# Assessment of Acoustic Adaptations for Noise Compensation in Marine Mammals

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## LONG-TERM GOALS

The proposed research will address the fundamental theoretical issue of noise compensation mechanisms in the vocal communication of marine mammals. Noise compensation mechanisms are important for improving signal transmission with an energy limited source. A better understanding of marine mammal noise compensation mechanisms can potentially provide effective means of improving signal transmission in a noisy marine environment and for assessing the impact of man-made sounds on the use of sound by marine mammals.

## OBJECTIVES

The primary objectives of this project are to: 1) generate testable hypotheses of general vocal responses of marine mammals to particular noise types; and 2) test these hypotheses with data from two low-frequency baleen whale species in coastal shallow water environments using existing data from North Atlantic right whale (*Eubalaena glacialis*) acoustic tag recordings (Digital Archival Tag - Dtag) (Johnson and Tyack 2003) and new acoustic data collected from Southern right whales (*Eubalaena australis*).

## APPROACH

The approach for this study was to first develop hypotheses about common mechanisms of noise compensation in marine mammals by investigating the matching of marine mammal signals to their acoustic habitats and general trends for noise compensation documented from different species of animals in response to noise sources in the environment. These hypotheses were then tested using an extensive existing database of acoustic tag data collected from the North Atlantic right whale in the Bay of Fundy to determine what, if any, vocal compensation mechanisms were employed by North Atlantic right whales. The second stage of this study involved collecting additional data from Southern right whales. Commercial shipping activity is significantly lower in the Southern hemisphere, providing the opportunity to compare the vocal behavior of a single species of right whale in areas with very low human activity to areas with active commercial ports in the same region. The primary proposed location to study the Southern right whale population was in Argentina, in two adjacent gulfs, Golfo San José and Golfo Nuevo. Both gulfs experience similar weather conditions and are used by a single population of Southern right whales but differ in the level of human activity. Due to permitting limitations, this portion of the data collection was moved to a similar right whale population off the Southern coast of Brazil. Data collection was conducted in two bays to compare the vocal behavior of individual whales in very low and moderate noise conditions. Vessel noise was documented by continuous acoustic recorders in multiple habitat areas to quantify the levels of

acoustic disturbance presented to the whales and any detectable changes in the calling behavior of the whales. These data will be used to further test the general noise compensation hypotheses developed in the first part of the study and compare the vocal behavior between the two right whale species.

## WORK COMPLETED

A literature review of existing vocal noise compensation mechanisms in mammalian species has been completed and a review manuscript has been conditionally accepted for publication. A propagation modeling study comparing transmission loss characteristics of baleen whale vocalizations for a variety of species in different shallow and deep water habitats to assess the role of environmental propagation characteristics on signal evolution has been completed and a manuscript is currently in preparation. Copies of the existing Dtag data from North Atlantic right whales were obtained and vocalizations from the tagged whales have been extracted. Measurements of call parameters (include duration, frequency content, and receive level) and noise levels have been completed and the resulting article was published online in the journal Biology Letters in July 2010. These results were presented at the Society of Marine Mammalogy conference in Quebec, Canada in October 2009, the Acoustical Society of America meeting in Baltimore, MD in April 2010, and at the 2nd International Conference on the Effects of Noise on Aquatic Life in Cork, Ireland in August 2010. A second publication resulting from the extended abstract for the talk at the Ireland meeting was published in early 2012. Permits for acoustic data collection in Brazil were obtained through a Scientific Expedition process to Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq - Brazilian government agency that issues such permits) by Universidade Federal de Santa Catarina, with collaboration from Projeto Baleia Franca, Universidade Federal do Rio Grande do Norte and Centro Nacional de Pesquisa e Conservação de Mamíferos Aquáticos, the Brazilian counterparts for this study. The scientific permit to collect inside of a protected area was issued to K.R Groch, Paulo A.C. Flores and Renata S.Sousa-Lima (ICMBio SISBIO #29774-1). Our Brazilian collaborators successfully deployed acoustic recorders in two habitats in October and November 2011 and we obtained recordings of numerous right whale calls, along with ambient background noise conditions from both habitats. Results from this study are currently in preparation for publication.

## RESULTS

A literature review of vocal noise compensation mechanisms in mammalian species revealed three parameters that are modified to improve signal detectability in noise (Table 1). The Lombard effect and other vocal noise compensation mechanisms have been observed across diverse taxa ranging from birds to mammals, indicating that the effects of noise on vocal communication are similar across a wide variety of species and types of noise conditions. These results will allow for predictions for what call modifications animals may make in response to novel sound sources in their environment.

| Parameter | Modification |
|---|---|
| Vocalization | Amplitude<br>Call type |
| Temporal | Call duration<br>Call rate<br>Serial redundancy<br>Timing of production |
| Frequency | Minimum frequency<br>Maximum frequency<br>Peak frequency<br>Spectral tilt |

***Table 1. A summary of three calling parameters, and the observed types of modifications that different mammalian species exhibit in increased noise.***

An acoustic recording tag, the Dtag, was used to record the noise levels received by individual whales and the vocalizations they produced in the Bay of Fundy, Canada. These data were used to assess the variability in the received levels (and therefore source level), duration and frequency content of calls produced by the tagged whale in varying ambient noise environments. Results from the analysis of the 2001-2005 Dtag data from the Bay of Fundy indicate that individual call production is modified in increased ambient noise conditions with changes to call intensity. Individual whales producing multiple calls showed increases in received call amplitude in increasing ambient noise conditions (Figure 1). These results are consistent with previous studies that have shown similar vocal modifications in odontocetes (Scheifele et al. 2005; Holt et al. 2009).

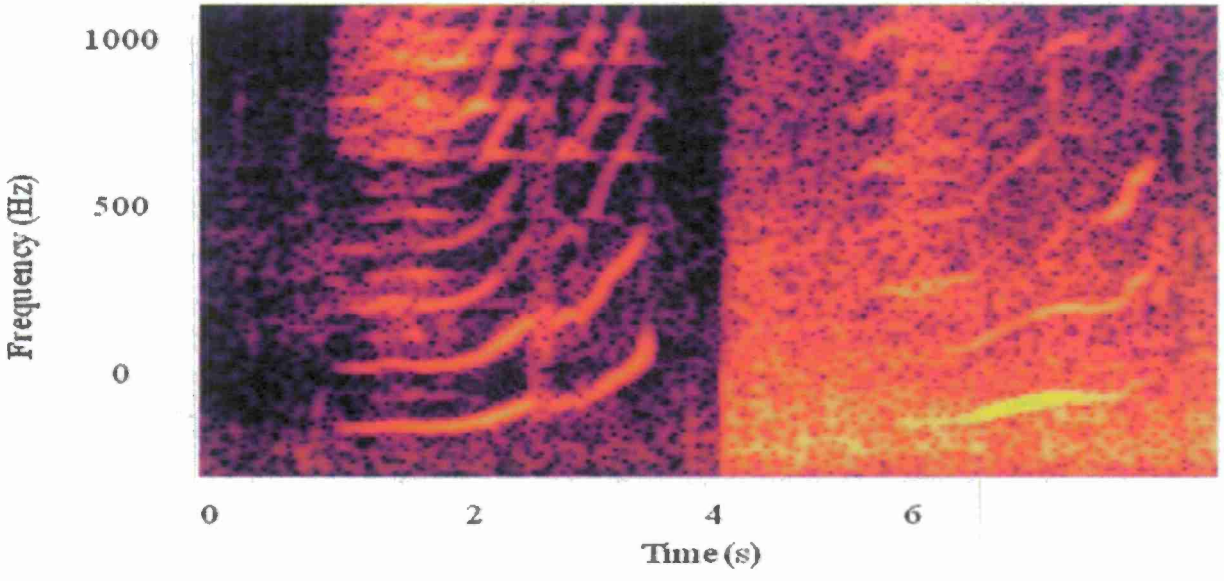


***Figure 1. Spectrograms of two upcalls from a single North Atlantic right whale illustrating increased call intensity in the higher noise recording.***

Acoustic recordings were made in Brazil by collaborators from Projeto Baleia Franca and Centro Nacional de Pesquisa e Conservação de Mamíferos Aquáticos, in cooperation with Universidade Federal de Santa Catarina, and Universidade Federal do Rio Grande do Norte. Preliminary analyses

indicate a lower mean frequency of right whale contact calls from the Brazil recordings (Figure 2). These results are similar to the observation of lower frequency contact calls from Southern right whales recorded in Argentina when compared to North Atlantic right whales. A publication of the full results from this study, including measurements of the ambient noise at the time of right whale vocalizations, is currently in preparation and will provide information on the impacts of environmental noise on call structure in right whales.

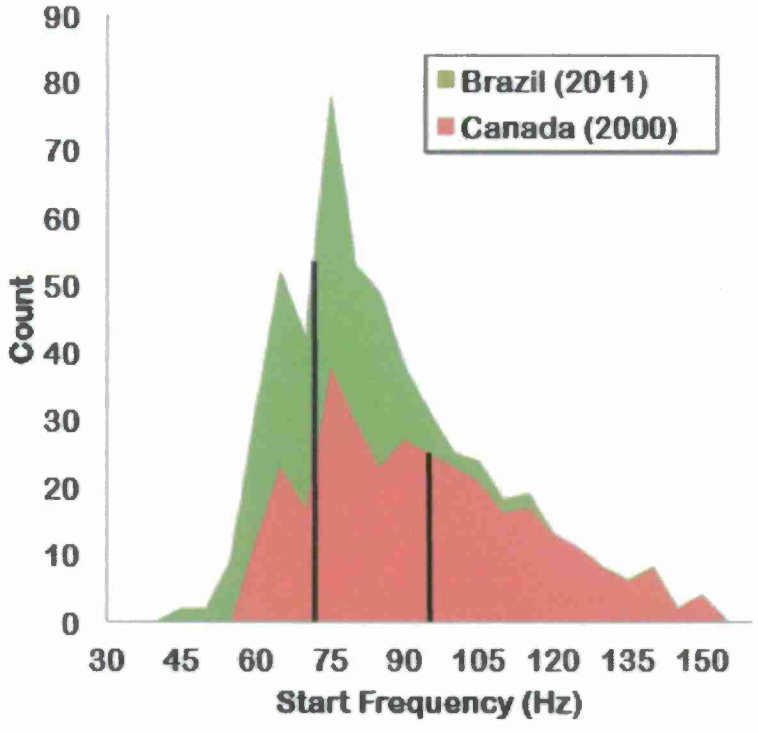


***Figure 2. Histogram of the start frequency of right whale upcalls from Brazil and Canada, indicating a trend towards lower frequency calls in Brazil.***

## IMPACT/APPLICATIONS

This study will lead to a better understanding of the existence of acoustic adaptations in right whale vocalizations and the types of vocal compensation mechanisms that they employ for coping with increased ambient noise conditions, including both natural and man-made sound sources. This project is a first step in developing a general theory regarding noise compensation mechanisms in marine mammal species.

## RELATED PROJECTS

None

## REFERENCES

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Johnson MP, Tyack PL (2003) A digital acoustic recording tag for measuring the response of wild marine mammals to sound. IEEE Journal of Oceanic Engineering 28:3-12

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## PUBLICATIONS

Parks SE, Johnson, M, Nowacek, D, Tyack, PL (2010) Individual right whale call louder in increased environmental noise. Biology Letters. Published online July 7, 2010 doi: 10.1098/rsbl.2010.0451.

Parks, S.E., Johnson, M.P., Nowacek, D.P., and Tyack, P.L. 2012. Changes in Vocal Behavior of North Atlantic Right Whales in Increased Noise. In:The Effects of Noise on Aquatic Life, Popper, A.N., Hawkins, A. Eds., Springer, 317-320.

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**14. ABSTRACT**

Marine mammals use sound for communication and navigation in the ocean. Studies of noise compensation mechanisms used by marine mammals can provide a starting point for research to uncover new techniques of improving signal transmission in a noisy marine environment. These noise compensation mechanisms can be used to improve Navy system designs for underwater detection, communication, and navigation. Understanding how marine mammals compensate for noise can also be used to help predict and reduce impacts of man-made noise. A comprehensive review of documented vocal responses to noise by animals was used to develop testable hypotheses of general vocal responses to particular noise types. These hypotheses were then tested through analysis of acoustic data collected from North Atlantic right whales (E. glacialis). The results allowed us to assess the general vocal compensation mechanisms that marine mammals employ to cope with noise in a shallow water coastal environment and how these function in the presence of man-made noise sources of different types.

**15. SUBJECT TERMS**

marine mammal, noise compensation.

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