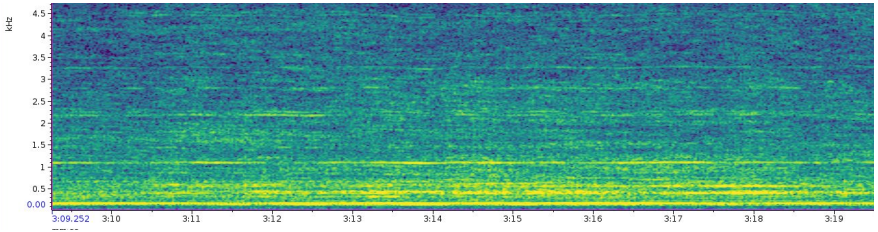
ANTHROPOGENIC ACTIVITIES

- High fishing activity : 400 000 t per year
- Whale watching activities
- Acoustic pollution in low-frequency (10-200 Hz)

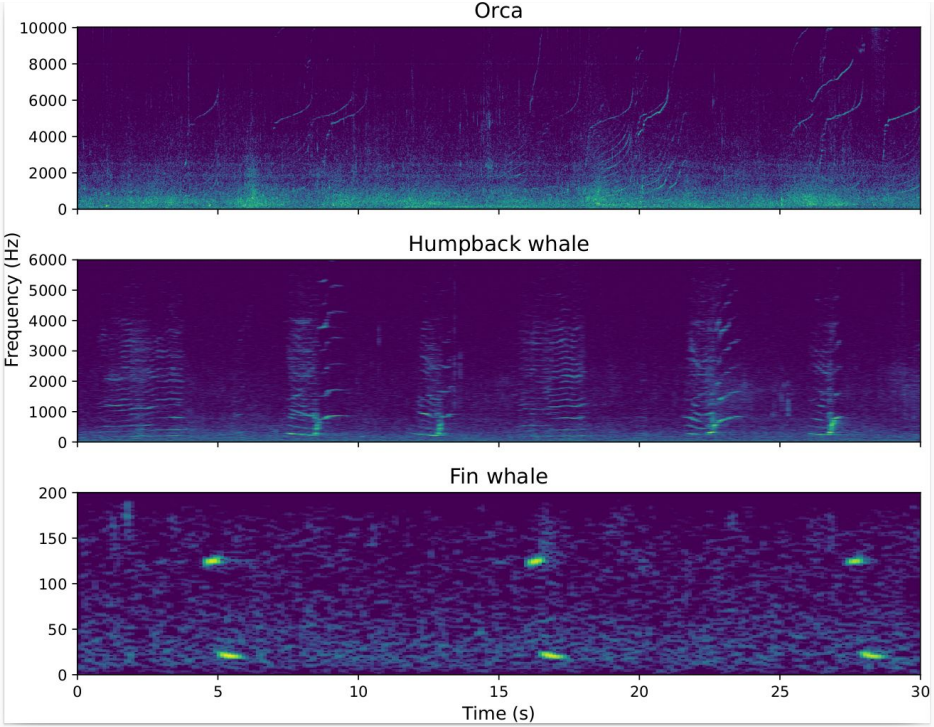
Killer whales feeding near fishing net, winter 2023

Humpback and killer whales feeding near fishing net, winter 2024

Spectrogram of boat noise, 2023-01-15 13:01



ACOUSTIC COMMUNICATION



- Interference with cetaceans behavior

  → What kind of interactions ?

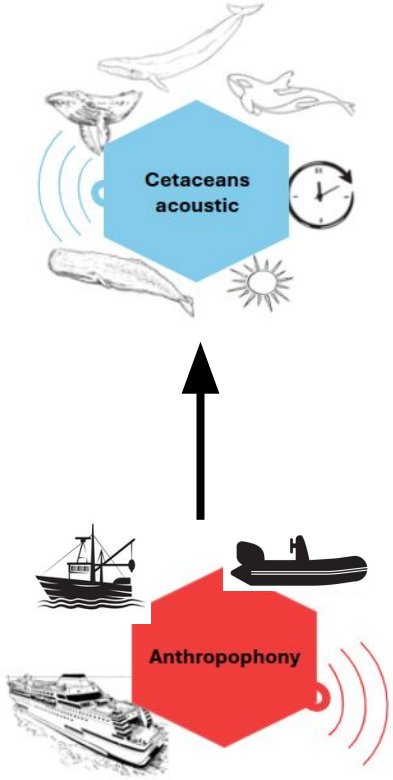
  → Competition ? Depredation ?

OBJECTIVES

Define the daily and seasonal pattern of cetaceans acoustic behavior

Distinguish geophony and anthropophony

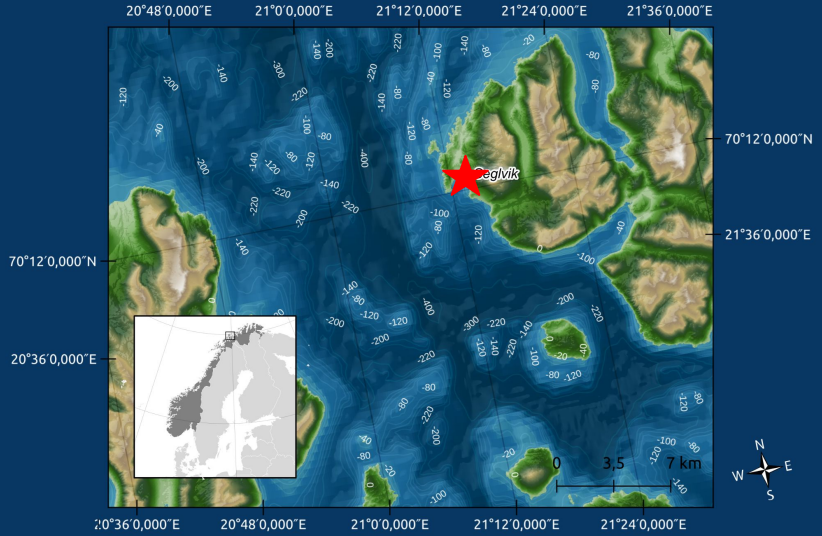
How anthropophony influence the pre-defined patterns ?



DATA ACQUISITION

- November 2022 - January 2023
- Continuous recording
- Fixed stereo antenna
- 1500 hours of recordings

The stereo antenna
(H. Glotin, deployed with M. Poupard nov. 2022)



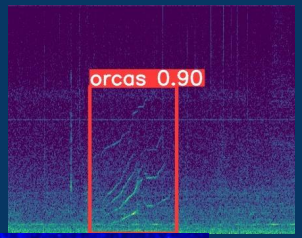
Bathymetric map of the Kvaenangen fjord and location of the antenna (Red star). © S. Chavin

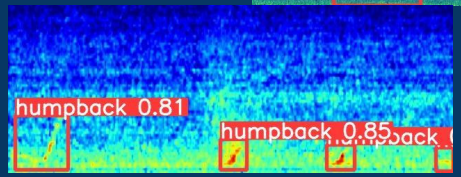
DATA PROCESSING

YOLO

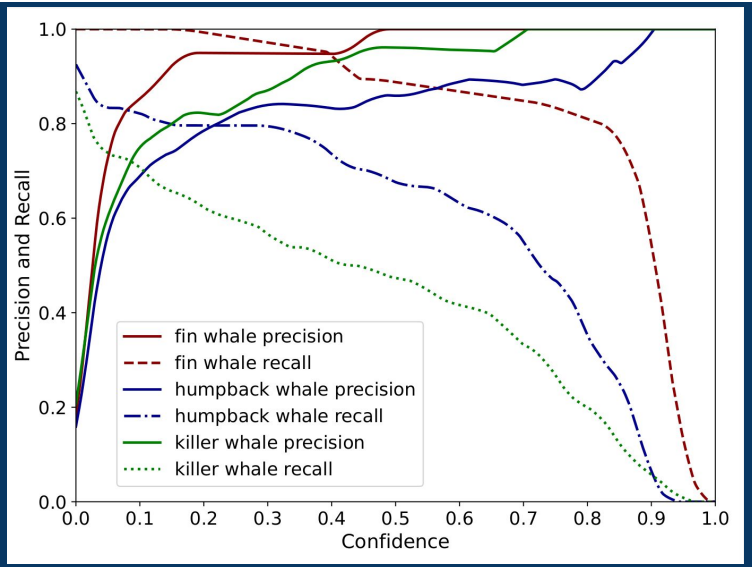
- Neural network
- Based on object detection in images
- One model per species
- Tested in different ambient noise conditions

Prediction examples made by YOLO for humpback and killer whale with the detection confidence.





Species	Fin	Humpback	Orcas
Map50 (%)	99	82	74



Precision and recall versus confidence curves for the validation set of YOLO models trained for each species.
Precision : True Positives among all detections
Recall : False negatives
Girardet et al. 2025

DATA ANALYSING

METRICS

Performed for different time unit (daily, hourly (each hour of each day), circadian, and diel (light dependent)).

- Presence rate (PR) = proxy of presence of vocalizing animals

$$= \frac{\textit{number of recordings with detections}}{\textit{total number of recordings}}$$

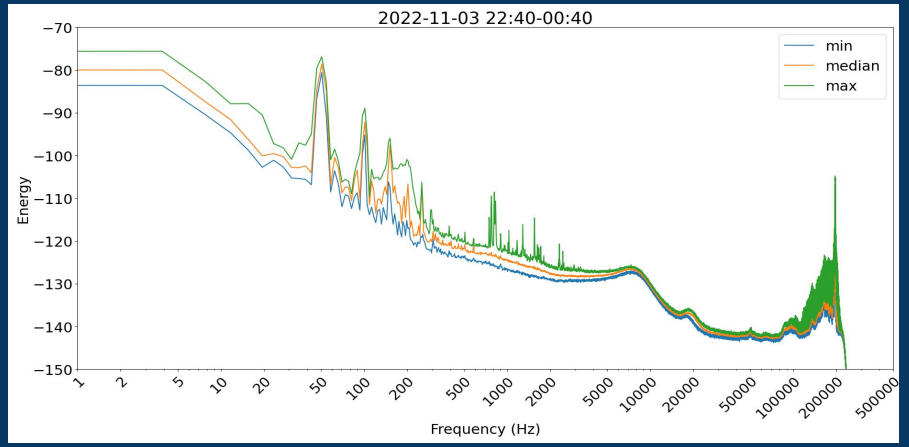
- Detection rate (DR) = proxy of the intensity of acoustic activity

$$= \frac{\textit{number of vocalizations}}{\textit{total recording time (in min)}}$$

AMBIENT NOISE

AMBIENT NOISE

- Power spectral density (PSD) estimation
  - PSD converted in decibel
  - Normalized by hydrophones parameters



Example of DSP in the fjord in November 2022

DATA SPLITTING

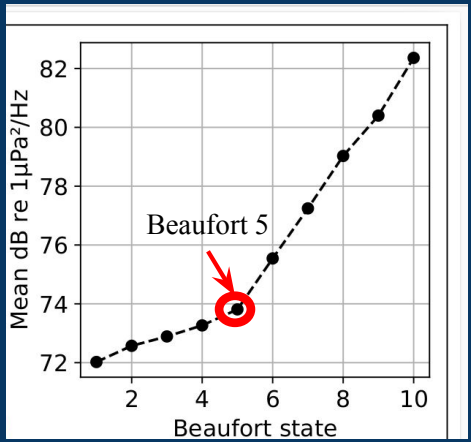
SEA STATE - GEOPHONY

Meteorologisk institutt

- Wind speed retrieved from Meteorological institute
- Wind speed converted into Beaufort scale
- Influence of Beaufort on ambient noise
- Threshold selection

Force	Wind Speed (knots)	Description
0	0–1	Calm
1	1–3	Light air
2	4–6	Light breeze
3	7–10	Gentle breeze
4	11–16	Moderate
5	17–21	Fresh breeze
6	22–27	Strong breeze
7	28–33	Moderate gale
8	34–40	Fresh gale
9	41–47	Strong gale
10	48–55	Whole gale
11	56–63	Storm
12	64+	Hurricane

Beaufort scale



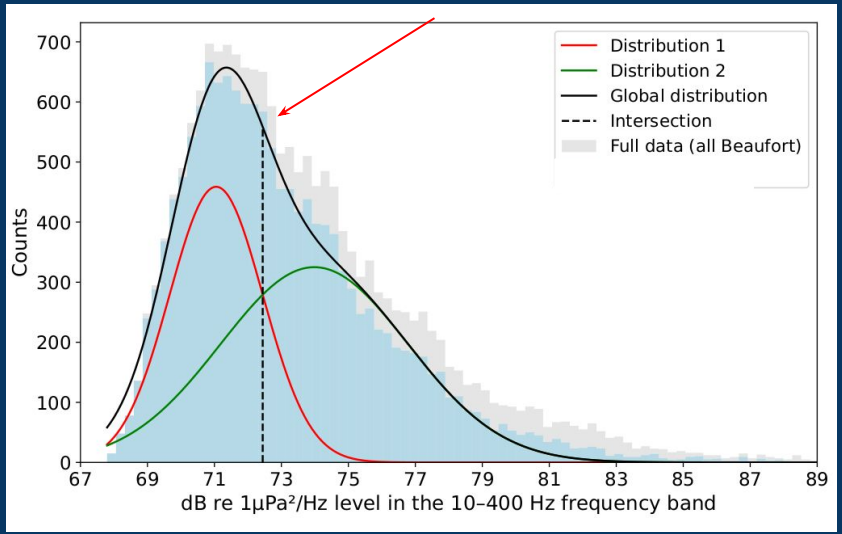
Mean dB re 1µPa²/Hz level for each Beaufort level.

DATA SPLITTING

AMBIENT NOISE - ANTHROPOPHONY

- 10-400 Hz frequency band for anthropophony
- Gaussian fit
- Threshold selection for predominant anthropophony

Selected threshold
72.44 dB re 1µPa²/Hz



Distribution of dB re 1µPa²/Hz levels in the 10-400 Hz. Girardet et al. 2025

MODEL PERFORMANCES

Species	Fin	Humpback	Orcas
Map50 (%)	99	82	74

- Decrease in performances in higher sea state

Performances for each models in different sea states.

	Fin	Humpback	Orca
All B	82	73	70
B < 3	84	77	73
B = 3-5	79	75	80
B = 6-8	85	76	60
B > 8	86	64	64

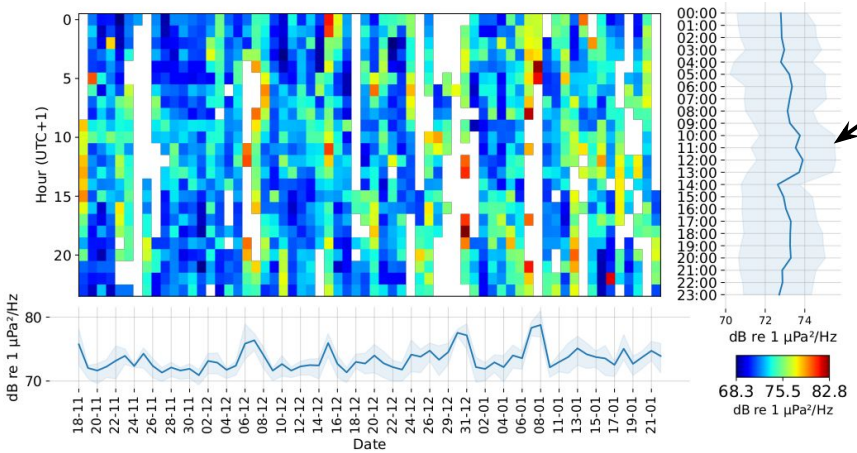
- Similar performances for different anthropophony-like level

Performances for each models in different ambient noise in 10:400 Hz frequency band

	Fin	Humpback	Orca
All A level	95	75	80
A < 72.4	92	79	71
A = 72.5-77.9	96	74	80
A = 78-81.9	98	78	80
A > 82	95	76	90

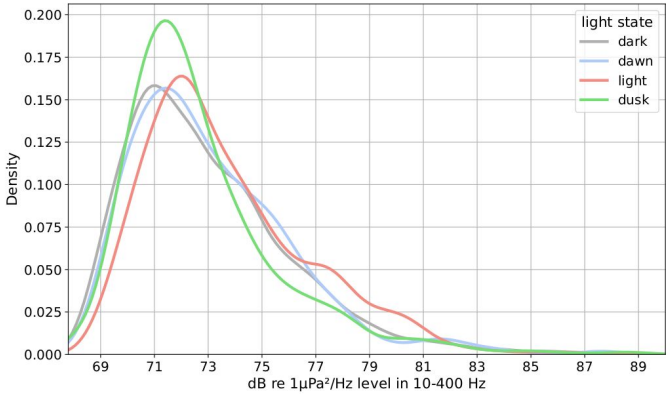
ANTRHOPOPHONY-LIKE

◊ No clear circadian pattern



Calendar heatmap showing mean anthropophony levels (anthropophony subset) per hour (y-axis) for each day from 18 Nov. 2022 to 23 Jan. 2023 (x-axis). White cells represent hours without recordings. Evolution of ambient noise levels: daily (bottom) and circadian (right) median values (solid lines) with interquartile ranges (shaded areas between the 25th and 75th percentiles). Girardet et al. 2025

◊ Anthropohony higher during light



Smoothed distributions (KDE) showing noise levels during dark (n = 10544, grey), dawn (n = 1096, blue), light (n =3398, red) and dusk (n = 1066, green) periods. Girardet et al. 2025

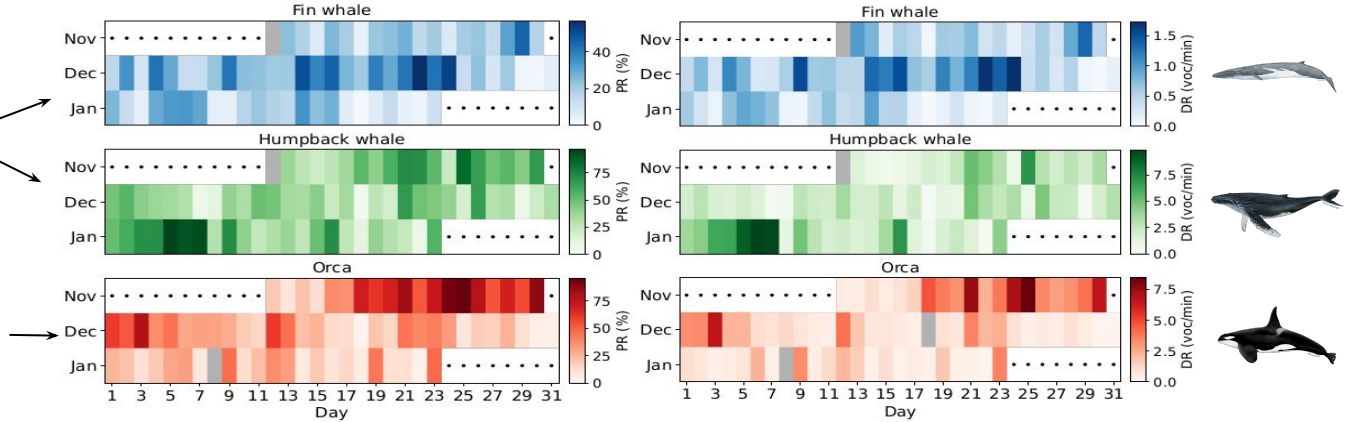
ACOUSTIC BEHAVIOR

◊ Distinct period of maximum presence and activity

Continuous acoustic presence

Maximum presence and activity: end of november

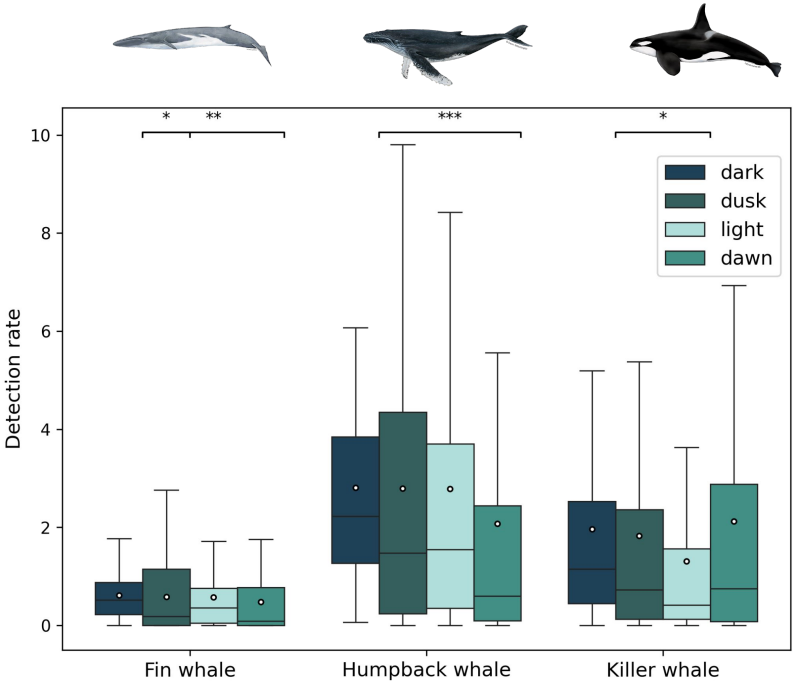
*Acoustic **presence** rate* | *Acoustic **detection** rate*



Calendar of daily PR and DR for the three species. Girardet et al.2025

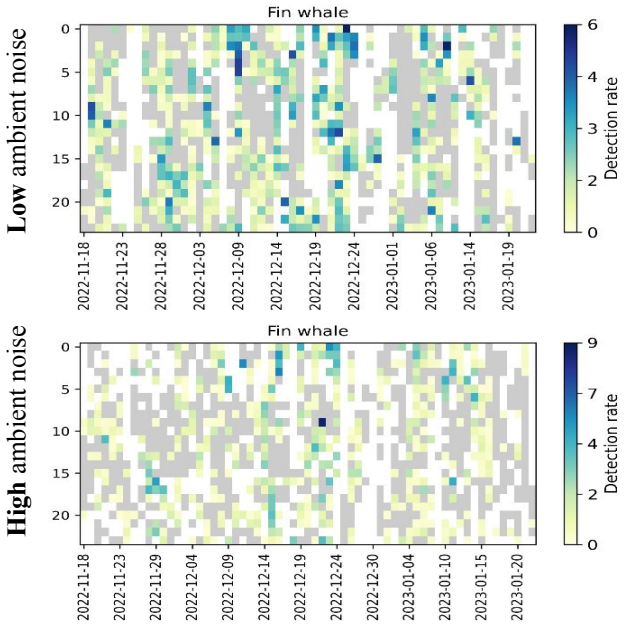
DIEL PATTERNS

- Fin whales significantly more active during dark than dusk and dawn
- Humpback whales lower activity during dawn
- Killer whales significantly more active during dark than light.



*Detection rate according to light conditions and differences between them for the three species. Significance levels are illustrated with stars (*p < 0.05; **p < 0.01; ***p < 0.001). Girardet et al. 2025*

ANTHROPOPHONY INFLUENCES

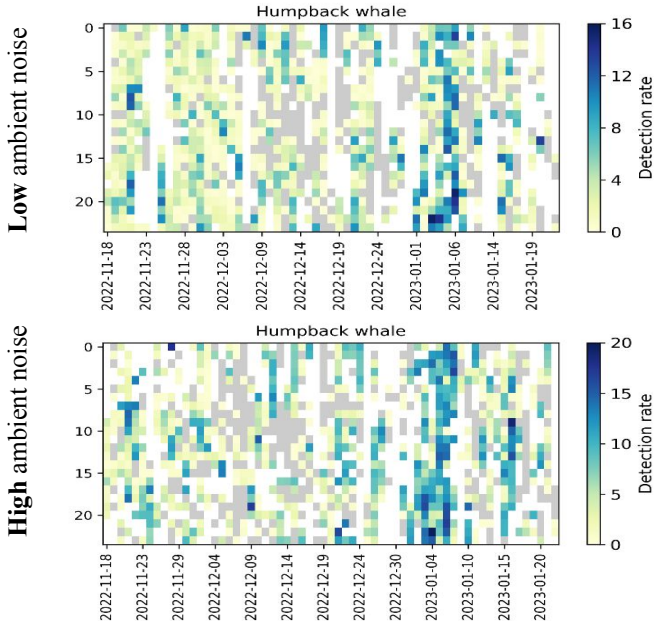


Calendar of DR for each hour of each day of the recording period. Grey cells represent hours without detection, white cells represent hours with no data. Girardet et al. 2025

- Hourly : PR and DR significantly lower in noisy conditions
- Daily : negative correlation between noise and PR or DR

- Limitations in detection performances ?
- **Avoidance ?**
- **Cease vocal activity ?**

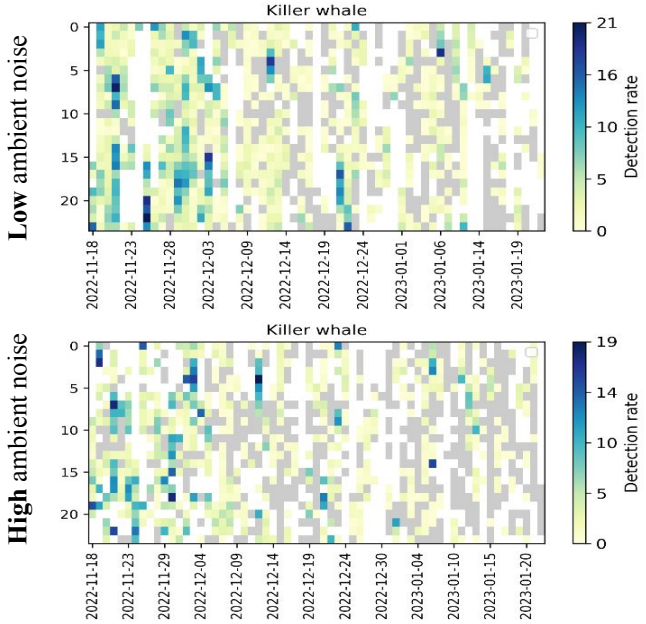
ANTHROPOPHONY INFLUENCES



Calendar of DR for each hour of each day of the recording period. Grey cells represent hours without detection, white cells represent hours with no data. Girardet et al. 2025

- Hourly : Higher DR in noisy condition, unchanged PR
- Daily : negative correlation between noise and DR but not PR
- Complex response, time scale dependant
- **More individuals ? Lombard effect on short term ?**
- **Avoidance on long term ? Cease vocal activity ?**

ANTHROPOPHONY INFLUENCES



Calendar of DR for each hour of each day of the recording period. Grey cells represent hours without detection, white cells represent hours with no data. Girardet et al. 2025

- Hourly : DR slightly lower, PR significantly reduced in noisy conditions
- Daily : negative correlation between noise and PR or DR
- Avoidance ?
- **Decreased vocal activity ?**

GEOPHONY INFLUENCES

*Daily and hourly spearman correlation coefficient (ρ) between species PR and geophony noise level with significance levels shown as stars (*p < 0.05; **p < 0.01; ***p < 0.001). n.s. for non significant.*

Species	daily	hourly
Fin	$\rho = -0.41^{***}$	$\rho = -0.21^{***}$
Humpback	$\rho = -0.34^{***}$	n.s.
Orca	$\rho = -0.4^{***}$	$\rho = -0.25^{***}$

- Presence rate only
- Greater influence on daily basis
- PR of three species negatively influence by geophony

SUM UP

Cetaceans change their acoustic behavior according to ambient noise sources.

Next step:

Distinguish thank to AIS data the impact of fisheries and whale watching.

	Presence rate / Detection rate	Anthropophony	Geophony
	Daily		
			
			
	Hourly		
			
			

Significant positive correlation in green*, *significant negative correlation in red*, *insignificant correlation in gray*, *and non tested in white.

Acknowledgements

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