

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

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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 (AUTEK) in the Andros-AUTEK 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).

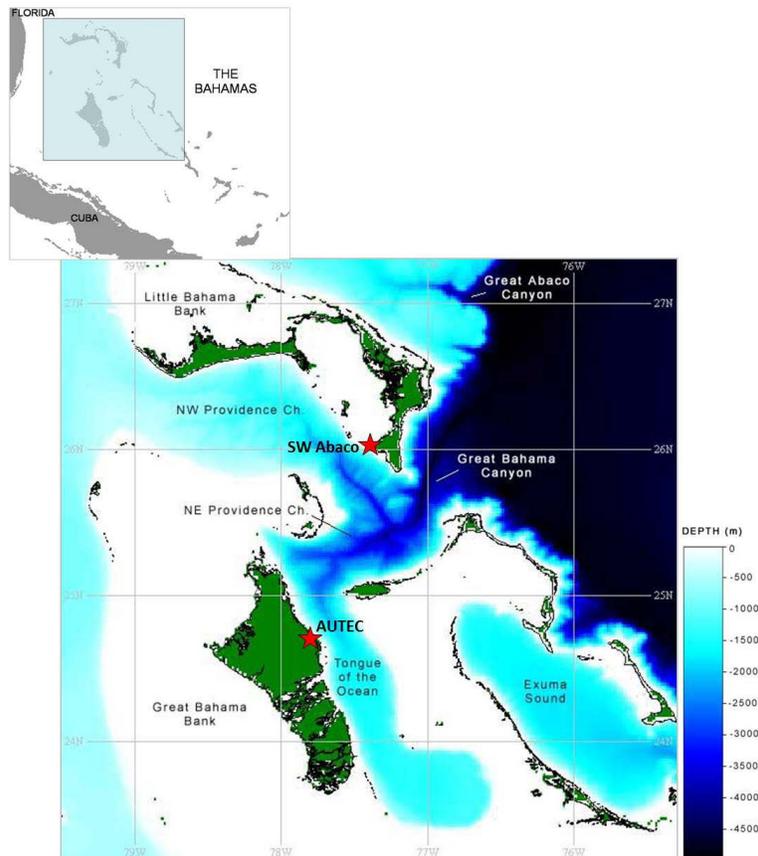


Figure 1. Map of the northern Bahamas showing the location of the two areas where blubber biopsy samples are being collected: AUTEK and SW Abaco. Both lie within the Great Bahama Canyon, a submarine canyon that reaches depths of more than 4000m. Additional sampling is occurring throughout the canyon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

Stress levels for whales at AUTECH are being evaluated using biopsy samples collected primarily before scheduled Submarine Commanders Courses (SCC) as part of an N45 (now Living Marine Resources) funded satellite tagging study. Five 15-day field efforts were planned under this study, in Oct/Nov 2011, July 2012 and April/May 2011-13. 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 AUTECH 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 AUTECH. 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 AUTECH'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 AUTECH 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. Pregnancy state will also be assessed by measuring progesterone concentrations in blubber (Kellar *et al.* 2006; Trego and Kellar 2009), and pregnancy rates will be examined relative to measured stress levels by comparison between samples collected at AUTECH 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

During FY13, ONR sponsored two directed field efforts to collect blubber biopsies: 10-23 May at SW Abaco (14 days) and 2-17 August at AUTECH (16 days). During the time in the field, vessel surveys were conducted as weather and range access permitted covering over 1210 km of search effort (Figure 2). This effort was augmented by additional time at AUTECH during the LMR-supported satellite tagging work from 25 April - 7 May 2013.

The field effort at Abaco during May 2013 was fairly productive; weather permitted vessel work during 7 days which covered 443 km of track line, totaling 43.1 hours of search effort. At AUTEK the vessel covered a larger area (totaling 767 km of track lines), and visual search effort totaled 41.6 hours. When all efforts were combined, there were 7 encounters with groups of Blainville's beaked whales and 4 with sperm whales (summarized in Table 1).

Table 1. Summary of field efforts when sightings took place of either target species providing opportunity to collect blubber biopsies at both AUTEK and SW Abaco during FY13.

DATE	EFFORT (KM)	EFFORT (HR)	SPECIES	GROUP SIZE	DUR. (MIN)	NO. BIOPSIES
<i>AUTEK – supported by LMR</i>						
04-May-13	127	9.7	Sperm whale	4	306	1
06-May-13	129	11.5	Sperm whale	2	242	2
07-May-13	120	10.4	Blainville's beaked whale	2	64	2
			Blainville's beaked whale	2	22	1
			Blainville's beaked whale	1	10	1
<i>SW Abaco – supported by ONR</i>						
13-May-13	71	10.1	Blainville's beaked whale	2	4	0
15-May-13	77	6.1	Sperm whale	3	46	1
18-May-13	63	6.0	Blainville's beaked whale	5	91	3
<i>AUTEK – supported by ONR</i>						
05-Aug-13	75	11.7	Sperm whale	3	93	0
			Blainville's beaked whale	2	221	0
			Blainville's beaked whale	2	150	2

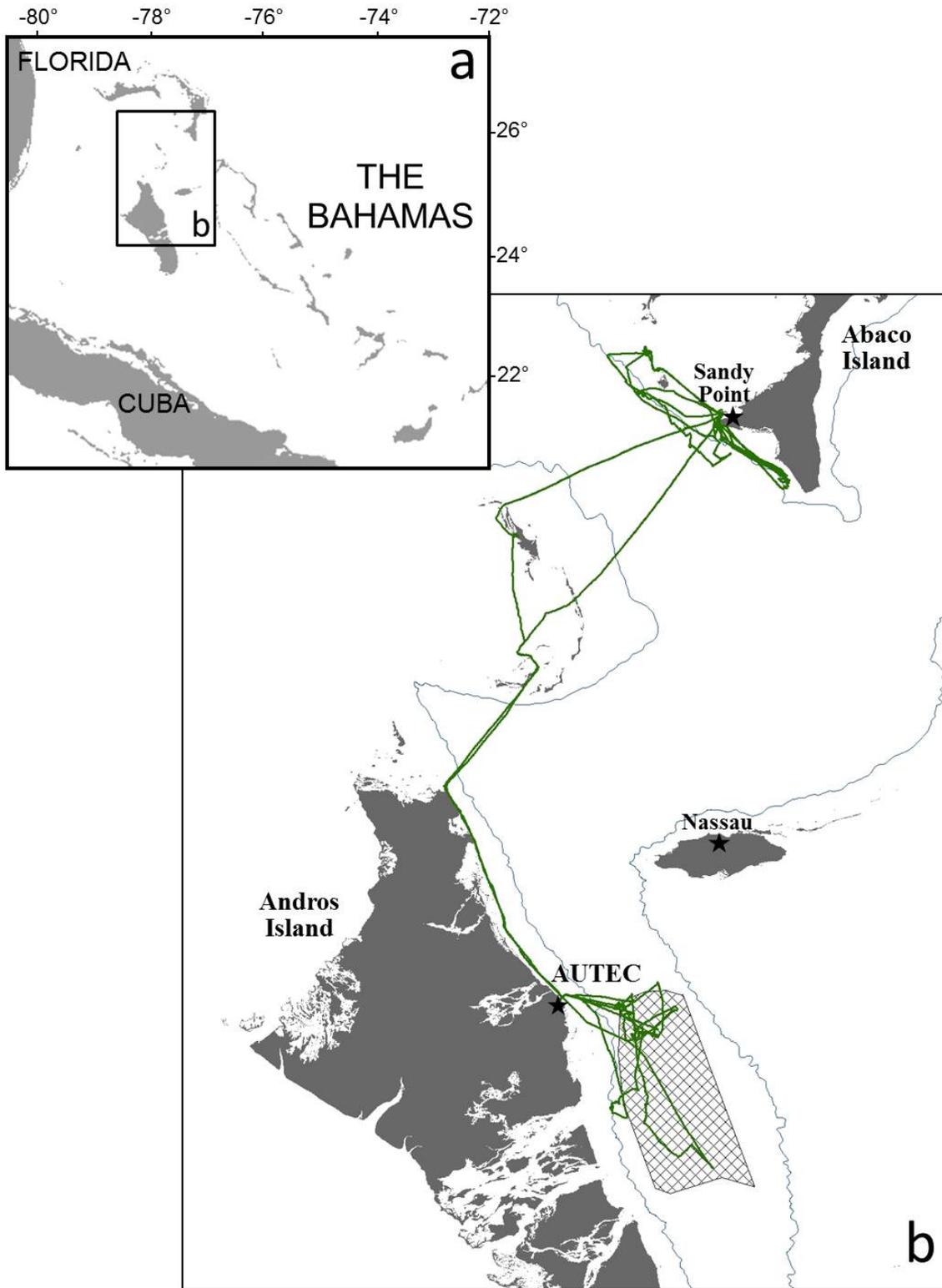


Figure 2. (a) Map of The Bahamas showing the Abaco and Andros study areas. Vessel tracks (in green) show survey efforts supported by ONR off SW Abaco Island and off AUTEC during FY13. The 1000 m isobaths (blue lines) and the outer boundary of the instrumented hydrophone array at AUTEC (hatched area) are also shown.

RESULTS

New Data Collected in 2013

A total of 12 biopsy samples were collected from our target species in 2013. The majority of biopsy samples were collected at AUTEK during the May 2013 field efforts supported by LMR, when biopsies were obtained from both Blainville's beaked whales and sperm whales. The May effort in Abaco was not as successful as in 2012 due to windy conditions, and in August when we returned to AUTEK there was only one day in which sea states were calm enough to find animals visually and collect samples. The locations where blubber biopsies were collected at both study sites are shown in Figure 3.

Photo-identification analyses are still underway, but here are some preliminary results presenting the sightings histories for known individuals from both study areas (summarized in Table 2). Of the three blubber biopsies collected from Blainville's beaked whales in SW Abaco, two were of the same whale, Md233. This individual was identified as a mature female when seen previously in SW Abaco in 2008 and 2012, although she has never been seen with a calf. The other beaked whale sampled in Abaco (Md213) is an adult male also seen previously in the same area in 2006, 2007 and 2008. At AUTEK, of the six whales biopsied in FY13, three are known previously from the AUTEK range. Md568 is a mature female seen at AUTEK three times between years 2009 – 2012 but never seen with a calf. Md553 is also a mature female first seen in 2008 with a calf and resighted again in 2012 without a calf. Md504 was first seen when immature in 2005. This individual was seen again in 2006 and 2007 when it was tagged with a Dtag during the Behavior Response Study (Tyack *et al.* 2011). It had not been seen again until FY13 and although this individual is now of reproductive age, she was not seen with a calf during the 2013 encounter. This resighting represents the longest known for an individual at AUTEK demonstrating long-term site fidelity of this species on the AUTEK Range.

Preliminary matching of the sperm whale identification photographs revealed only short-term resightings but some interesting movements between the two study areas. Two whales seen together at AUTEK on May 4th were resighted off SW Abaco on May 15th. One individual (Pm228) was tagged with a LIMPET satellite tag which was still transmitting when it was resighted 11 days later, and we were able to collect a biopsy sample during the Abaco sighting. The other whale (an unknown individual) was biopsied during the field effort at AUTEK.

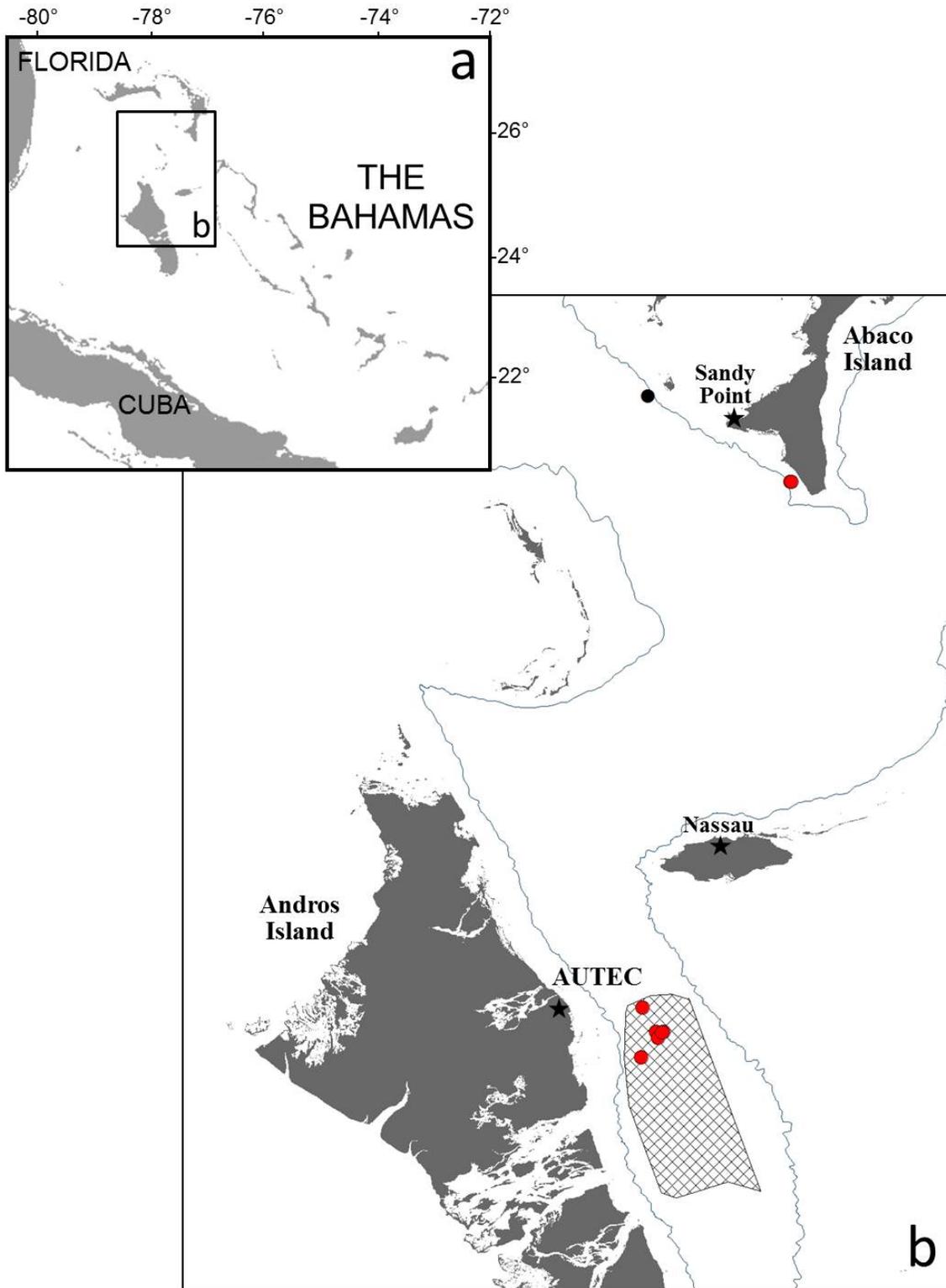


Figure 3. Map of the northern Bahamas showing locations where blubber biopsies were collected from Blainville's beaked whales (red circles) and sperm whales (black circles) off SW Abaco and AUTEC during FY13. The 1000 m isobaths is shown by the blue lines.

Table 2. Summary of blubber biopsies collected from Blainville’s beaked whales and sperm whales at SW Abaco and AUTEK during FY13.

FIELDID	YR	MO	DA	LATD	LATM	LOND	LONM	LOC	SEX	AGE	ID
Blainville's beaked whale - <i>Mesoplodon densirostris</i>											
130507_Md01	2013	5	7	24	38.47	77	33.64	AUTEK	U	SA	Md603
130507_Md02	2013	5	7	24	38.53	77	32.67	AUTEK	U	SA	Md604
130507_Md03	2013	5	7	24	35.07	77	35.64	AUTEK	F	AD	Md568
130507_Md04	2013	5	7	24	41.72	77	35.51	AUTEK	U	SA	Md586
130518_Md01	2013	5	18	25	52.48	77	15.62	Abaco	M	AD	Md213
130518_Md02	2013	5	18	25	52.45	77	15.53	Abaco	F	AD	Md233
130518_Md03	2013	5	18	25	52.43	77	15.51	Abaco	F	AD	Md233
130805_Md01	2013	8	5	24	37.64	77	33.39	AUTEK	F	AD	Md504
130805_Md02	2013	8	5	24	38.42	77	32.85	AUTEK	F	AD	Md553
Sperm whale - <i>Physeter macrocephalus</i>											
130504_Pm01	2013	5	4	24	28.19	77	32.15	AUTEK	M	SA	Unk.
130506_Pm01	2013	5	6	24	37.03	77	27.86	AUTEK	M	SA	Unk.
130506_Pm02	2013	5	6	24	38.24	77	23.57	AUTEK	M	SA	Unk.
130515_Pm01	2013	5	15	26	3.97	77	34.73	Abaco	M	SA	Pm228

When blubber samples collected from FY11-13 are tallied, we have a total of 42 Blainville’s beaked whale samples (10 from AUTEK and 32 from SW Abaco) and 30 sperm whale samples (15 from both sites) 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-FY13.

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
Total	10	32	15	15

Next Phase (FY14)

1st quarter: Molecular sexing on final biopsy set (samples collected in FY13)

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.
- Simmonds, M. P. and Lopez-Juraco, L. F. (1991) Whales and the military. *Nature* 351:448.
- Trego, M. L., and Kellar, N. M. *Submitted*. A comparison of progesterone in the blubber of female delphinoids: *Delphinus capensis*, *Stenella attenuata*, *Stenella longirostris*, and *Phocoenoides dalli*. *Theriogenology*.
- 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.