The Acoustic Behavior of Minke Whales in Relation to Mid-Frequency Active Sonar

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Introduction

- A preliminary analysis of Atlantic minke whale (*Balaenoptera acutorostrata*) acoustic behavior using data collected off Jacksonville, FL in fall and winter 2009-2010 indicated a possible change in vocal activity during periods of Mid-Frequency Active Sonar (MFAS) (Charif *et al.* 2014).
- **Our objective was to conduct an exploratory analysis to compare characteristics of pulse trains between four treatment periods: 24 hrs. before, during, between, and 24 hrs. after sonar events.**

Methods

Data Collection

- March 15th-April 11th 2012 using a High-frequency Acoustic Recording Package (HARP) deployed off Cape Hatteras, North Carolina.

Sonar Events

- Periods of MFAS were annotated using the custom MATLAB® software, Triton.
- Sonar events (n=13) were defined as having <30 min intervals between consecutive MFAS pings.

Pulse train annotation

- Triton was used to annotate pulse trains 24 hours before, during, between, and 24 hours after MFAS.

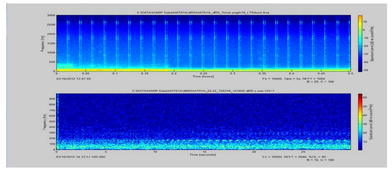


Figure 1. Triton LTSA and spectral display respectively

Pulse train characteristics analyzed

- Duration (start of first pulse to end of last pulse)
- Bandwidth (upper minus lower frequencies)
- Pulse train type: constant, slow-down, speed-up, or unidentified (too faint to determine)

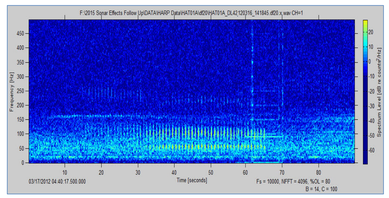
Pulse train characteristics were compared within four treatment periods based on sonar events

1. Before Sonar (24 hours)
2. During Sonar (21.7 hours)
3. Between Sonar (51.4 hours)
4. After Sonar (24 hours)

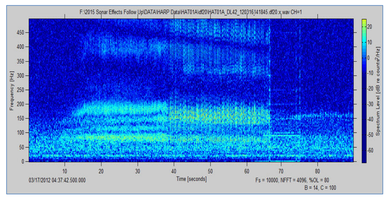
Statistical Analyses

- Fisher's exact test
- Non-parametric Kruskal-Wallis test
- Post-hoc Dunn's test with Bonferroni adjustment

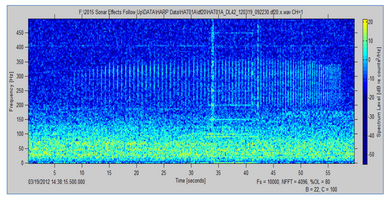
Pulse Train Types



A. Constant: Change in pulse rate between -0.5 and 0.5 s



B. Slow-down: change in pulse rate >0.5 s



C. Speed-up: change in pulse rate <-0.5 s

Results

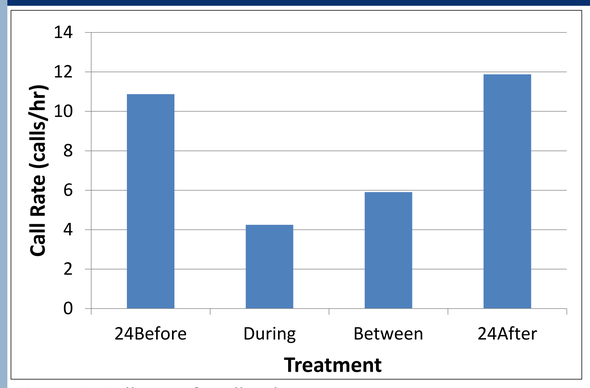


Figure 2. Call rates for all pulse trains per treatment period.

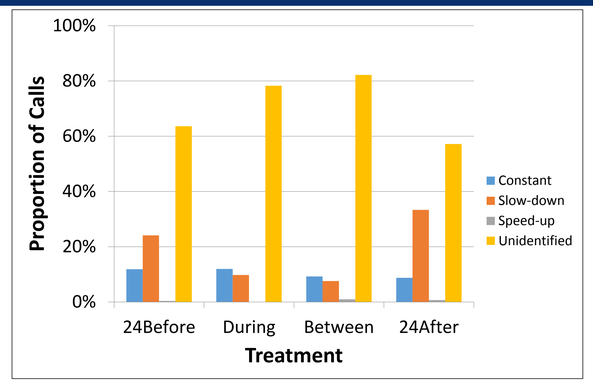
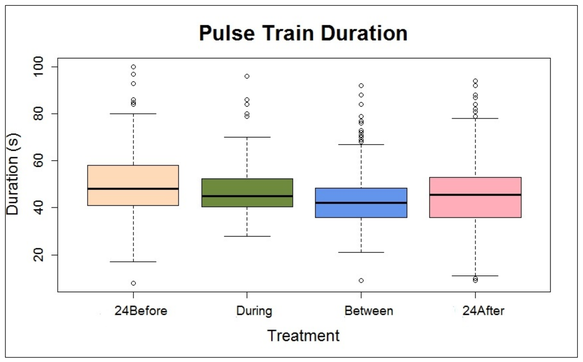


Figure 3. Proportion of each pulse train type in each treatment period. Speed-up type was limited in sample size (< 1% per treatment)

Table 1. Number of pulse trains for all treatment periods combined

Slow-Down	Constant	Speed-up	Unidentified	Total
190	95	6	650	941

- **The proportion of pulse train types was significantly different within and among treatments (Fisher's exact test p<0.001).**



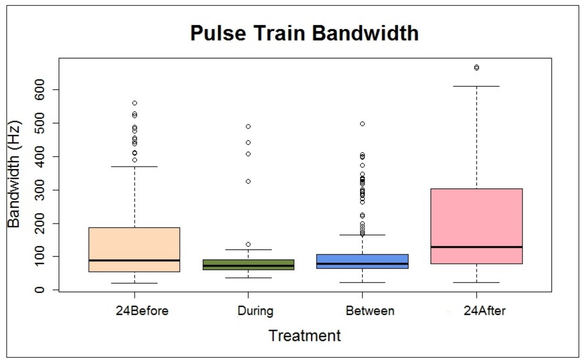


Figure 5 & 6. Box plots showing duration and bandwidth measures for all call types (y-axis) by treatment category (x-axis).

Table 2. Pairwise comparison p values resulting from Dunn's test with Bonferroni adjustment to compare duration and bandwidth measures among treatments.

Treatment	Variable	24Before	Between	24After
24Before	*Duration*	-	p < 0.05	p < 0.05
	Bandwidth	-	0.75	p < 0.05
During	*Duration*	0.36	p < 0.05	1
	Bandwidth	p < 0.05	0.12	p < 0.05
Between	*Duration*	-	-	p < 0.05
	Bandwidth	-	-	p < 0.05

Summary/Conclusions

Summary of Results

These analyses are preliminary; more sophisticated methods will be used in future analysis to address issues such as temporal dependence. Preliminary results suggest:

- Call rates were lower during and between MFAS compared to before and after MFAS.
- Proportion of "unidentified" pulse train types increased during and between MFAS while the proportion of other pulse train types decreased during these time periods.
- Duration was significantly shorter during and between MFAS compared to after MFAS.
- Pulse train bandwidth was significantly lower during and between MFAS, and it was significantly higher after MFAS compared to all treatment periods.

Conclusions

- Aspects of minke whale vocal behavior (call rate, vocal type, and pulse train duration and bandwidth) appeared to show significant differences among treatment periods.
- These results suggest that minke whale vocal behavior may change in response to MFAS.
- More research (i.e., larger sample sizes) is needed to examine these potential responses in more detail.

Recommendations/Future Work

Suggestions for data collection and survey design

- Use more advanced statistical methods to address temporal dependencies.
- Tagging or acoustic localization of individual animals is needed to help understand movement patterns and vocalization behaviors relative to MFAS.

Acknowledgements

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References

- Charif, R. A., C. S. Oedekoven, A. Rahaman, B. J. Estabrook, L. Thomas, and A. N. Rice. 2014. Development of Statistical Methods for Assessing Changes in Whale Vocal Behavior in Response to Mid-Frequency Active Sonar. Technical report to HDR, Inc.