Temporal-Spatial Distributions for a Repertoire of Fin Whale Vocalizations From Directional Sensing with a Coherent Hydrophone Array

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1. Whale Calls Passively Recorded Using a Coherent Receiving Array

- A densely sampled towed horizontal linear hydrophone array was used to record various distinct marine mammal species simultaneously including Fin, Humpback, Orca, and Pilot Whales.
- Fin Whale vocalizations were detected between the 10 – 140 Hz frequency region and were received at different rates.

2. Fin Whale Call Types Observed

- Three distinct Fin Whale Call Types observed:
  - 20-Hz “Classic” note
  - Higher frequency downsweeps (between 30 Hz to 100 Hz)
  - 130-Hz note
- Fin Whale Monitoring Challenges:
  - Clustering and classifying fin whale call types among multiple marine mammal species
  - Varying vocalization intensity and frequency

3. Fin Whale Detection Process

- 10 features are extracted from each detection to aid in clustering known and unknown signals
  - Minimum frequency
  - Maximum frequency
  - Mean frequency
  - Pitch Track – average frequency
  - Max signal bandwidth
  - Mean signal bandwidth
  - Time duration
  - Signal-to-Noise Ratio
  - Pitch Track - slope from 1st order polyfit
  - Pitch Track - curvature from 2nd order polyfit

4. Determining Fin Whale Vocalization Arrival time and Azimuthal Bearing through Beamforming

- The relative horizontal azimuthal direction of each detection, measured from array broadside, was estimated using time-domain delay-and-sum beamforming.
- The max peak energy corresponds to the correct relative horizontal azimuthal direction for each detection with the corresponding time.

5. Clustering Fin Whale Call Types

- After feature extraction, detections are clustered using Principle component analysis, bayesian information criteria, and k means clustering.
- The Average Frequency (Pitch Track) feature seems to be one of the most dominate features in clustering marine mammal vocalizations.
- Below are 2 plots displaying the Average Frequency (Pitch Track) feature vs. time for the 20-Hz “Classic” note and 130-Hz note.

6. Localization in far-field of the towed horizontal coherent receiver array using Moving Array Triangulation

- The source horizontal location is obtained from:
  \[ \hat{x} = \mathbf{r} \sin(\beta) \]
  \[ \hat{y} = \mathbf{r} \cos(\beta) \]

7. Results - Fin Whale tracking and localizations for Lofoten, Norway: March 07-08, 2015

- The Fin 30-100 Hz Calls were classified by using the directional sensing capability of POWARS to associate three calls to Track 2.

Conclusions

- Fin whale off the coast of Lofoten, Norway have been passively localized, tracked, and classified using a single low frequency, densely sampled, towed horizontal coherent receiver array system.
- Three distinct for whale call types were observed in this region despite multiple marine mammals simultaneously vocalizing in this region and in the same frequency range.
- Future work: Our research team is finishing up fin whale tracking and localizations for the Alesund, Norway and northern Finmark region. The goal is to quantify the relative diel occurrence of the distinct fin whale vocalization types and apply the results to infer their behaviors as a function of these regions.

References


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