Do echolocation clicks produced by delphinid species in the northwest Atlantic contain species-specific cues?



INTRODUCTION

Free-ranging dolphins use echolocation clicks to forage and navigate. Species-specific differences in echolocation clicks produced by dolphin species in the northwest Atlantic Ocean were investigated using visually validated, single species recordings. These recordings were collected by Duke University and Northeast Fisheries Science Center using towed hydrophone arrays. Echolocation click parameters were examined for seven species of delphinids; short-beaked common dolphin (*Delphinus delphis*, Dd), Risso's dolphin (*Grampus griseus*, Gg), short-finned pilot whale (*Globicephala macrorhynchus*, Gm), rough-toothed dolphin (*Steno bredanensis*, Sb), striped dolphin (*Stenella coeruleoalba*, Sc), Atlantic spotted dolphin (*Tursiops truncatus*, Tt),



METHODS

- PAMGuard's (Gillespie et al., 2009) automated click detector module used to automatically detect echolocation clicks
- Newly developed PAMGuard ROCCA tools used to measure six click parameters; duration, center frequency, peak frequency, sweep rate, and number of zero crossings
- Clicks with a signal-to-noise ratio < 10 dB and > 35 dB removed from analysis.
- Statistical comparisons among species
- o Kruskal-Wallis test
- Post-Hoc Dunn's test with a bonferroni adjustment
- Discriminant Function Analysis (DFA) used to classify species.



Figure 1. PAMGuard display showing bottlenose dolphin click trains in the bearing time display (A) with bearing along the Y-axis and time along the X-axis. The selected click waveform (B), click spectrum ((C), and wigner plot (D) are displayed on the bottom panels. Kerry J. Dunleavy¹, Tina M. Yack¹, Julie N. Oswald¹, and Thomas F. Norris¹ (1) Bio-Waves, Inc., 364 2nd St. Ste. 3, Encinitas, CA 92024 USA



Figure 3. Box plots displaying the median, first and third quartiles for each echolocation click parameter with species along the x-axis and each parameter along the y-axis. The inter-click interval measures are measured automatically and not by individual click train, and thus are not an accurate representation for each species due to multiple individuals clicking simultaneously in many cases.

 $\label{eq:table1} \begin{array}{l} \textbf{Table 1}. \mbox{ Matrix displaying echolocation click parameters that were significantly different when compared among species (p<0.05). Risso's dolphin clicks were significantly different (\alpha=0.05) for all comparisons. \end{array}$

	Common Dolphin	Risso's Dolphin	Pilot Whale	Rough-toothed Dolphin	Striped Dolphin	Atlantic Spotted Dolphin
Risso's Dolphin	All Parameters Significant					
Pilot Whale	All Parameters Significant	All Parameters Significant				
Rough-toothed Dolphin	All Parameters Significant	All Parameters Significant	Duration Center Frequency Peak Frequency Inter-Click Interval			
Striped Dolphin	Center Frequency Peak Frequency Sweep Rate	All Parameters Significant	Duration Center Frequency Peak Frequency Zero Crossings Inter-Click Interval	Duration Peak Frequency Zero Crossings Inter-Click Interval		
Atlantic Spotted Dolphin	All Parameters Significant	All Parameters Significant	Duration Peak Frequency Center Frequency Zero Crossings Inter-Click Interval	Duration Peak Frequency Zero Crossings Inter-Click Interval	Duration Zero Crossings Inter-Click Interval	
Bottlenose Dolphin	All Parameters Significant	All Parameters Significant	All Parameters Significant	All Parameters Significant	Duration Center Frequency Peak Frequency Zero Crossings Inter-Click Interval	All Parameters Significant

 Table 2. Classification matrix for DFA (with equal prior probability distribution; variables used: peak frequency, center frequency, duration, sweep rate and no. zero crossing) showing the percentage of clicks classified to each species with the correct classification score by species highlighted yellow.

	Common Dolphin	Risso's Dolphin	Pilot Whale	Rough-toothed Dolphin	Striped Dolphin	Atlantic Spotted Dolphin	Bottlenose Dolphin
Common Dolphin	67%	6%	0%	2%	7%	6%	11%
Risso's Dolphin	2%	68%	0%	2%	7%	3%	16%
Pilot Whale	0%	0%	100%	0%	0%	0%	0%
Rough-toothed Dolphin	22%	0%	1%	16%	2%	14%	44%
Striped Dolphin	28%	14%	0%	10%	16%	12%	20%
Atlantic Spotted Dolphin	19%	5%	0%	13%	4%	22%	36%
Bottlenose Dolphin	16%	6%	1%	11%	5%	12%	48%



DISCUSSION/CONCLUSIONS

- Many significant differences in echolocation click parameters are evident among species.
- Pilot whales had 100% correct classification rate
- Very low center frequency
- Very low peak frequency
- Risso's dolphin, common dolphin, and bottlenose dolphins' all had high correct classification rates
- Compared to 14% correct classification expected by chance alone
- Clicks are significantly different across almost all parameters for almost all species pairwise comparisons
- Testing was conducted to determine how the frequency response of the hydrophones affected measures. Applying transfer functions made no significant difference in any of the measurements that we selected to compare.

Conclusions

- Results suggest that clicks can be used for classification of at least some species.
- Combining information from clicks with other information such as whistle measurements and recording context has the potential to increase classification success
- Improved classifiers will allow researchers to more effectively and efficiently study these species.

Future Work

- Results from this analysis will be used in conjunction with information extracted from whistles to train automated classifiers for differentiating Atlantic delphinid species.
- Future classifier development will utilize geographic variation in clicks for select species

REFERENCES

iillespie, D., C. Dunn, J. Gordon, D. Claridge, C. Embling, and I. Boyd. 2009. Field recordings of Gervais beaked whales Mesoplodon europaeus from the Bahamas. *The Journal of the Acoustical Society of America*, 125:2428–33.

ACKNOWLEDGEMENTS

We would like to thank Sofie Van Parijs, Danielle Cholewiak, and Lynn Hodge for providing the data for this analysis. Photo's were taken under NMFS scientific research permit 779-1633.

