ID 58: Calling Behavior and Localization of Blue Whales in Southern California

Understanding temporal and spatial distributions of D call sequences

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Introduction

The Eastern North Pacific Blue Whale population is present off the coast of Southern California from summer to early fall (Hazen et al. 2017)

- These whales produce a foraging associated call classified as a D call
- **D calls are highly variable in (Fig.1):**
  - Duration **(1-4s)**
  - Frequency **(30-100Hz)**
  - Downsweep slope
- **Unlike other blue whale calls, D calls have not been shown to be produced in regular sequences to form song**
- D calls are produced during shallow dives that are between deeper, lunge feeding dives (Oleson et al. 2007b)

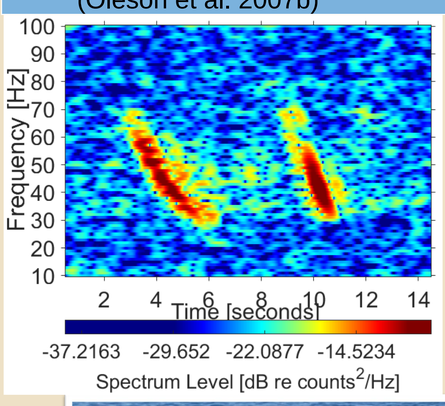

Figure 1 (left). D call example with two D calls with variable duration and frequency range.

Methods

Site Information:

- Long term passive acoustic data:
  - **July 14, 2007 to Oct 26, 2020**
- Large aperture array deployment:
  - **July 2019**
  - **3 recording sites** approximately 1 km from each other in a triangular configuration at 1200 m (Fig.2)

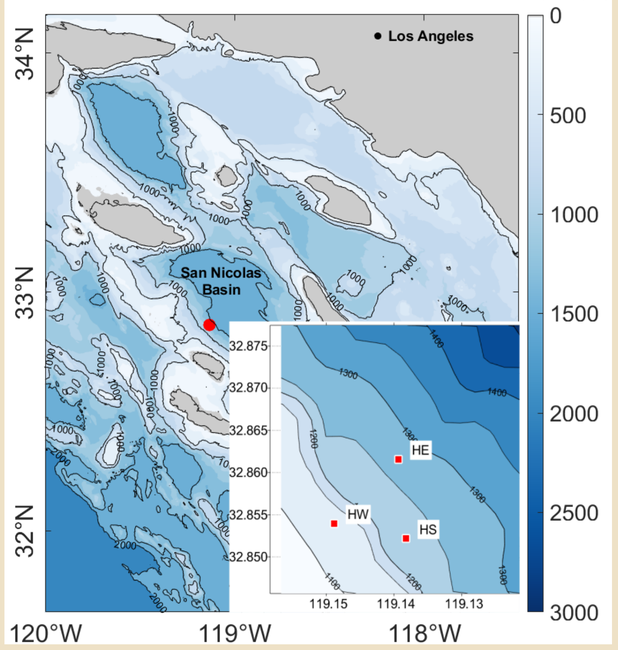

Figure 2. Site map with large aperture array deployed in 2019 in the bottom right corner.

D Call Detection:

- The **generalized power law (GPL) detector** was used to filter through data and look for signals that fit specific D call parameters (Helbe et al. 2016)
- Detections were verified by a skilled analyst using GPL Review

Localization:

- D sequences were manually detected on **July 22nd, 2019 10-14 UTC** and localized
  - **# of Sequences = 37**
  - **# of Calls = 271**
- Time series of each sequence were **cross correlated** between the 3 recording sites to get **time difference of arrivals (TDOAs)**
- These calculated TDOAs were then compared with modeled TDOAs in a 5000m-by-5000m grid using a **least squares best-fit grid search method** (Wiggins and Hildebrand 2020)
- Source level (SL) was calculated using this formula for 3 different received level (RL) types:
  - **SL = RL + 20*log10*(slant range)**

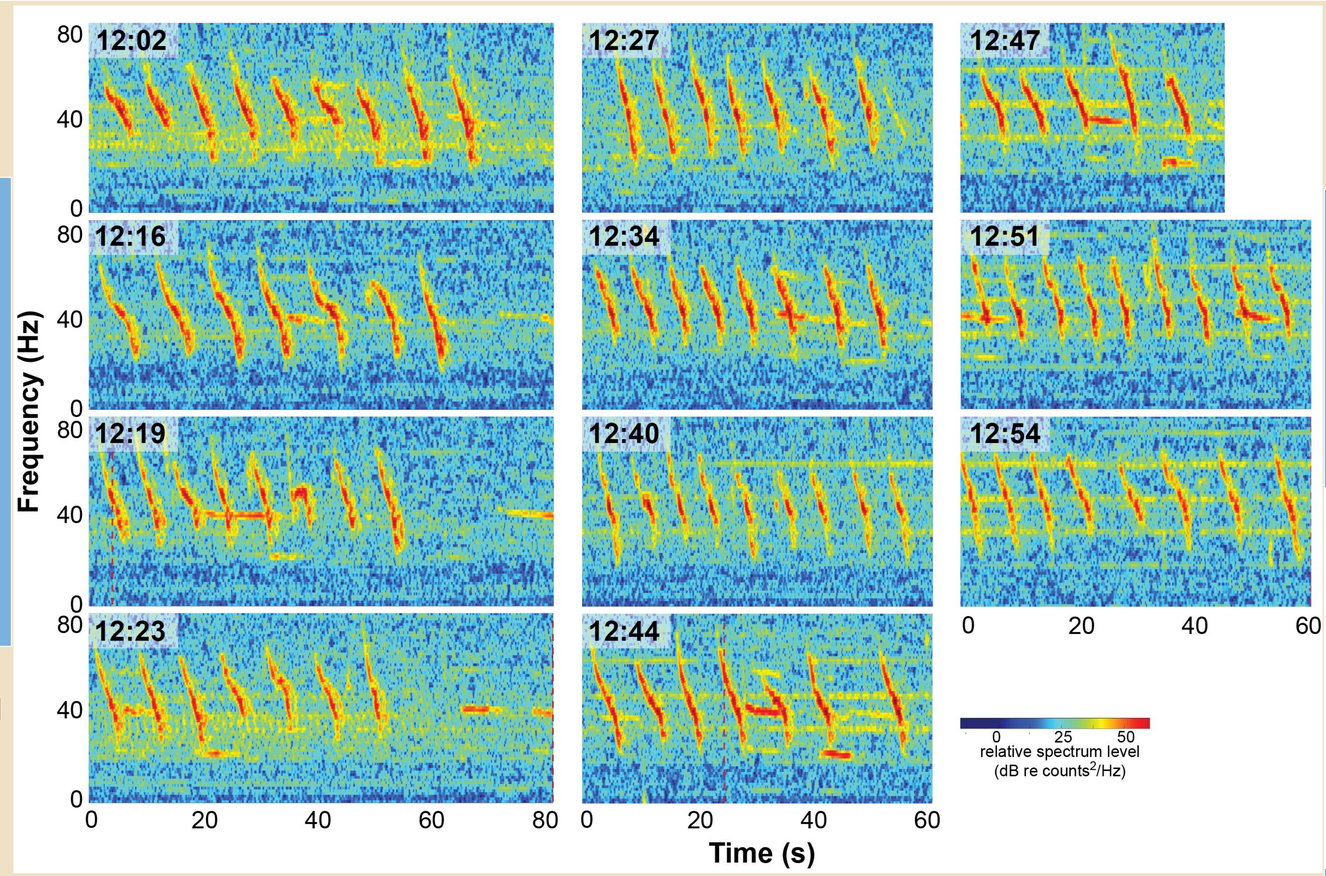

Figure 3. D call sequences included in the localization from 07/22/2019 12-13 UTC.

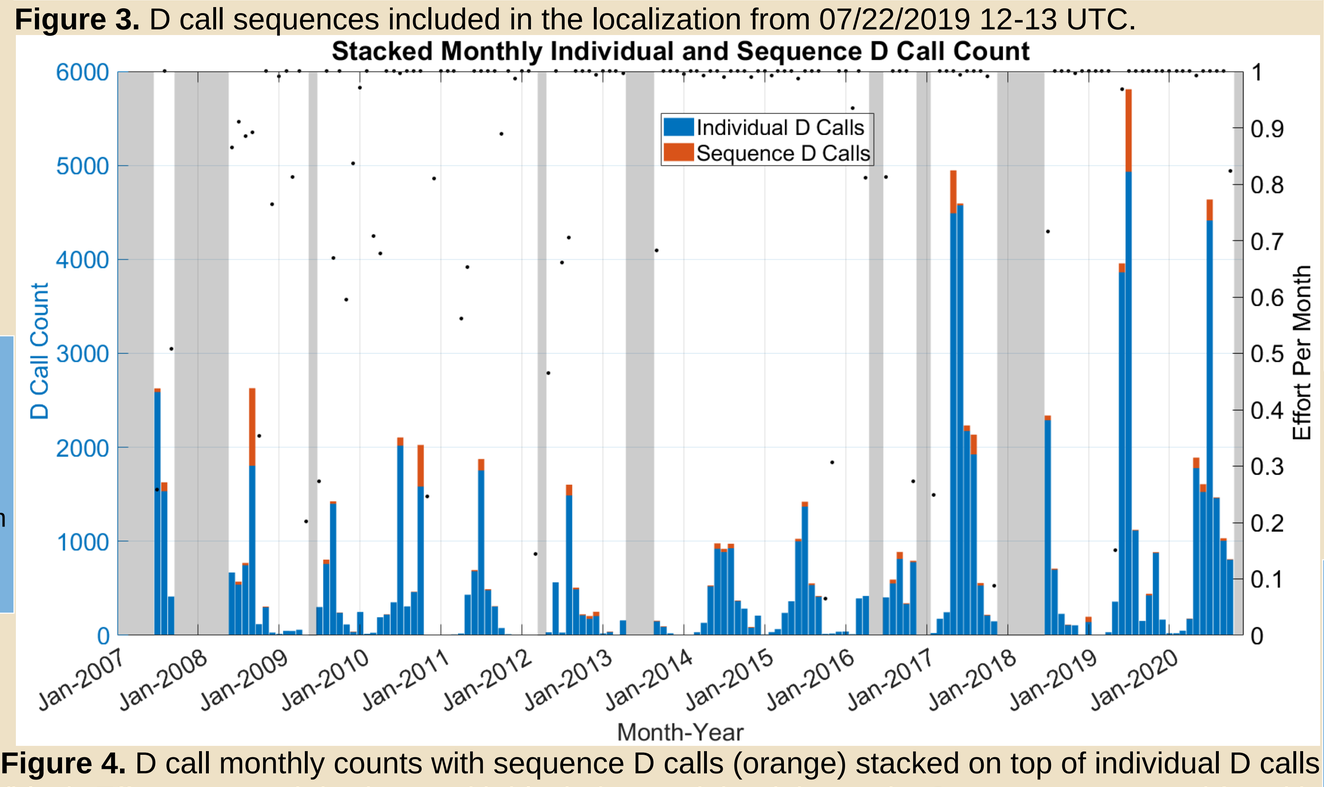

Figure 4. D call monthly counts with sequence D calls (orange) stacked on top of individual D calls (blue). Effort per month is shown with black dots and the right y-axis. Counts are corrected for with effort linearly using percent effort per month. Shaded regions indicate periods with zero effort.

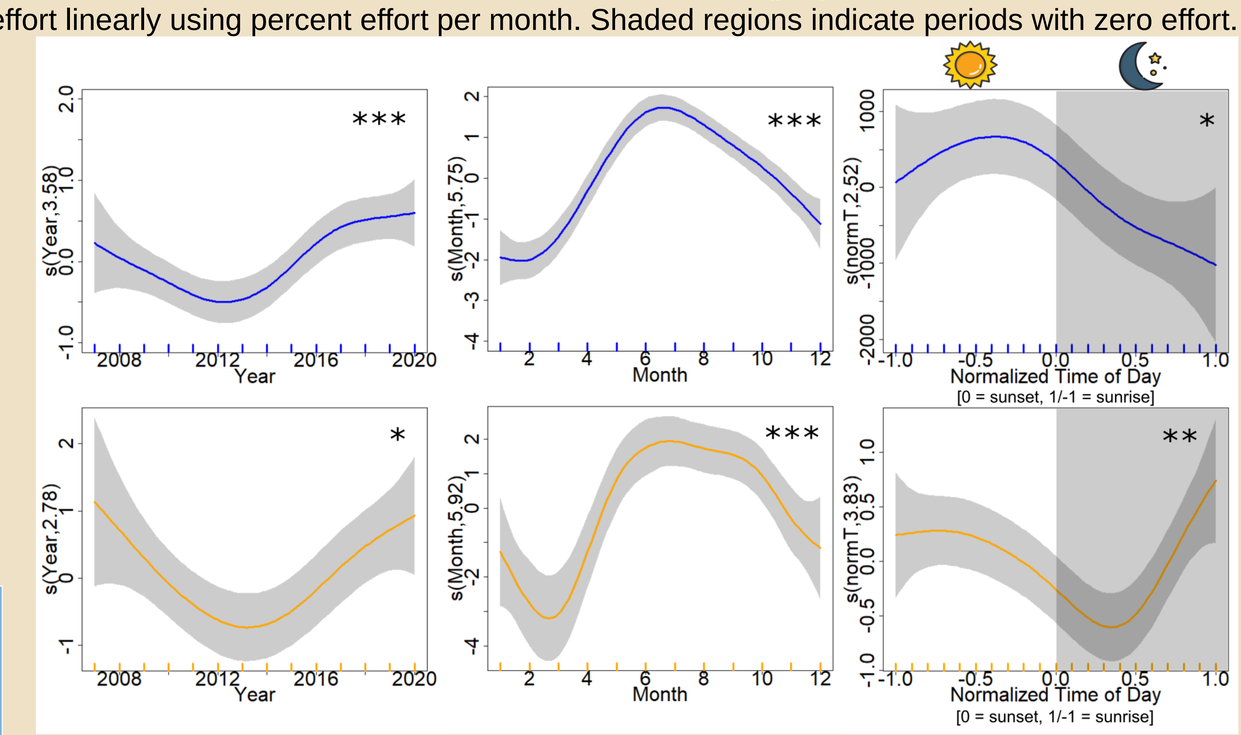

Figure 5. Generalized additive model (GAM) results for individual D calls (top) and sequence D calls (bottom) for month, year and normalized time of day variables. Asterisks indicate the significance of the explanatory variable in the model and grey shaded regions indicate night.

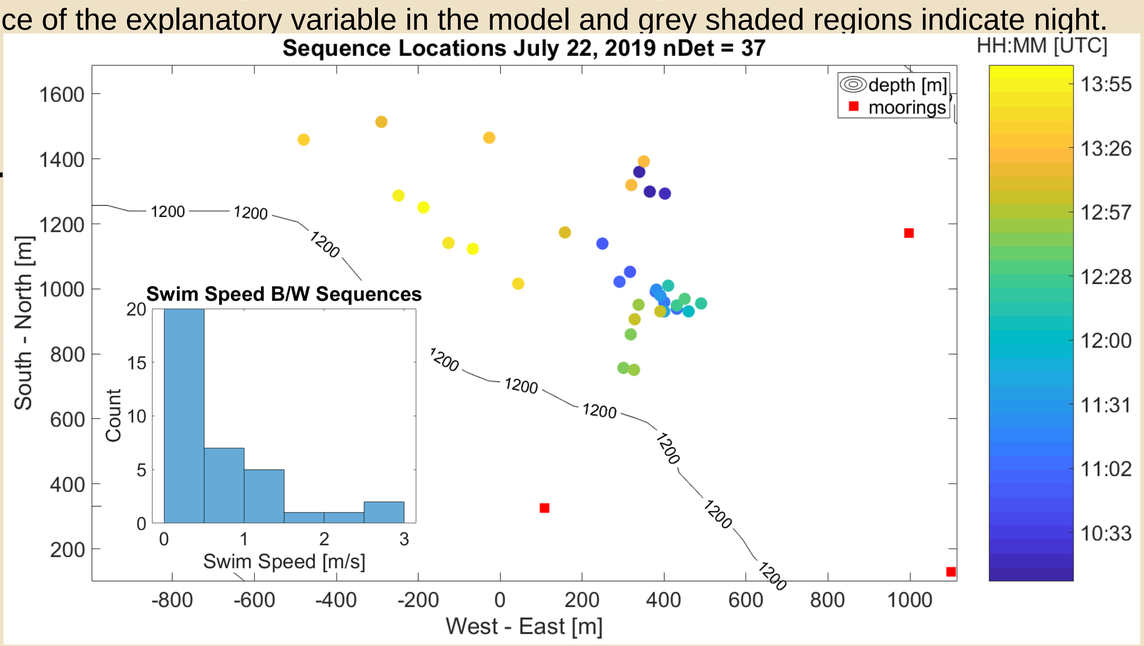

Figure 6 (right). Localization results with 37 locations for each sequence from 10-14 UTC with histogram of swim speed between sequences in the bottom left.

Table 1. Average source level (SL) and standard deviation for each type of received level (RL) calculated over 30 to 80 Hz using a 5 second time window.

RL type	Average SL [dB re 1uPa/1m]	Standard Deviation [dB re 1uPa/1m]
peak to peak	178.69	1.15
zero to peak	174.02	1.14
root-mean-square	162.23	1.27

Additional Info:

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D Call Sequence Definition

To filter out D sequences from 13 years of data we first had to define what a sequence was:

- **Data:** manual D call detections on 07/22/2019 1000 to 1400 UTC
- Distributions of D sequence inter-call interval and number of calls per sequence were used to filter through total D call detections
  - **5-15s inter-call interval**
  - **4 or more calls per sequence**

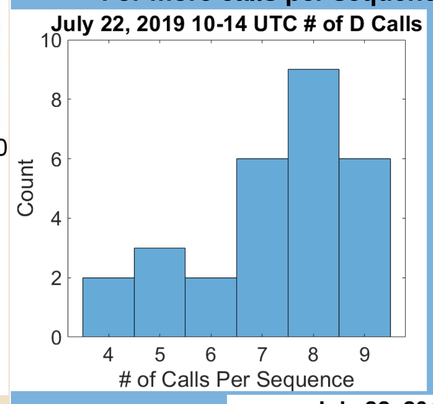
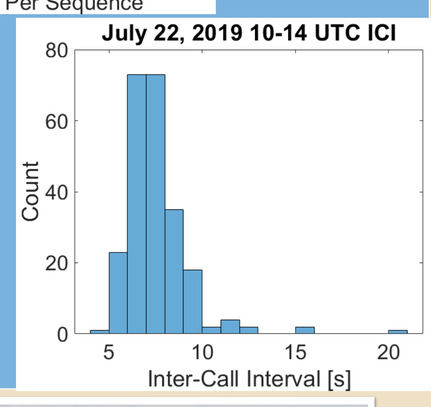


Figure 7 (left). Histogram of number of D calls per sequence for localized time period.

Figure 8 (right). Histogram of inter-call interval within sequences.



Results

Temporal Trends (Long-Term Dataset):

- **Yearly Trends:**
  - **2014 to 2016 =** ↓ individual D ↓ D sequences
  - **2017 to 2020 =** ↑ individual D ↑ D sequences
- **Monthly Trends:**
  - **May to October =**
    - ↑ individual D ↑ D sequences
- **Diel Trends:**
  - Individual D calls =
    - **Peak** at **sunset and** ↓ at **night**
  - D sequences =
    - **Peak** at **sunrise and** ↑ at **night**

Spatial Trends (Localization):

- In a **4-hour period,** sequence locations spanned **970 m horizontally and 762 m vertically**
- Most locations were clustered in the middle of the eastern and western sites from 11 to 13 UTC
- Swim speeds between sequential sequences were **less than 3 m/s** indicating that an **individual whale** may be the one who produced all 37 sequences

Conclusion

- **D sequences** have probably never been documented before due to their low presence compared to individual D calls
- Understanding the **temporal distributions and spatial behaviors** of D call sequences is important for understanding blue whale behavior while foraging
- The increase in D calls since 2014 show a unique trend in blue whale behavior which may have been influenced by environmental factors such as the Marine Heat Wave that appeared in Southern CA in 2014 to 2016
- It is possible that sequences, like individual D calls, are produced in between foraging dives, but more research needs to be done to determine a behavioral difference
- The presence of D call sequences drastically changes **call rates** when blue whales are present near a site which is important for **density estimation**
- **Localizing** sequences allows us to calculate **source level** values with have yet to be reported empirically for the Eastern North Pacific blue whale population
- More streamlined call detection methods and localization methods of D calls are needed to make further conclusions about the importance of D call sequences

Acknowledgements:
Funding was provided by the Office of Naval Research, Michael Weise and US Navy Pacific Fleet, Chip Johnson. This research is currently being prepared as part of a publication. Arrieta, G; Wiggins, S; Cohen, K; Thayre, B; Hildebrand, J; Širović, A; Baumann-Pickering, S. The poster author was the primary investigator and author of this material. Thank you to my co-authors, family and friends for their constant support and advice.