



# Comparison of vocalizations produced by killer whale ecotypes, communities, and pods 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. Currently, pulsed calls can be used to acoustically classify killer whales to ecotype, community or pod level, but echolocation clicks and whistles have not yet been evaluated for this purpose. Here, we examine differences in these signal types in relation to ecotypes and communities.

## Methods

### Data Collection

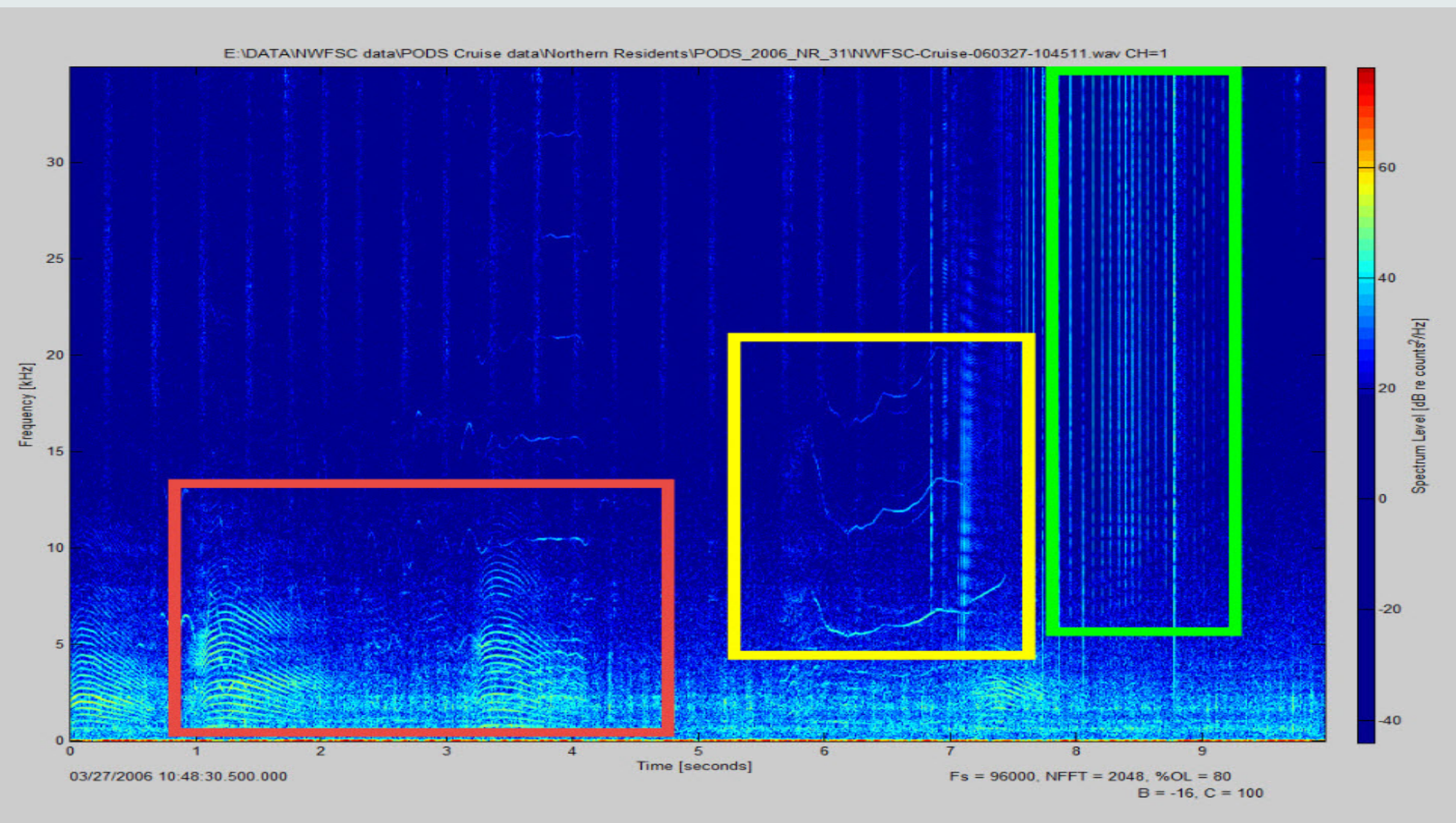
- Pacific *Orcinus* Distribution Surveys (PODS) conducted by NOAA/Northwest Fisheries Science Center
  - Coastal Oregon and Washington
  - Winters 2006-2009, 2012, 2013, and 2015
- Visually-validated towed hydrophone array recordings of four killer whale communities
  - Northern resident
  - Southern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

### Call Measurement

- PAMGuard
  - **Whistles and pulsed calls:** *ROCCA* (*Real-time Odontocete Call Classification Algorithm*)
  - **Echolocation clicks:** *click detector module*, *ROCCA*, *ViewerMode*

### Statistical Analysis

- Kruskal-Wallis test
- Post-hoc Dunn's test with a Bonferroni adjustment.



**Figure 1.** Spectrogram displaying the killer whale vocal repertoire. Pulsed call (red box) measurements include mean slope, mean positive slope, mean negative slope, inflection points, duration, perfect flat, percent up, and percent down. Whistle (yellow box) measurements include the slope measurements in addition to maximum, minimum, beginning end, and mean frequency. Echolocation click (green box) measurements include duration, center frequency, peak frequency, sweep rate, number of zero crossings, and inter-click interval.

## Results

### Echolocation Clicks

Table 1. Matrix displaying echolocation click parameters that were significantly different between communities ( $p < 0.05$ ). Peak frequency and center frequency were significantly different ( $\alpha = 0.05$ ) for all comparisons.

	Offshore	Transient	NRKW
Transient	All Parameters Significant		
NRKW	Duration Center Frequency Peak Frequency Inter-Click Interval Zero Crossings	Center Frequency Peak Frequency Zero Crossings Sweep Rate	
SRKW	Duration Center Frequency Peak Frequency Inter-Click Interval Zero Crossings	All Parameters Significant	Duration Center Frequency Peak Frequency Inter-Click Interval

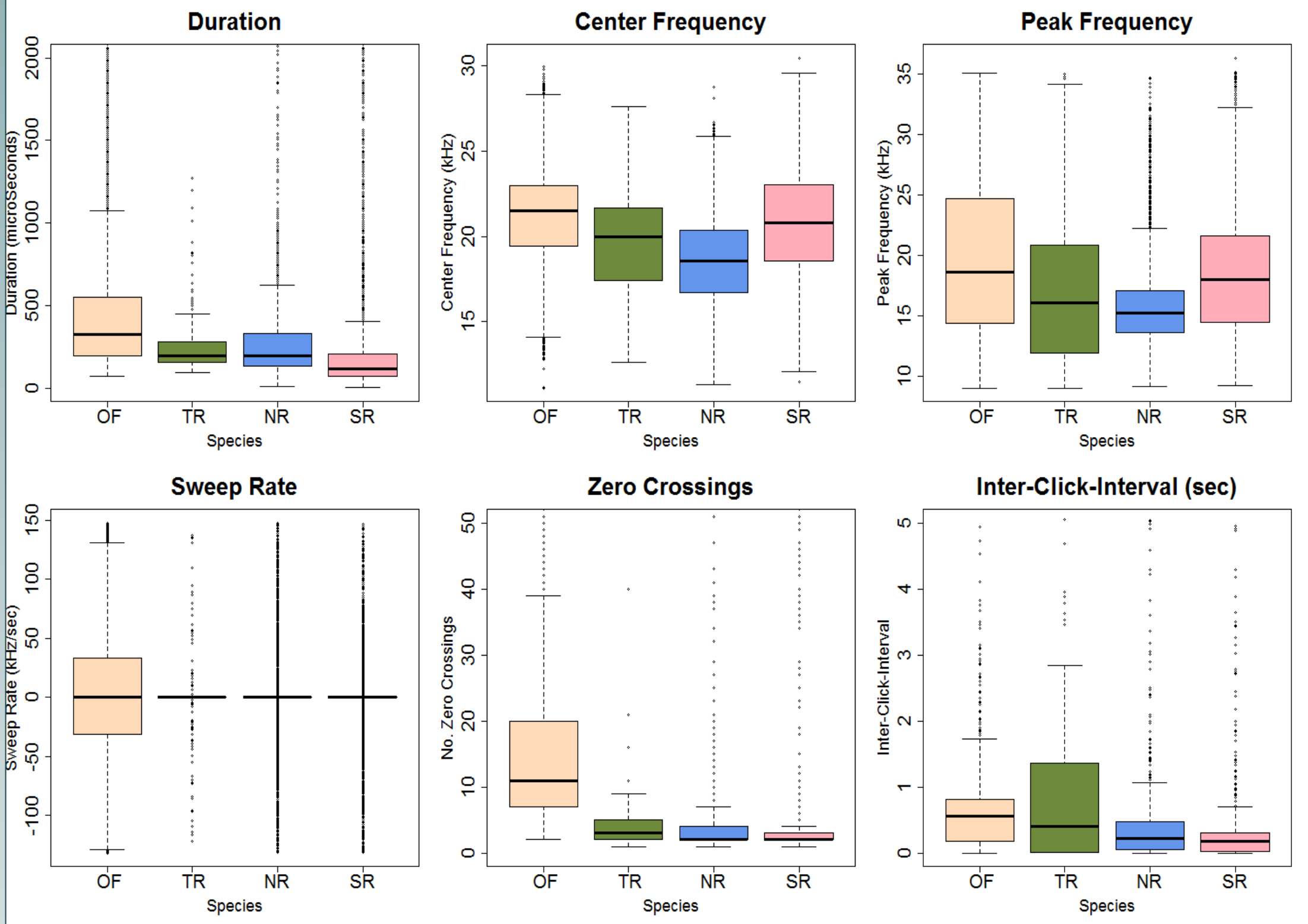


Figure 2. Box plots displaying the median, first and third quartiles for each echolocation click parameter with community along the x-axis and parameters along the y-axis.

- **All variables except sweep rate were significantly different ( $\alpha = 0.05$ ) for the offshore community compared to the other three communities**

### Whistles

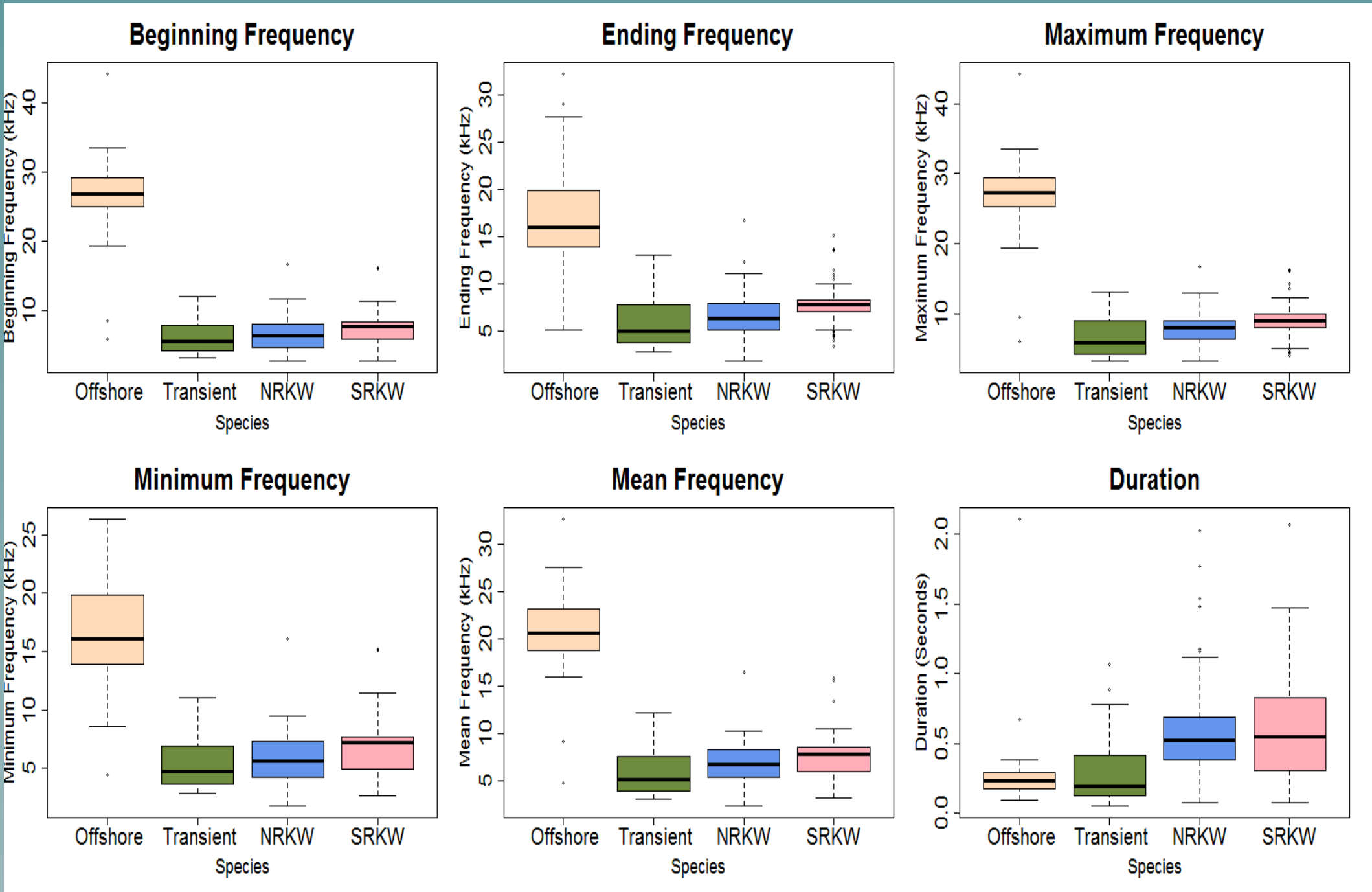


Figure 3. Box plots displaying the median, first and third quartiles for the whistle frequency parameters with community along the x-axis and parameters along the y-axis.

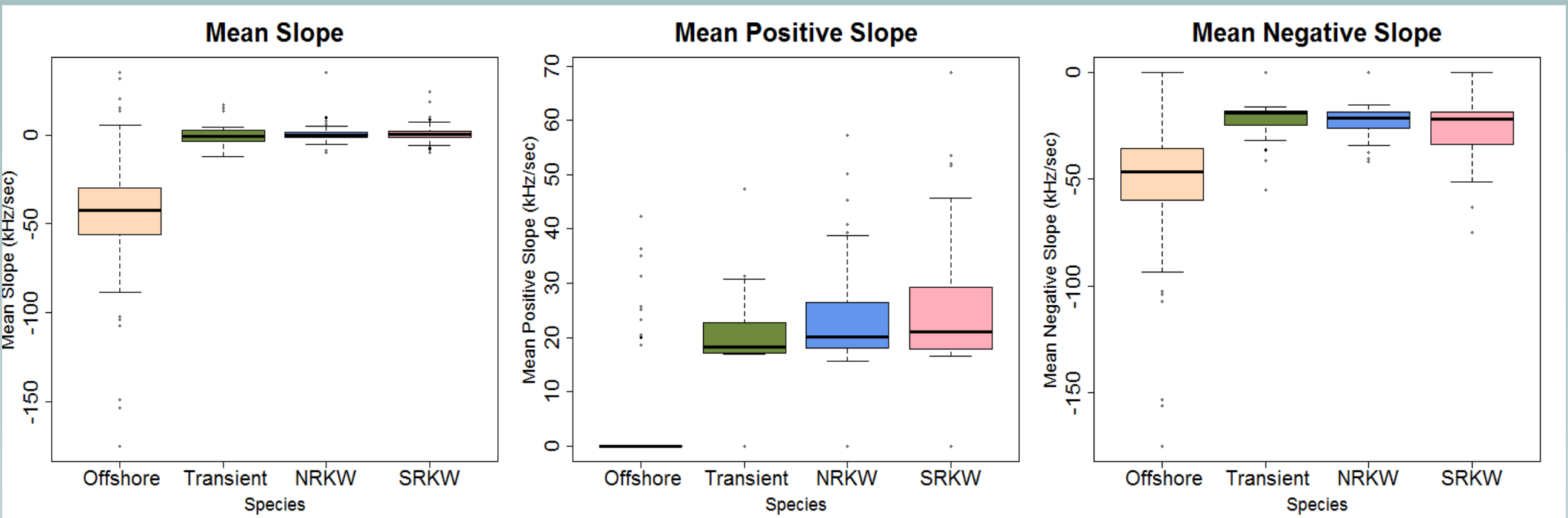


Figure 4. Box plots displaying the median, first and third quartiles for the whistle slope parameters with community along the x-axis and parameters along the y-axis.

- **All variables were significantly different ( $\alpha = 0.05$ ) for the offshore community compared to the other three communities.**
- **There were no significant differences between the northern resident community and the transient community or the northern resident and the southern resident communities.**

### Pulsed Calls

Table 2. Matrix displaying pulsed call parameters that were significantly different between communities ( $p < 0.05$ ).

	Offshore	Transient	NRKW
Transient	Duration Mean Slope Mean Positive Slope Mean Negative Slope Percent Flat Percent Up Percent Down		
NRKW	Duration Mean Slope Mean Positive Slope Mean Negative Slope Percent Flat Percent Up Percent Down Inflection Points	Duration Mean Negative Slope Percent Flat Percent Up Inflection Points	
SRKW	Duration Mean Slope Mean Positive Slope Mean Negative Slope Percent Flat Percent Up Percent Down	Mean Slope Mean Positive Slope Percent Down	Duration Mean Slope Mean Negative Slope Percent Flat Percent Up Percent Down Inflection Points

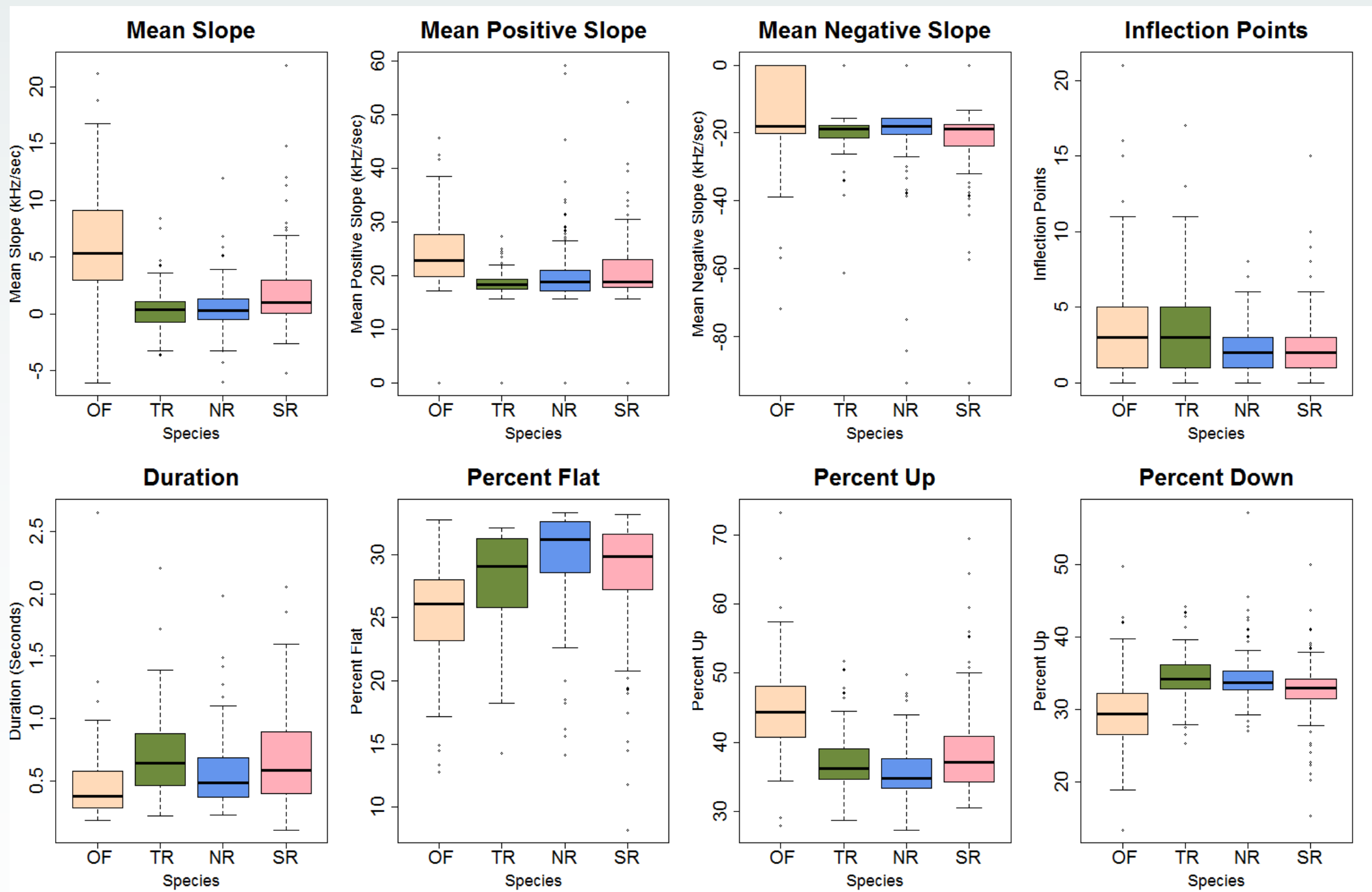


Figure 4. Box plots displaying the median, first and third quartiles for each pulsed call parameter with community along the x-axis and each parameter value along the y-axis..

## Summary/Conclusions

### Differences

- There are many significant differences in echolocation click variables between all communities.
- Offshore echolocation clicks, whistles, and pulsed calls are very different from those produced by the other three communities.
- Pulsed call variables are very different between northern and southern residents.
- Differences may be due to differences in prey items, environment, anatomy, and/or behavioral state or some other factor.

### Similarities

- Whistle characteristics are similar for transient, northern resident, and southern resident communities
- Transient and northern resident killer whales exhibit the most similarities in all three signal types

### Conclusions

- Our results indicate that classifier development will benefit greatly by creating a comprehensive classifier that includes all vocal types (i.e. pulsed calls, whistles, and clicks)



## Future Work

- Obtain and analyze a larger sample of recordings from each community.
- Train acoustic classifiers for killer whale ecotypes/communities/pods using all vocal types.
- 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.

## Acknowledgements

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