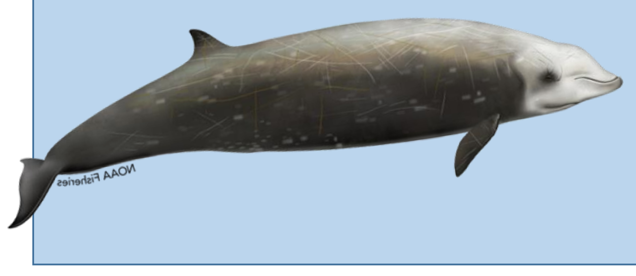

Ziphius cavirostris Presence Relative to Vertical and Temporal Variability of Oceanographic Conditions in the Southern California Bight

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Research Question:

What environmental conditions influence goose-beaked whale (*Ziphius cavirostris*) acoustic presence in the Southern California Bight?

Southern California Oceanography

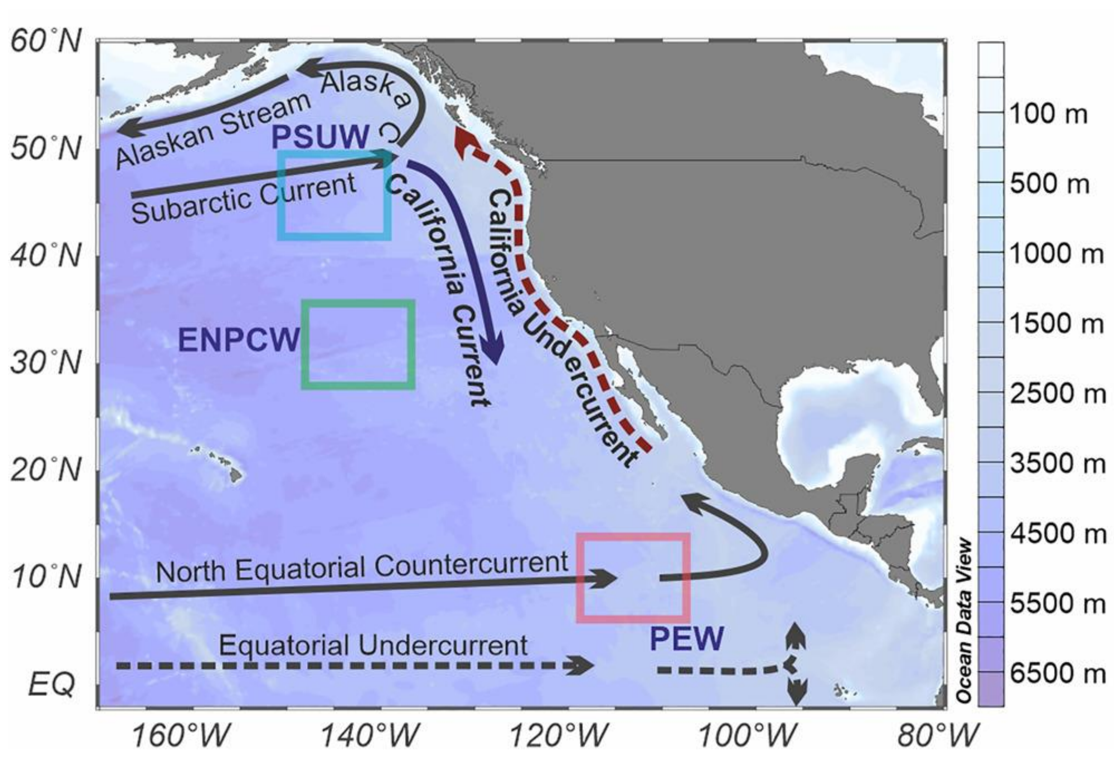


Fig. 1. Map of the California Current System featuring the local currents and source waters. Illustration from Alfken *et al.* (2021), adapted from Bograd *et al.* (2019) and Thomson and Krassovski (2010).

Source Water	Temperature	Salinity	Dissolved Oxygen	Nutrients
Eastern North Pacific Central Water (ENPCW)	↑	↑	↓	↓
Pacific Subarctic Upper Water (PSUW)	↓	↓	↑	↑
Pacific Equatorial Water (PEW)	↑	↑	↓	↑

Table 1. Source water properties.

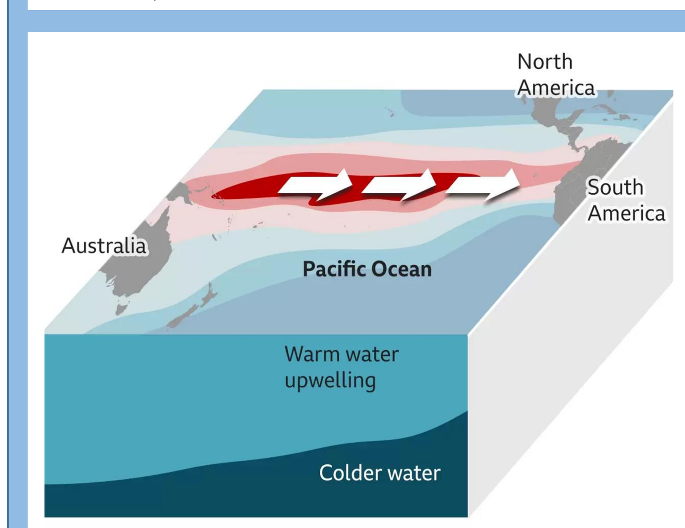


Fig. 2. Illustration of **ENSO (El Niño-Southern Oscillation)** from NOAA.

El Niño brings anomalously warmer waters, changing water composition at the surface and depth.

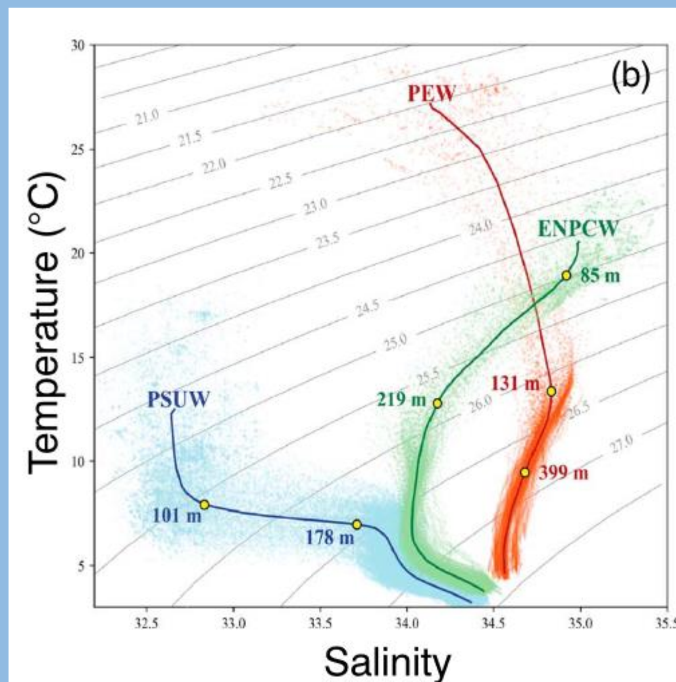


Fig 3. Temperature-salinity plots defining the source waters. From Bograd et al. 2019 for the period of 1984-2017.

Changes in these individual source waters are not isolated variables, and instead reflect the seasonal changes in the vertical distribution and fraction of all three source waters: the ENPCW, PSUW, and PEW.

Results

Goose-beaked whale temporal variability, with lowest probability of detecting them in the late summer, early fall.

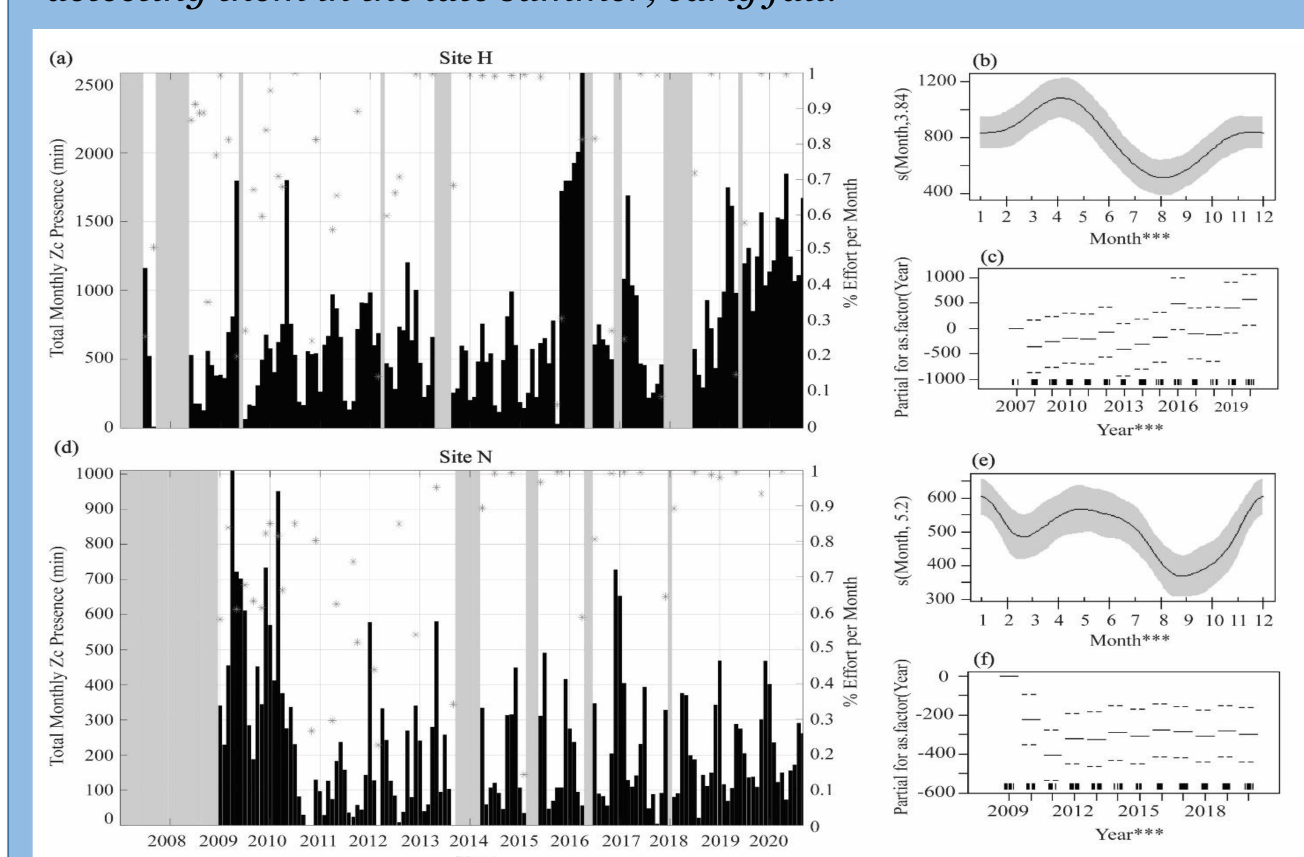


Fig. 6. Total monthly goose-beaked whale presence at sites H and N (a & d). GAM results documenting goose-beaked whale seasonality (b & c, e & f).

At both sites H and N, there is a higher probability of goose-beaked whale presence during El Niño events.

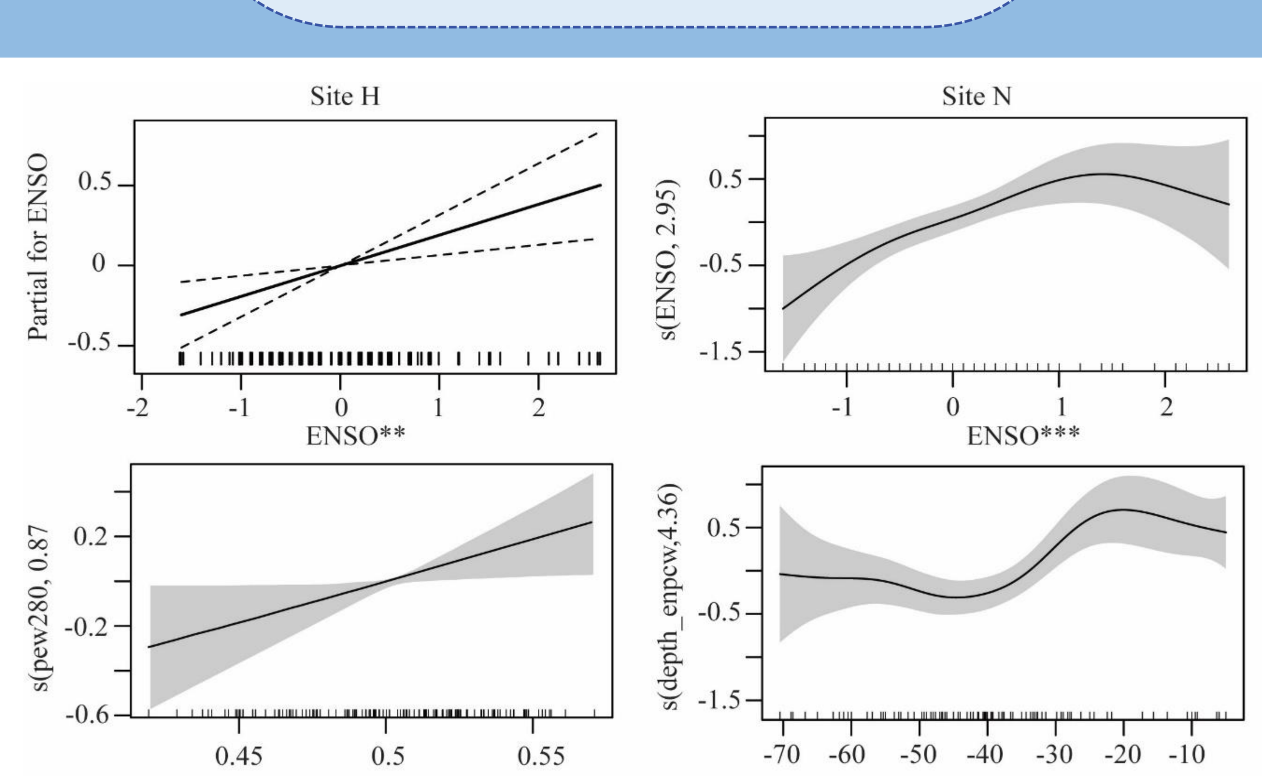


Fig. 7. Modeled relationships of the probability of goose-beaked whale presence in relation to the significant environmental variables

There is higher goose-beaked whale presence during seasons when the ENPCW is shallower (weakened) and there is more nutrient-rich PEW at depth.

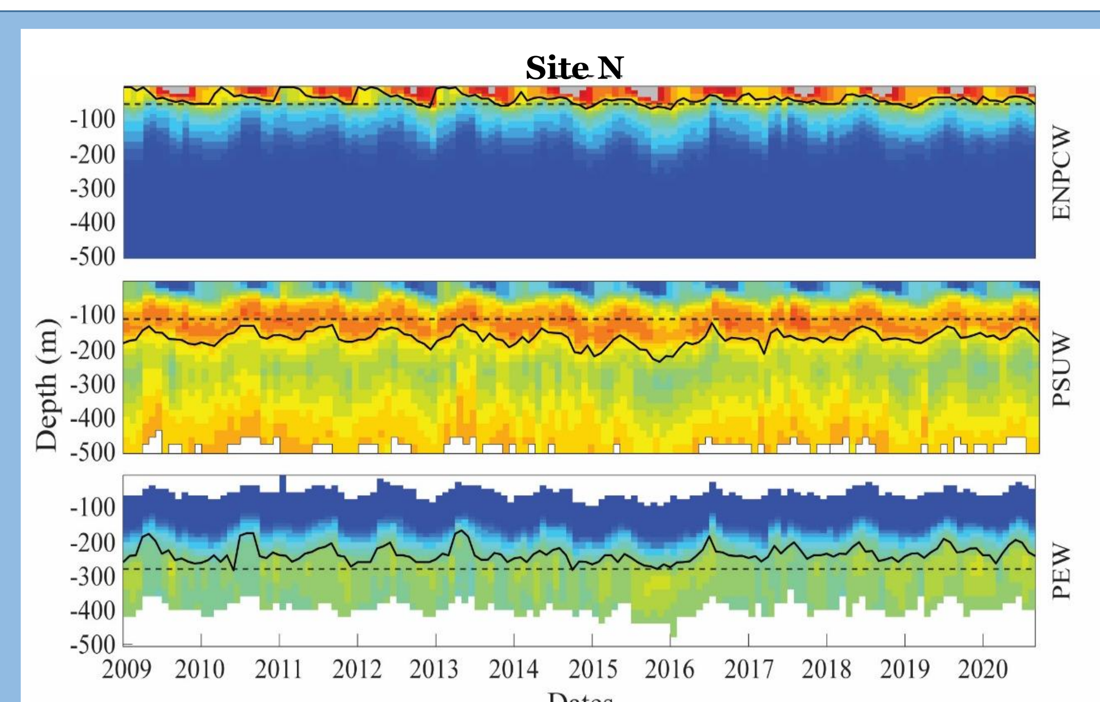


Fig. 8. Fractions of source waters and vertical distributions over time at site N. Water mass composition was quantified by the fraction of source water of (dashed line). The change in depth of each water mass was quantified by tracing the depth of the selected fraction (upper quartile fraction of the averaged fractions at each depth, black line) .

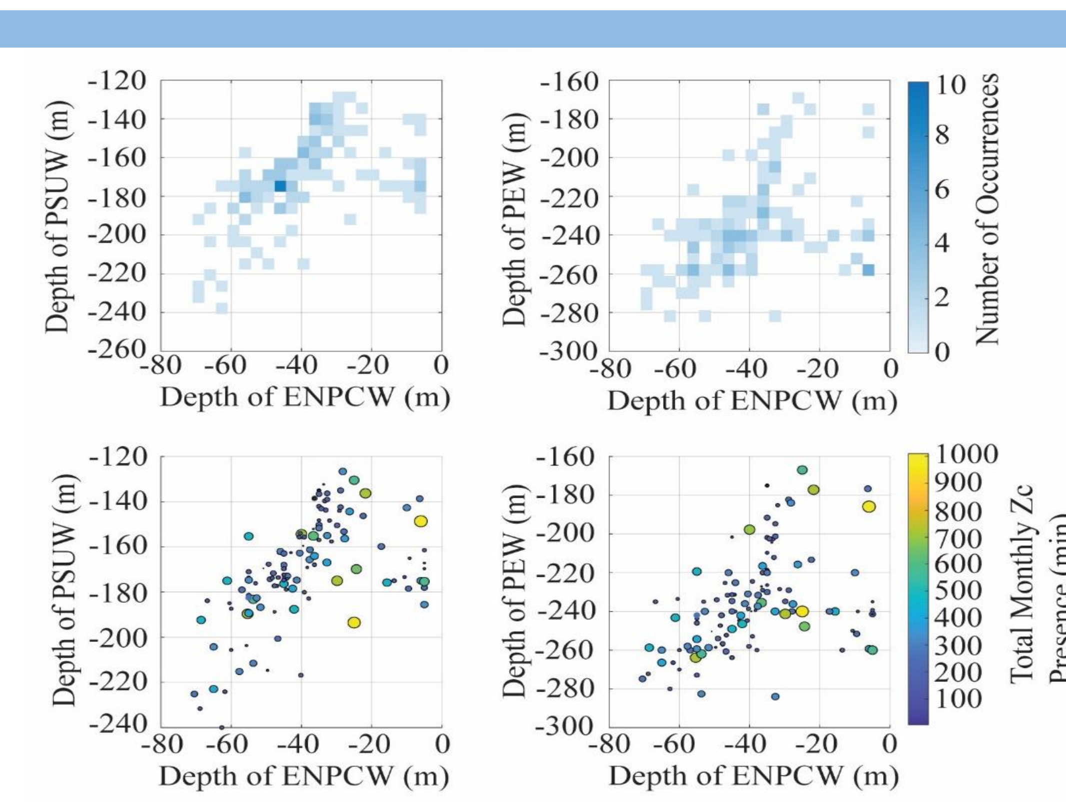


Fig. 9. Interactions between the depth of the ENPCW and the other source waters in relation to goose-beaked whale acoustic presence.

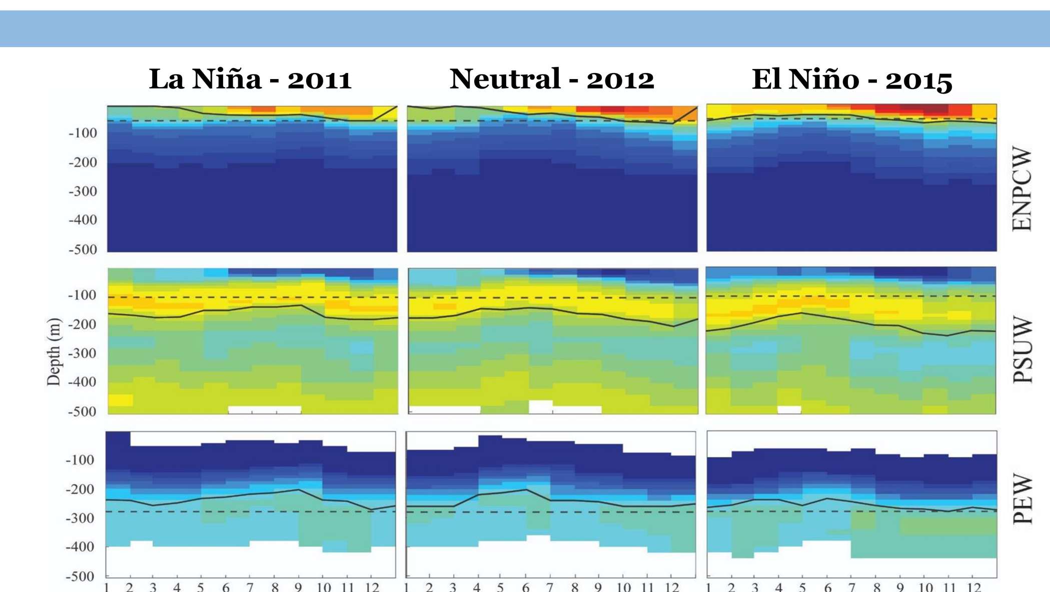


Fig. 10. Variability of water mass composition during different ENSO events.

Materials and Methods

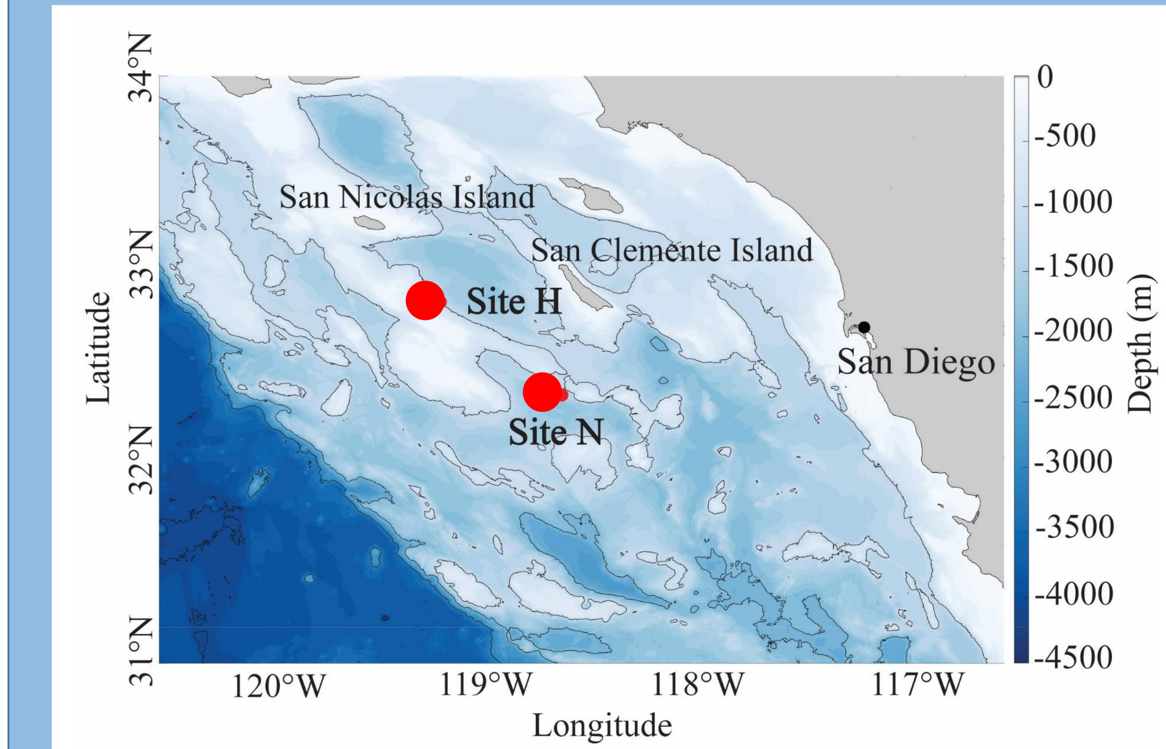


Fig. 4. Map of Sites H and N

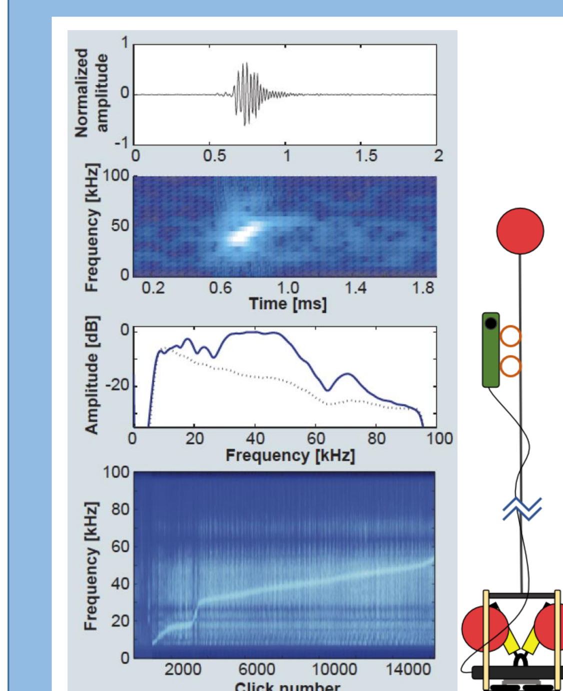


Fig. 5. HARP and goose-beaked whale echolocation click characteristics (Baumann-Pickering et al. 2013). HARP Illustration by Eric Snyder.

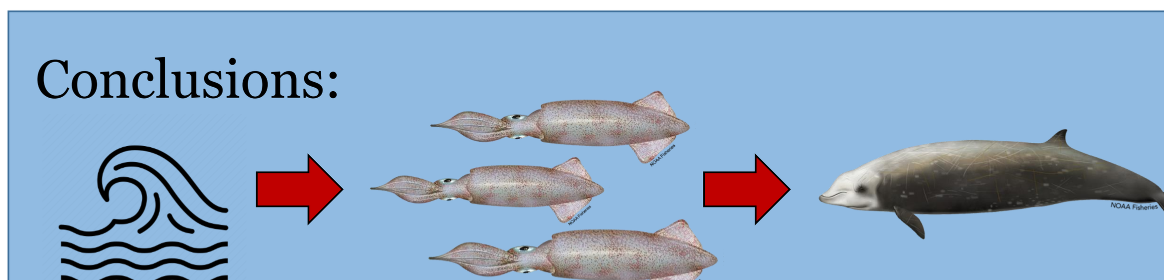
Data Sources

- Modeled temperature and salinity data from California State Estimate – Short-Term State Estimate (CASE-STSE) product. ENSO events quantified using the Oceanic Niño Index (NOAA product) from 3-month running average sea surface temperatures.
- Acoustic data was collected using high-frequency acoustic recording packages deployed at sites H and N (Fig. 4) between 2007-2020

Data Analysis

- Water mass compositions between 0-500 m were calculated using optimum multi-paramenter analysis, described by Bograd et al. (2019) and Tomczak & Large (1989).
- Goose-beaked whale clicks were automatically detected with false detections removed using open-source software DetEdit (Solsona-Berga et al. 2020).
- Temporal and interannual goose-beaked presence was modeled using additive models (GAMs) that included ENSO cycle, a subsurface temperature value, a subsurface salinity value, the fraction of each water mass at the constant depths (Fig. 8) and the depths at which the upper quartile fraction for each water mass was traced

Conclusions:



Variability in the oceanography drives changes in prey distribution and abundance, which these mobile top-predators respond to.

Seasonal Variability

- Goose-beaked whale presence drops during the summer when there is high amounts of nutrient-poor, central water.
- High presence occurs when there is less central water and more nutrient-rich subarctic and equatorial waters.

Interannual Variability

- Goose-beaked whale presence increases during El Niño events, when there is a more nutrient-rich equatorial water.

Works Cited and Additional Information:

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Acknowledgements:

We would like to thank Dr. John Hildebrand, Dr. Sean Wiggins, Bruce Thayre, Kieran Lenssen, Shelby Bloom, Erin O'Neill, and the many other past and current members of the Marine Bioacoustics Research Collaborative for their work building and maintaining equipment, recovering and deploying instruments, and processing and archiving acoustic data. We would also like to thank Dr. Bruce Cornuelle for providing additional support with the environmental data model. Funding was provided by the Office of Naval Research, Marine Mammal and Biology Program, Michael Weise and the U.S. Navy Pacific Fleet, Chip Johnson.

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