

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

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LONG-TERM GOALS

Atypical mass strandings and behavioral responses of beaked whales have been correlated with exposure to naval sonar (e.g. Simmonds and Lopez-Juraco 1991; Frantzis 1998; Evans and England 2001), highlighting a need to understand the potential physiological impacts to individual whales and if these in turn represent a biologically significant threat to exposed populations. The long-term 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 the U.S. Navy's Atlantic Undersea Test and Evaluation Center (AUTECH) in the Andros-AUTECH Operating Area 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.

OBJECTIVES

The primary objectives of the study are:

- 1) To assess stress levels measured from glucocorticoid concentrations in blubber biopsies relative to sonar activity, and relate these to pregnancy rates from progesterone concentrations in the same tissue for Blainville's beaked whales (*Mesoplodon densirostris*) and sperm whales (*Physeter macrocephalus*).
- 2) To collect photo-identification data to monitor repeated sampling of individuals, construct sighting histories and identify consistent associates as covariates for stress analyses; and to document successful calving events for comparison to hormone-derived pregnancy rates.

APPROACH

The experimental design of this study is based on a population comparison: to compare beaked whale and sperm whale stress levels and pregnancy rates between areas with contrasting sonar activity: at the U.S. Navy's Andros-AUTEC Operating Areas and off the southwest coast of Abaco Island and other regions throughout the Great Bahama Canyon (Figure 1).

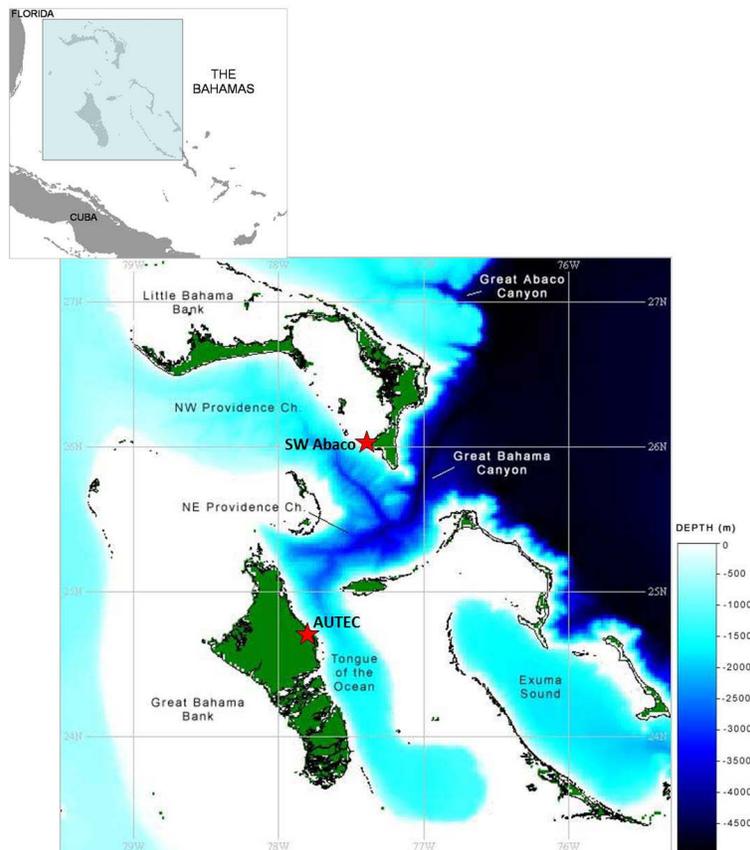


Figure 1. Map of the northern Bahamas showing the location of the two areas where blubber biopsy samples are being collected: AUTEC and SW Abaco. Both lie within the Great Bahama Canyon, a submarine canyon that reaches depths of more than 4000m. Additional sampling is occurring throughout the canyon region.

Stress levels for whales at AUTEK are being evaluated using biopsy samples collected primarily before scheduled Submarine Commanders Courses (SCC) as part of a Living Marine Resources (LMR) funded satellite tagging study. Five 15-day field efforts were planned under this study, in Oct/Nov 2011 and 2013, July 2012 and April/May 2011-14. Reproductive rates will be examined relative to measured stress levels and sonar activity on the range during the preceding months through collaboration with David Moretti at the Naval Undersea Warfare Center. A further 15-day summer sampling effort was conducted at AUTEK in summer 2012 and 2013. In addition, three 15-day field efforts have been conducted in the control area at SW Abaco, spanning May 2011- May 2013, closely matching the timing of the spring SCC at AUTEK. These control samples are being augmented by samples collected during a concurrent annual SERDP-funded sightings-survey around the northern Bahamas, as well as samples collected opportunistically as part of the ONR-funded Bahamas Beaked whale Ecology Study (N000140710120) until that project ended in May 2012. The species targeted are Blainville's beaked whale (*Mesoplodon densirostris*) and sperm whale (*Physeter macrocephalus*).

Using AUTEK's instrumented array of bottom-mounted hydrophones on the Weapons Range, beaked whales and other odontocetes can be monitored and localized in real time by passive acoustic detection of their echolocation clicks (DiMarzio *et al.* 2008). Acoustic technicians from the Naval Undersea Warfare Center relay real-time cetacean localizations using the marine mammal monitoring system at AUTEK and direct observers on a 6.8 m rigid-hulled inflatable (RHIB) to the whales, increasing the opportunities for locating animals and obtaining biopsies. No such array exists off SW Abaco Island; so instead, boat-based surveys are concentrated in areas of known higher density of beaked whales, identified from over a decade of research in the area (Claridge 2006). A hand-held hydrophone is deployed to detect foraging sperm whales. Combined these approaches increase opportunities for finding animals off Abaco Island.

When animals are located, remote biopsy sampling (e.g. Hooker *et al.* 2001) is being used to obtain skin and blubber biopsies. Stress levels are being examined relative to sonar activity by measuring glucocorticoid concentrations in blubber biopsies (Kellar *et al.* 2014). Pregnancy state will also be assessed by measuring progesterone concentrations in blubber (Kellar *et al.* 2006; Trego *et al.* 2009), and pregnancy rates will be examined relative to measured stress levels by comparison between samples collected at AUTEK and the control area around Abaco.

Photo-identification data are providing a record of all individuals sighted, and being used to build sighting histories, using new data and the existing BMMRO database. These data will provide information on ranging patterns and demographics that can serve as covariates for analysis of stress patterns. Similarly, photo-identification data will be used to evaluate the stability of individual associations to identify consistent associates that may have similar exposure and stress levels. Longitudinal photo-identification records will also enable documentation of successful calving events, to compare with hormone-derived pregnancy rates.

WORK COMPLETED

In April/May 2014, LMR sponsored a directed field effort to deploy satellite telemetry tags on beaked whales and other odontocetes during which blubber biopsies were collected opportunistically. During this time, there were four encounters (three Blainville's beaked whale and one sperm whale) from which two sperm whale biopsies were successfully collected (Table 1).

Table 1. Summary of field efforts at AUTECH prior to spring 2014 SCC events (supported by LMR). Total effort during each survey day is shown as well as tag deployments and blubber biopsies collected during encounters. (DUR. is the amount of time spent with each group encountered.)

DATE	EFFORT (KM)	EFFORT (HR)	SPECIES FOUND	GROUP SIZE	DUR. (MIN)	NO. BIOPSIES	NO. TAGS
24 Apr 14	209.0	11.2	<i>M. densirostris</i>	2	2	0	0
			<i>G. macrorhynchus</i>	40	167	9	2
			<i>K. sima</i>	3	3	0	0
			<i>G. griseus</i>	12	20	0	0
25 Apr 14	90.5	3.8	<i>T. truncatus</i>	2	6	0	0
26 Apr 14	145.2	11.5	<i>G. macrorhynchus</i>	35	33	1	1
			<i>M. densirostris</i>	2	20	0	0
			<i>Z. cavirostris</i>	3	270	0	1
27 Apr 14	156.9	9.5	<i>P. electra</i>	80	113	2	2
			<i>P. macrocephalus</i>	2	164	2	1
4 May 14	104.7	6.2	<i>M. densirostris</i>	2	13	0	0
6 May 14	270.1	7.1	<i>S. attenuata</i>	45	34	0	0
			<i>K. sima</i>	4	8	0	0
			<i>K. breviceps</i>	1	1	0	0

RESULTS

New Data Collected in 2014

Two biopsy samples were collected from two different sperm whales in 2014. The survey effort at AUTECH (vessel tracks) and locations where blubber biopsies were collected at both study sites are shown in Figure 2.

Field observations combined with the photo-identifications of the flukes of the two sperm whales biopsied suggested both whales are sub-adult males. These included body length estimated to be 10-12m, feeding behavior, and small group size. Due to their presumed young age, both whales had with very few unique features (e.g. nicks) so could not be matched to any sperm whales previously photographed in the Bahamas. Genetic sex analysis of the skin collected in the biopsy samples later confirmed that both individuals are males (K. Parsons, *pers. comm.*).

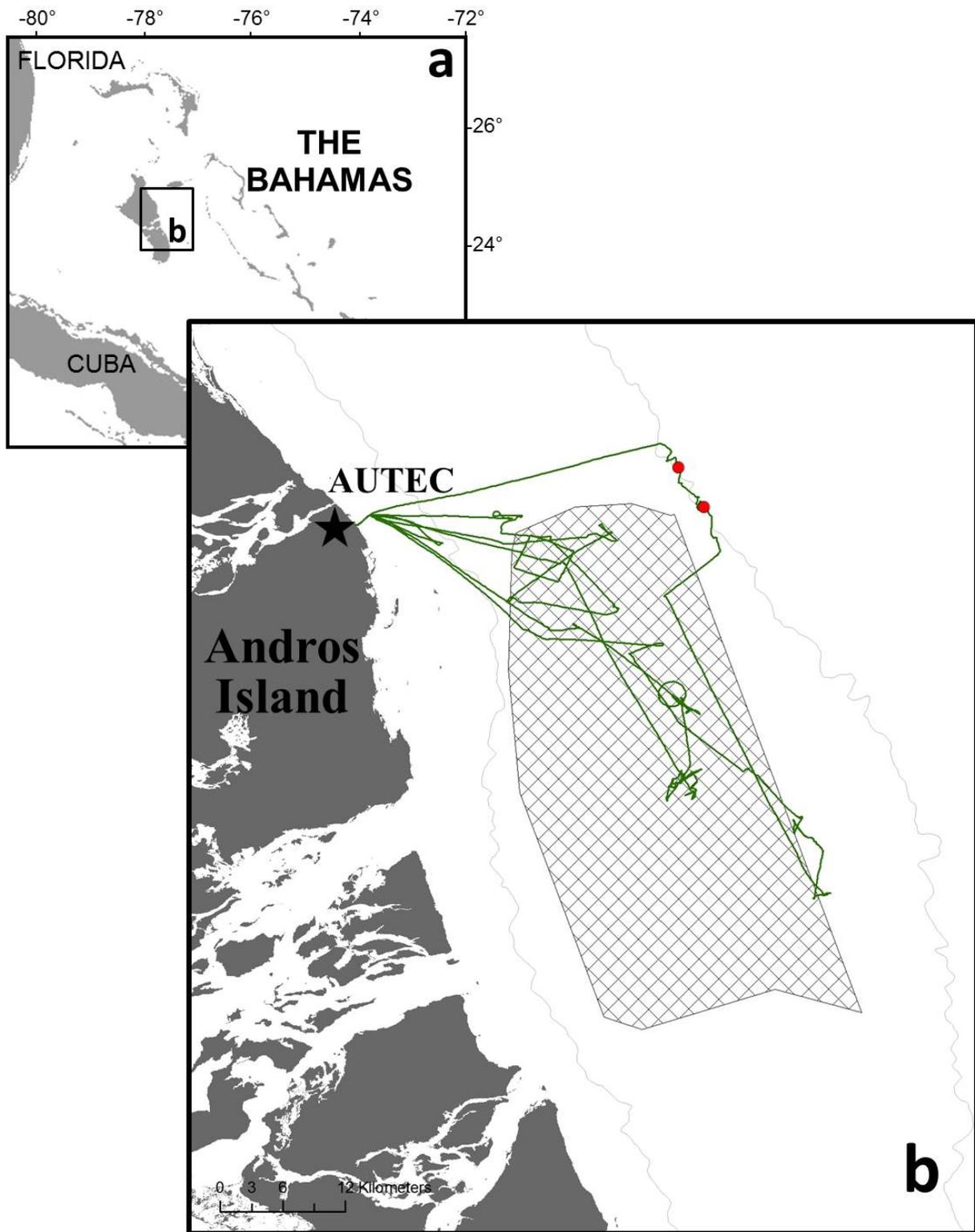


Figure 2. Map of the AUTEC Weapons Ranges (hashed area) off Andros Island, Bahamas showing vessel tracks (green lines) and locations where blubber biopsies were collected from sperm whales (red circles) in April/May 2014. The 1000 m isobaths is shown by the grey line.

Table 2. Summary of blubber biopsies collected from sperm whales at AUTEK during FY14.

FIELDID	YR	MO	DA	LATD	LATM	LOND	LONM	LOC	SEX	AGE	ID
Sperm whale - <i>Physeter macrocephalus</i>											
140427_Pm01	2014	4	27	24	45.42	77	29.12	AUTEK	M	SA	Unk.
140427_Pm02	2014	4	27	24	443.35	77	27.79	AUTEK	M	SA	Unk.

When blubber samples collected from FY11-14 are tallied, we have a total of 42 Blainville’s beaked whale samples (10 from AUTEK and 32 from SW Abaco) and 32 sperm whale samples (17 from AUTEK and 15 from SW Abaco) for use in the hormone analyses (Table 3). These will be augmented by 41 additional Blainville’s beaked whale samples left from previous work with sufficient blubber remaining as well as samples currently being processed for the SERDP project, some of which will also be available.

Table 3. Summary of blubber biopsies collected for target species at AUTEK and SW Abaco from FY11-FY14.

YEAR	BLAINVILLE’S BEAKED WHALE		SPERM WHALE	
	AUTEK	SW ABACO	AUTEK	SW ABACO
FY11	0	5	8	2
FY12	4	24	4	12
FY13	6	3	3	1
FY14	0	0	2	0
Total	10	32	17	15

Next Phase (FY15)

1st quarter: Molecular sexing on final biopsy set (samples collected in FY14-FY15)

2nd – 3rd quarters: Hormone isolation and measurement of all beaked whale samples and sperm whale samples not yet processed.

4th quarter: Population-level analysis of stress hormone concentrations and reproductive condition in AUTEK and Abaco beaked whales, with sperm whales as control group.

IMPACT/APPLICATIONS

Improving our understanding of the population responses of beaked whales relative to sonar usage will aid the US Navy in assessing the potential need for additional mitigation practices for protected marine mammals. In particular, central questions for effective management and potential mitigation are whether sonar use causes detectable physiological stress responses and whether these responses are linked to biologically significant reductions in population health or condition.

This study will build upon ongoing research by Kellar *et al.* assessing stress levels in odontocetes associated with Navy sonar exercises at the Southern California Offshore Range (SCORE). Novel

laboratory techniques, recently developed at Southwest Fisheries Science Center (Kellar *et al.* 2006, Kellar *et al.* 2009), are successfully being used to measure steroid hormones in marine mammal blubber indicating that these studies are both realistic and feasible. The combined results of these studies at both AUTEK and SCORE will provide greater power for assessing the extent and magnitude of stress responses in cetaceans exposed to sonar.

RELATED PROJECTS

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, NOAA 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 Atlantic Undersea Test and Evaluation Center (AUTEK) 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 AUTEK. This project has been supported by the US Department of Defense (NACFAC - Living Marine Resources Program).

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

- Claridge, D.E. (2006) Fine scale distribution and habitat selection of beaked whales. Thesis presented for Master's of Science degree in Zoology at University of Aberdeen, Scotland, UK. 119 pp.
- DiMarzio, N., D., *et al.* (2008) Passive acoustic measurement of dive vocal behavior and group size of Blainville's beaked whale (*Mesoplodon densirostris*) in the Tongue of the Ocean (TOTO). *Canadian Acoustics* 36, 166-173.
- 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
- Frantzis, A. (1998) Does acoustic testing strand whales? *Nature* 392:29.
- Hooker, S. K., Iverson, S. J., Ostrom, P., and Smith, S. C. (2001) Diet of northern bottlenose whales inferred from fatty-acid and stable-isotope analyses of biopsy samples. *Canadian Journal of Zoology*. 79, 1442-1454.

- Kellar, N. M. *et al.* (2006) Determining pregnancy from blubber in three species of delphinids. *Marine Mammal Science* 22:1-16.
- Kellar, N. M. *et al.* (2009) Blubber testosterone: A potential marker of male reproductive status in short-beaked common dolphins. *Marine Mammal Science* 25:507-522.
- Kellar, N. M. *et al.* (*In press*) Blubber cortisol: A potential tool for assessing stress response in free-ranging dolphins without effects due to sampling. PLoS One.
- Simmonds, M. P. and Lopez-Juraco, L. F. (1991) Whales and the military. *Nature* 351:448.
- Trego, M. L., *et al.* . (2013) Validation of blubber progesterone concentrations for pregnancy determination in three dolphin species and a porpoise. PLoS One 8(7): e69709. .
- Tyack PL, Zimmer WMX, Moretti D, Southall BL, Claridge DE, Durban JW, Clark CW, D'Amico A, DiMarzio N, Jarvis S, McCarthy E, Morrissey R, Ward J, Boyd IL (2011) Beaked whales respond to simulated and actual Navy sonar. *PLoS ONE* 6(3): e17009 doi:10.1371/journal.pone.0017009.