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Influence of Ocean Dynamics on Cuvier's Beaked Whale *(Ziphius cavirostris)* Presence and Their Prey

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Question

Do mesoscale ocean-surface and prey dynamics influence the presence of Cuvier's beaked whales in a submarine canyon?

Background

- Cuvier's beaked whales *(Ziphius cavirostris)* dive below 1000 m to forage predominantly on deep-sea squids.
- Long-term passive acoustic monitoring identified Site E, a submarine canyon in Tanner Basin (~1350 m deep), and particularly Site W, northwest of Tanner Basin (~1500 m deep), (Fig 1) as foraging hotspots for Cuvier's beaked whales (Zc).
- Little is known about the prey abundance and how ocean dynamics might impact the availability and distribution of prey.

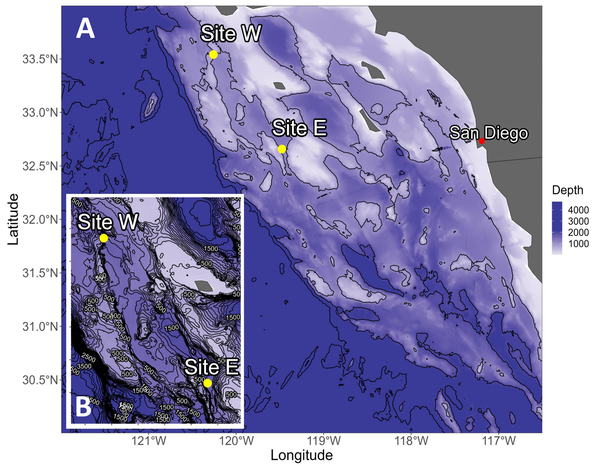

Fig 1. Study locations (Site E and Site W) off the coast of California. Panel A has 1000 m contour lines. Panel B has 100 m contour lines. GEBCO data.

Methods

Ocean Surface Dynamics: Gridded daily Aviso backwards-in-time finite-size Lyapunov exponents (FSLEs), serve as a proxy for surface mesoscale features. Averaged within a 25 km radius of the study site, they yield a daily FSLE strength value. Increased magnitude of FSLE strength indicates a frontal edge or eddy boundary, representing high horizontal stretching[1].

Prey-field Estimation: A Simrad Wideband Autonomous Transceiver (WBAT), deployed intermittently from 2017 and 2022 at ~1285 m (Site E) and ~1400 m (Site W) depth, recorded 70 kHz acoustic backscatter for 5 minutes every 30 minutes. Data was processed (Echoview v13.1) to retain putative prey backscatter between 1125-1275 m (Site E) and 1000-1150 m (Site W). The daily integrated backscatter, in units of Nautical Area Scattering Coefficient (NASC, m^2/nm^2) was used as a proxy for biomass.

Predator Detection: High-Frequency Acoustic Recording Packages[2] (HARPs) were deployed in Tanner Basin throughout 2017-2022. Cuvier's beaked whale echolocation clicks were detected in the recordings and summed as minutes of Zc presence per day.

Generalized Additive Model: Zc presence, was modeled using a 4-day average of NASC and FSLE, and season, exhibiting a 4-day autocorrelation.

Data

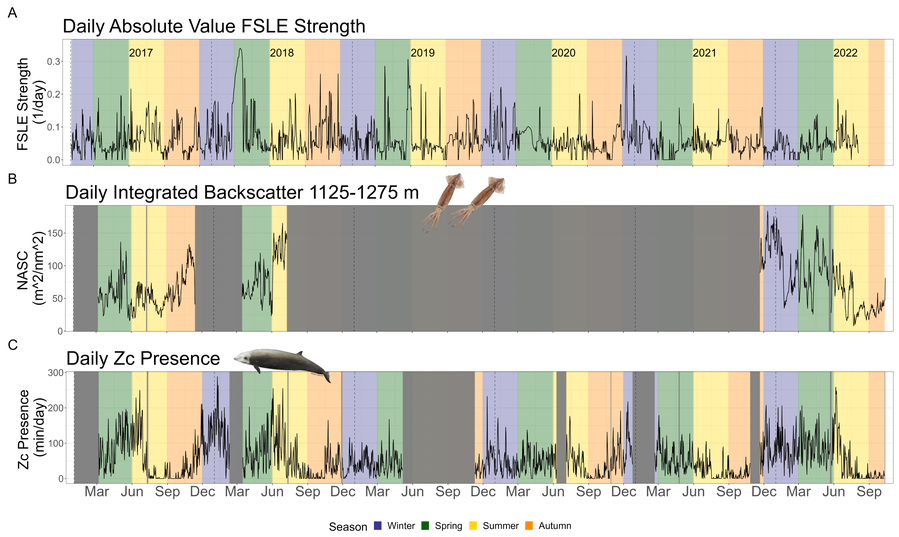

Fig 2. Time series of FSLEs (A), integrated acoustic backscatter data (B), and Cuvier's beaked whale presence from 2017 to 2022 at Site E. Grayed sections indicate no data.

Results

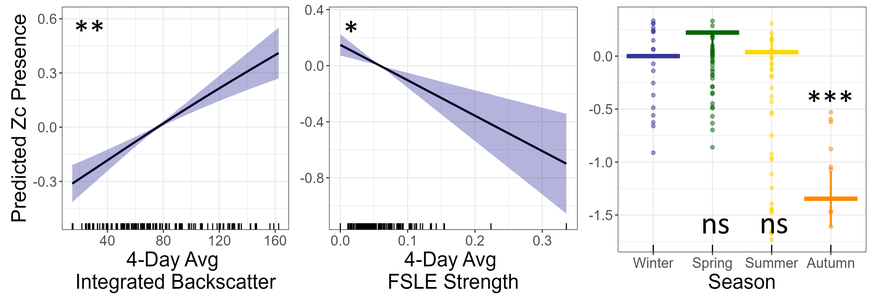

Fig 3. A Tweedie-distributed GAM, accounting for 29.1% of the deviance (adjusted $R^2 = 0.261$), revealed significant p-values for the smooth integrated backscatter (<0.01) and smooth FSLE (<0.05). Autumn has a significant parametric p-value (<<0.001).

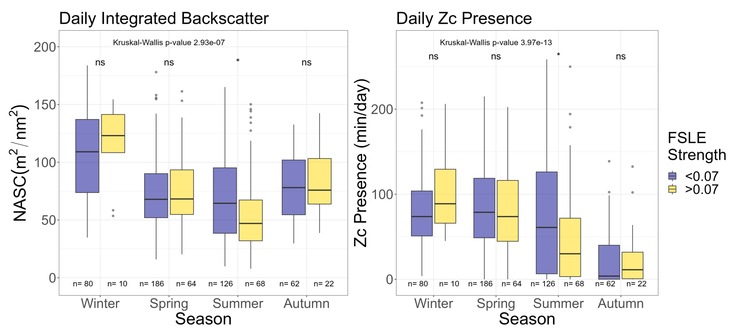

Fig 4. Integrated backscatter and Zc presence boxplots for each FSLE strength category. FSLE strength is heuristically either high (>0.07) or low (<0.07) as in previous studies[3-5]. The number of data points per season and FSLE strength are displayed. If the Kruskal-Wallis test on 50 random samples per season was significant, a Wilcoxon rank-sum test was run on the pairs (<0.07 and >0.07).

Conclusions

- **The presence of Cuvier's beaked whales increases with the presence of their prey.**
- **Zc presence is also significantly predicted by FSLE strength, but the GAM does not fully explain the variation (Fig 4).**

Discussion

It is important to consider temporal lags between ocean-surface dynamics and deep-sea biology in future studies. By including long-term passive and active acoustic data from other sites (Fig 5) and matching beaked whale dive segments[6] with prey availability, a more comprehensive understanding of the relationships (Fig 6) may be obtained.

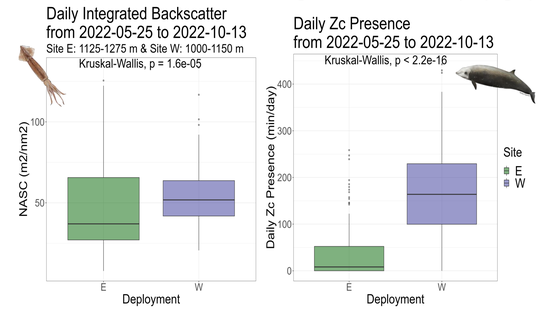

Fig 5. A comparison of integrated backscatter and Zc presence at two sites in Southern California. A Kruskal-Wallis test indicates that the prey abundance and Zc presence is significantly higher at Site W.

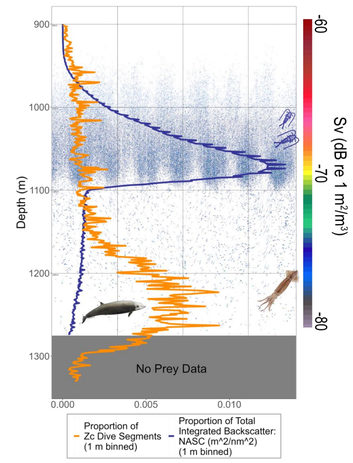

Fig 6. Zc dive segments (orange line) and integrated backscatter (blue line) proportions per 1 m depth bin at Site E from 03/15/18-07/11/18. Volume backscatter (Sv) versus depth and time indicates two prey layers ~980-1100 m and below 1100 m. Zc dive segments are observed predominantly in the lower prey field layer. There is no backscatter data below 1275 m due to instrument depth (1285 m) and the transducer near-field.

Animations

References

SCRIPPS ACOUSTIC ECOLOGY LABORATORY

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