

Comparison of echolocation clicks produced by four killer whale communities in the northeastern Pacific Ocean



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INTRODUCTION

The northeastern Pacific Ocean is home to three distinct ecotypes of killer whales (*Orcinus orca*): (1) resident; (2) transient; and (3) offshore. The resident ecotype includes northern and southern resident communities. These ecotypes and communities exhibit differences in their vocal behavior. Here we examine differences in echolocation clicks among ecotypes and communities and present an acoustic classifier that uses information from echolocation clicks, pulsed calls and whistles.

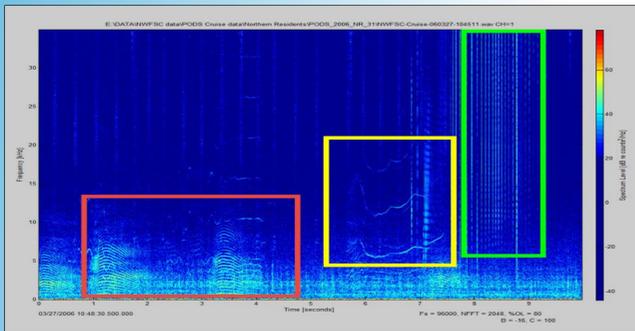


Figure 1. Spectrogram displaying types of sounds produced by killer whales. Pulsed calls (red box), whistle (yellow box), and echolocation clicks (green box).

METHODS

Data Collection

- Pacific *Orcinus* Distribution Surveys (PODS) conducted by NOAA/Northwest Fisheries Science Center
 - Coastal Oregon and Washington
 - Winters 2006-2009, 2012, 2013, and 2015
- Visually-validated towed hydrophone array recordings of four killer whale communities

Click Measurement in PAMGuard

- Click detector module
- ROCCA (Real-time Odontocete Call Classification Algorithm). Measurements include duration, center frequency, peak frequency, sweep rate, number of zero crossings, and inter-click interval.

Classification

- Discriminant Function Analysis (DFA)
- Random Forest Classification (RF)

Table 1. Number of encounters (with the number of individual acoustics signals measured in parenthesis) for echolocation clicks, whistles, and pulsed calls. Number of echolocation clicks refers to the number of clicks after low and high SNR clicks were pruned from the dataset.

Community	No. Click Encounters (No. Clicks)	No. Whistle Encounters (No. Whistles)	No. Pulsed Call Encounters (No. Pulsed Calls)
Southern Resident	26 (22483)	10 (150)	20 (150)
Northern Resident	4 (5080)	4 (150)	4 (166)
Offshore	1 (9729)	1 (148)	1 (132)
Transient	2 (254)	2 (44)	2 (101)
Total	33 (37546)	17 (492)	27 (549)

RESULTS

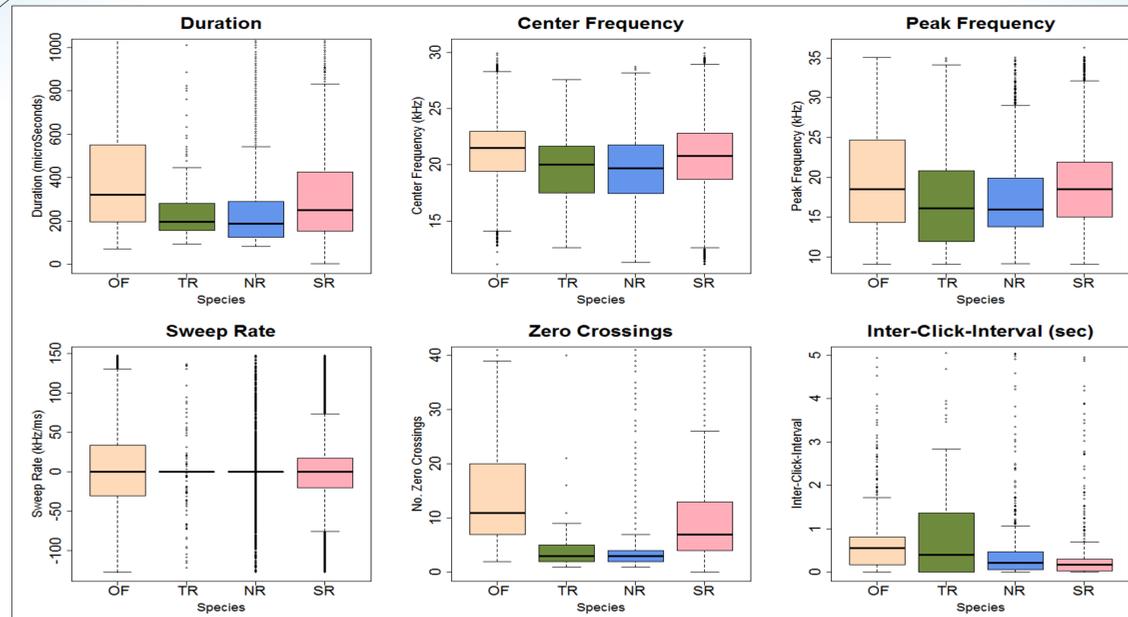


Figure 2. Box plots displaying the median, first and third quartiles for each echolocation click parameter with community along the x-axis and parameters along the y-axis. OF=offshore, TR=transient, NR=northern resident, and SR=southern resident.

Table 2. Matrix displaying echolocation click parameters that were significantly different between communities (Kruskal-Wallis test and post-hoc Dunn's test with Bonferroni adjustment $p < 0.05$).

	Offshore	Transient	Northern Resident
Transient	All Parameters Significant		
Northern Resident	Duration Center Frequency Peak Frequency Inter-Click Interval Zero Crossings	No Parameters Significant	
Southern Resident	Duration Center Frequency Peak Frequency Inter-Click Interval Zero Crossings	All Parameters Significant	All Parameters Significant

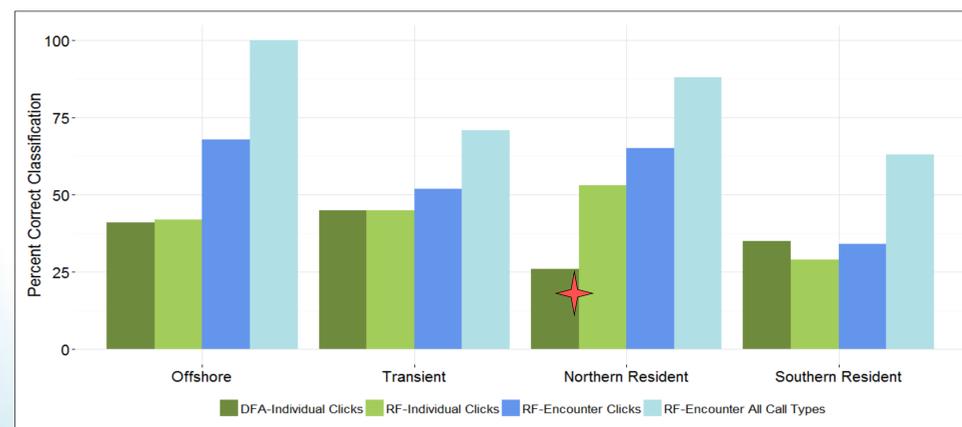


Figure 3. Bar graph displaying the percent of individual clicks classified correctly using DFA (dark green) and RF (light green), and the percent of encounters classified correctly using a RF that only included clicks (dark blue) and a RF that included information from clicks, whistles and pulsed calls (light blue). Community is along the x-axis and percent correct classification is along the y-axis. The DFA classifier and the RF classifier for individual clicks were only significantly different (Fisher's exact test $\alpha = 0.05$) for northern residents, noted by the red star.

- Using whistle and pulsed call measures in addition to click measures resulted in significantly higher correct classification scores for all four communities (Fisher's exact test $\alpha = 0.05$)

DISCUSSION/CONCLUSIONS

Click Measurements

- There are many significant differences in echolocation click parameters among all communities.
- Differences may be due to differences in prey items, environment, anatomy, and/or behavioral state.

Classifiers

- DFA and RF performed similarly on individual clicks except for the northern resident community
- The addition of whistle and pulsed call measures to classifiers resulted in significantly higher correct classification scores for all communities.
- These classifiers will ultimately allow researchers to more effectively and efficiently study the range and distribution of killer whales in the Northeast Pacific Ocean using passive acoustic methods.



FUTURE WORK

Obtain and analyze a larger sample of recordings from each community to improve classifiers.

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