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Vocal compensation to anthropogenic noise in pilot whales

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BACKGROUND

Anthropogenic noise affects marine life through **auditory masking**, where communication signals overlap with noise in time and frequency. Animals may adapt by shifting call frequencies, delaying calls, increasing call repetition, or raising call loudness — known as the **Lombard response**.

Aims

Investigate presence of the Lombard response

- **2** Test variation across call type and dive context
- 3 Assess call output level variation at depth



RESULTS

We analyzed 1336 calls from 18 individuals. Call output level generally increased with 0.50 ± 0.06 dB per 1 dB increase in noise (dB/dB; p<0.0001), indicating a **partial Lombard response [B]**.

METHODS

Resident pilot whale groups were simultaneously tagged with sound and movement recording **DTAGs** in the Strait of Gibraltar, a high-traffic area.

Calls were manually classified into four main call categories [C], then BirdNet-derived feature vectors were reduced via UMAP and clustered. Each call was linked to its **dive** context, categorized as surface (0-80m), shallow dive (0-300m), deep dive descent (0-800m), and deep dive ascent (800-0m).

Calls were extracted with tailored frequency bands based on normalized power spectra **[A]**, containing 95% of call energy. Background noise was measured from a 0.1 s window preceding each call.



Significant interaction between noise level and call type suggested a **call type-dependent** (p<0.0001) partial vocal compensation. Lombard response did not vary significantly between dive contexts (p = 0.08).

Each call type showed distinct slopes; high-frequency 0.86 \pm 0.10 dB/dB, low-frequency 0.36 \pm 0.05 dB/dB, short pulsed 0.20 \pm 0.09 dB/dB, and two-component 0.17 \pm 0.08 dB/dB **[C]**.



CONCLUSION

- Many cetacean species rely on acoustics and are vulnerable to masking due to increased anthropogenic noise.
- We showed a partial Lombard response in pilot whales, like other cetacean and terrestrial species. This may limit their ability to overcome masking and decrease their active **communication space**.
- Call-type specific Lombard response likely reflects a combination of masking, physiological constraints, and function.





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