

Population Consequences of Acoustic Disturbance of Blainville's Beaked Whales at AUTECH

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LONG-TERM GOALS

Atypical strandings and behavioral responses of beaked whales have been associated with the use of Navy mid-frequency active (MFA) sonar (e.g. Simmonds and Lopez-Juraco 1991, Evans and England 2001, McCarthy et al. 2011, Tyack et al. 2011). Yet MFA sonar operations occur repeatedly on Navy ranges that are known beaked whale habitat. The Bahamas Marine Mammal Research Organisation (BMMRO) has been studying beaked whales in the northern Bahamas (Claridge 2006, 2013), including a population of Blainville's beaked whales (*Mesoplodon densirostris*) found at the Atlantic Undersea Test and Evaluation Center (AUTECH) range. These data are providing critical information on abundance, survival, and reproductive rates which are being used to model the population consequences of acoustic disturbances at AUTECH. The long-term goal of this project is to develop a methodology for monitoring the long-term health of populations that are repeatedly exposed to sonar. This work is important for the continued operational integrity of Navy ranges.

OBJECTIVES

The overall objective of this study is to develop a methodology for evaluating and monitoring the health of beaked whale populations on navy ranges and to apply this to Blainville's beaked whales at AUTECH. The specific objectives for BMMRO are to analyze longitudinal data to investigate aspects of the life history and behavior of this species which will be needed to inform the population consequences model, thus forming part of a larger project, Population Consequences of Acoustic Disturbance (PCAD, for full details of the project, see the PCAD Working Group reports).

APPROACH

The PCAD model is based on a framework developed by the National Research Council (NRC) Committee on Characterizing Biologically Significant Marine Mammal Behavior (NRC 2005). The ONR PCAD Working Group is developing the beaked whale PCAD model. This model links changes in diving behavior to changes in body condition, and changes in body condition to vital rates

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(particularly calf survival and pregnancy). The key components of the model to which BMMRO is contributing through funding sponsored by this grant are the following:

1. **Mother-infant spatial relationships:** investigation of the diving and vocal behavior of mother-calf pairs using a combination of visual observations and acoustic detections. The primary question of interest is whether young calves are capable of diving for the same durations and to the same depths as their mother which will provide useful baseline mother-infant spatial relationships.
2. **Maturation:** analysis of longitudinal individual sightings data to determine age at sexual maturity, as well as the age at which calves first separate from the mother.
3. **Reproduction:** investigation of life history data to provide estimates of inter-calf interval and calf survival.

WORK COMPLETED

To determine if the diving and vocal behavior of calves mirrors that of their mother, acoustic recordings of click detections at AUTECH were analyzed. If both mother and calf are detected clicking during a foraging dive, then click duration and in some cases, dive depth, can be determined. The first step was to look at the age at which Blainville's beaked whales start clicking. We now have 4 recordings from AUTECH when the group composition was made up solely of a mother-calf and when acoustic recordings were made in the absence of any other whales within a three-hydrophone radius around the focal area (equivalent to six nautical miles distance). These events include calves of varying age: a neonate (< 2 months old), a 3-4 month old, and two calves at least 2 years old. Preliminary analyses have been completed for three of the recordings and we are awaiting receipt of the final recording from NUWC personnel.

To examine the age at the onset of sexual maturity, analyses of photographs of individual Blainville's beaked whales photographed off SW Abaco Island were carried out to assign age and sex classes to individuals throughout the sighting record (1997-2012). There were six individuals first observed as calves that were re-sighted repeatedly over 9 – 14 years, four of which (three females, one male) were monitored until sexually mature, which provided information on the minimum age at sexual maturity. Detailed examination of the individual sighting histories of these six whales was undertaken. Once the age of each of these calves was assigned, this formed the timeline on which to assign ages at the different stages of their maturity (see Claridge 2013 for further details).

As part of our work on the reproductive biology of Blainville's beaked whales, we compared abundance and age composition in two areas of equal size (~300 km²) inside and away from the AUTECH range. We fit Bayesian hierarchical models to photo-identification data collected from 2005-2010 to estimate abundance at AUTECH where mid-frequency active sonars are regularly used; and off southwest Abaco Island (~170 km away), a control study site where navy sonar is not used. A multinomial model of photographically-determined age-class counts was then fit to the same dataset.

Additionally, several datasets are being shared with the LATTE project (Linking Acoustic Tests and Tagging using statistical Estimation) which in turn will feed into the PCAD model. Specifically, we are working with the LATTE team (Thomas and Tiago) to provide data for *M. densirostris* group sizes and detections from visual and acoustic surveys conducted throughout the Great Bahama Canyon.

RESULTS

When do Blainville's beaked whales start clicking? Preliminary acoustic analysis carried out previously suggested that neonate calves are not vocalizing when diving with their mother yet individuals over 2 years old can be detected acoustically while diving. Additional analysis was conducted in FY13 of a recording made on July 25th, 2012 at AUTC. In this encounter, a single adult female was associated with a calf estimated to be 3-4 months old which was observed nursing. Preliminary analysis of this recording showed acoustic detections from two different whales suggesting that young calves may indeed be vocalizing but not when a neonate. More recordings are obviously needed to substantiate this initial finding.

Age at sexual maturity. New information on age at sexual maturity for Blainville's beaked whale is presented by Claridge (2013) which adds substantially to our previous knowledge. One adult female followed from a dependent calf through maturity was 9 years old at the onset of sexual maturity. A minimum age at sexual maturity of 8 – 9 years was estimated for a second individual. These findings provide support for a minimum age of 9 years old for a female examined post-mortem by Ross (1979), until now the only information for this species, and is also similar to ages reported from whaling data for female Baird's beaked whale (Kasuya 1977) and northern bottlenose whale (Christensen 1973). Male Blainville's beaked whales appear to mature at a similar age to females. One male first seen as a dependent calf matured when 9 years old but another male had not yet reached sexual maturity by age 10, suggesting some individual variation and demonstrating the need for larger sample sizes. Using similar methods, Gowans et al. (2000) showed that free-ranging northern bottlenose whale males mature at a similar age to those reported here. However, age reported here should not be considered absolute because it was based on a timeline beginning from an estimated age when a calf was first sighted and none of the whales that matured during the study were first seen as neonates. Assigned age could be wrong by +/- 1 year depending on individual differences in length at birth, growth rates, and scarring patterns.

Comparison of abundance and age composition. Notably no individuals were seen in both study sites and adult females exhibited long-term site fidelity. There were 39 reliably-marked whales identified from high-quality photographs at AUTC and 65 at Abaco, and we estimated a high probability ($p=0.88$) that average annual abundance was lower at AUTC. A multinomial model of age-class counts revealed that there was a high probability ($p=0.85$ and 0.91) of a lower proportion of calves and sub-adults, respectively, at AUTC.

IMPACT/APPLICATIONS

Measuring the health of populations utilizing Navy ranges has more relevance to the Navy than simply monitoring their size. This program focuses directly on that goal and represents the first attempt to combine data from various sources (visual, tag, biophysical, and passive acoustic data) for this purpose, including the long-term photo-identification and behavioral data provided by BMMRO. Using these data sets and expertise, a methodology is being developed for evaluating the population level effect of sonar on Blainville's beaked whales at AUTC. This will be valuable to apply to other beaked whale species and in other locations, e.g. Cuvier's beaked whales, a priority species, at the Southern California Offshore Range (SCORE).

Assessing population demographics of beaked whales on navy ranges is important for identifying whether population-level effects result from regular exposure to military sonars. At AUTC, *M.*

densirostris cease foraging and move tens of kilometres away during multi-ship sonar exercises, returning days later when the testing has ceased (Tyack et al. 2011). Higher energetic costs associated with displacement, combined with lower energy intake if foraging is disrupted, provide a possible mechanism to reduce individual condition. Energetic demands suggest this is of particular concern for lactating females, and may result in lower reproductive success and population consequences (New et al. 2013). Repeated exposure to navy sonar at AUTC may have contributed to lower recruitment and calf survival, and that effects on sub-adult numbers and overall abundance suggest prolonged disturbance over at least the last decade.

RELATED PROJECTS

Assessing Beaked Whale Reproduction and Stress Response Relative to Sonar Activity at the Atlantic Undersea Test and Evaluation Center (AUTC)

This project is a collaborative project between BMMRO, Southwest Fisheries Science Center (Nick Kellar, John Durban) and the Naval Undersea Warfare Center (David Moretti). The goal of this study is to assess glucocorticoid levels from blubber biopsies of targeted species, to assess stress levels relative to sonar exposure. Specifically, the project aims to collect biopsy samples at AUTC where fleet readiness training involves regular use of mid-frequency active sonars, and compare the levels to those measured in biopsies collected from control populations within the Bahamas region that are less exposed to sonar activity. In parallel, pregnancy states will be ascertained via blubber progesterone levels in both groups of animals to investigate whether there is a relationship between sonar activity, stress measures, and reproductive rates, to assess population-level impacts.

Monitoring beaked whale movements during the Submarine Commanders Course using satellite telemetry

This project is a collaborative project between the Bahamas Marine Mammal Research Organisation, Southwest Fisheries Science Center and the Naval Undersea Warfare Center (David Moretti). Satellite telemetry is being used to monitor the movements and diving behavior of beaked whales and other odontocete cetacean species on the US Navy's AUTC range before, during and after sonar exercises in which multiple ships are using their tactical sonars. Field work during this project is providing opportunity to collect biopsy samples and photo-identification data at AUTC. This project has been supported by the US Department of Defense (OPNAV N45 - Environmental Readiness Division).

Behavioral ecology of deep-diving odontocetes in the Bahamas

This project is examining key aspects of the behavioral ecology of six Department of Defense priority species in The Bahamas. We will integrate data acquired through individual photo-identification, molecular genetics, fatty acid, persistent organic pollutant and stable isotope profiles, satellite telemetry and acoustic recordings to characterize the social structure, residency patterns, reproductive biology, diet, foraging ecology, and population structuring of key cetacean species. Field work during this project is providing opportunity to collect biopsy samples and photo-identification data from throughout the northern Bahamas. The project has been supported by the Strategic Environmental Research and Development Program (US Department of Defense, Department of Energy and the Environmental Protection Agency).

REFERENCES

- Christensen I (1973) Age determination, age distribution and growth of bottlenose whales, *Hyperoodon ampullatus* (Forster), in the Labrador Sea. *Norwegian Journal of Zoology* 21(4): 331–340.
- Claridge, D.E. (2006) Fine scale distribution and habitat selection of beaked whales. Thesis presented for Master of Science in Zoology at University of Aberdeen, Scotland, UK. 119 pp.
- Claridge, D.E. (2013) Population ecology of Blainville's beaked whales (*Mesoplodon densirostris*). Thesis presented for Doctor of Philosophy in Marine Biology at University of St Andrews, Scotland, UK. 313 pp.
- Evans, D.I. and G.R. England. (2001) Joint interim report Bahamas marine mammal stranding event of 15 – 16 March 2000. National Oceanographic and Atmospheric Administration. 59 pp. Available from:
http://www.nmfs.noaa.gov/prot_res/PR2/Health_and_Stranding_Response_Program/Interim_Bahamas_Report.pdf
- Gowans S, Dalebout ML, Hooker SK, Whitehead H (2000) Reliability of photographic and molecular techniques for sexing northern bottlenose whales (*Hyperoodon ampullatus*). *Canadian Journal of Zoology* 78: 1224-9.
- Kasuya T (1977) Age determination and growth of the Baird's beaked whale with a comment on the fetal growth rate. *Scientific Reports of the Whale Research Institute*, Tokyo 29: 1–20.
- Lande, R. (1993) Risks of population extinction from demographic and environmental stochasticity and random catastrophes. *American Naturalist* 142: 911-927.
- McCarthy, E., Moretti, D., Thomas, L., DiMarzio, N., Morrissey, R., Jarvis, S., Ward, J., Izzi, A., Dilley, A. (2011) Changes in spatial and temporal distribution and vocal behavior of Blainville's beaked whales (*Mesoplodon densirostris*) during multi-ship exercises with mid-frequency sonar. *Marine Mammal Science* 27: E206-E226. Doi: 10.1111/j.1748-7692.2010.00457.x
- National Research Council (2005) "Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects", Committee on Characterizing Biologically Significant Marine Mammal Behavior, National Research Council, The National Academies Press. 142 pp.
- New LF, Moretti DJ, Hooker SK, Costa DP, Simmons SE (2013) Using Energetic Models to Investigate the Survival and Reproduction of Beaked Whales (family *Ziphiidae*). *PLoS ONE* 8(7): e68725. doi:10.1371/journal.pone.0068725
- Ross G (1979) The smaller cetaceans of the south east coast of southern Africa. Unpublished thesis submitted to the University of Port Elizabeth, South Africa.
- Simmonds, M. P. and Lopez-Juraco, L. F. (1991) Whales and the military. *Nature* 351:448.
- Tyack, P.L., Zimmer, W.M.X., Moretti, D., Southall B.L., Claridge, D.E., et al. (2011) Beaked whales respond to simulated and actual Navy sonar. *PLoS ONE* 6(3): e17009 doi:10.1371/journal.pone.0017009