FINAL

Year 1 Report: Tagging and Tracking of Endangered North Atlantic Right Whales in Florida Waters

Submitted to:

Naval Facilities Engineering Command Atlantic under Contract No. N62470-10-D-3011, Task Orders 44 and 52, issued to HDR, Inc.

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Virginia Beach, VA

27 February 2015

Suggested Citation:

Nowacek, D.P., S.E. Parks, and A.J. Read. 2015. *Year 1 Report: Tagging and Tracking of Endangered Right Whales in Florida Waters. Draft Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-10-3011, Task Orders 44 and 52, issued to HDR, Inc., Virginia Beach, Virginia. 27 February 2015.

Cover Photo Credits:

Tag attachment to North Atlantic right whale (*Eubalaena glacialis*) in southeastern U.S. waters during 2014. Photo collected under National Marine Fisheries Service Permit #14791 to Douglas P. Nowacek.

This project is funded by US Fleet Forces Command and managed by Naval Facilities Engineering Command Atlantic as part of the US Navy's marine species monitoring program.

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Acronyms and Abbreviations

GPS	Global Positioning System
PAM	passive acoustic monitoring
SNR	signal-to-noise ratio

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1. Motivation for Proposed Research

Endangered North Atlantic right whales (*Eubalaena glacialis*) migrate to coastal waters off Florida and Georgia during the winter months. The planned construction and use of an undersea warfare training range (USWTR) off the Atlantic coast of Florida may result in interactions with the right whale on its winter calving ground. Aerial- and vessel-based visual surveys and passive acoustic monitoring (PAM) are currently being used to detect right whales in the coastal waters of Florida and Georgia, as well as the area of the planned USWTR. Aerial surveys give the positions of individual whales, but only provide information about location at single points in time; PAM provides a general location and presence of at least one whale, while multiple sensors can provide more accurate locations as well as estimates of numbers of whales. Currently there are few data on the movement patterns of individuals, including movement rates both in north/south and east/west directions, dive depths and durations, and the rates of sound production by individuals on the calving grounds. These data are important to assess the effectiveness of current monitoring techniques and to assess the potential for disturbance to right whales as the undersea welfare training range construction and implementation commences.

2. Proposed Study

Researchers proposed a targeted tagging program to fill in these knowledge gaps by collecting data on horizontal movement, dive profiles, and vocal behavior from individual right whales in February 2014. These objectives are accomplished using non-invasive suction cup tags (anticipated tag duration from 1 to 36 hours) that included Fastloc® Global Positioning System (GPS) technology, time-depth recorders, three-dimensional movement measurements, and acoustic recordings. National Marine Fisheries Service permits to conduct this research are held by Duke University with Dr. Nowacek as lead investigator and Dr. Parks as named co-investigator. Institutional Animal Care and Use Committee approval was obtained from Duke University and Syracuse University committees prior to data collection.

3. Results from February 2014

The field team, consisting of team members from Duke University and Syracuse University, operated out of Fernandina Beach, Florida, in the Jacksonville Study Area, in February 2014. Weather conditions were suitable for tagging operations on 11 days during the month, and right whales were located on 9 of these days. Tags were successfully deployed on right whales on seven occasions (**Table 1, Figures 1** and **2**). Individual whales showed variation in movement patterns along the coastline (**Figures 3** and **4**). Analyses of the data, including dive statistics and acoustic data, are ongoing and are being conducted under the supervision of Dr. Nowacek and Dr. Parks with students and technicians in their laboratories. Preliminary results of this work were reported at Navy's marine species monitoring program 2014 Atlantic Technical Review meeting held in Virginia Beach, Virginia, in March 2014 and at the North Atlantic Right Whale

Recovery Plan Southeast Implementation team meeting held in Palm Beach, Florida, in June 2014.

Table 1. Summary of data collection from February 2014

Date	No. Tagging Attempts	Tag On?	Whale ID (EGNO)	Mother/Calf	Duration (hh:mm)
03-Feb-14	1	No	2645	X	--
09-Feb-14	1	Yes	2123	X	1:35
10-Feb-14	2	Yes	2040	X	5:30
16-Feb-14	2	Yes	4057	--	3:36
17-Feb-14	3	No	2745	X	--
18-Feb-14	1	Yes	3157	X	11:36
19-Feb-14	2	Yes	2503	X	2:56
23-Feb-14	2	Yes	3546	X	6:41
25-Feb-14	3	Yes	2645	X	5:35

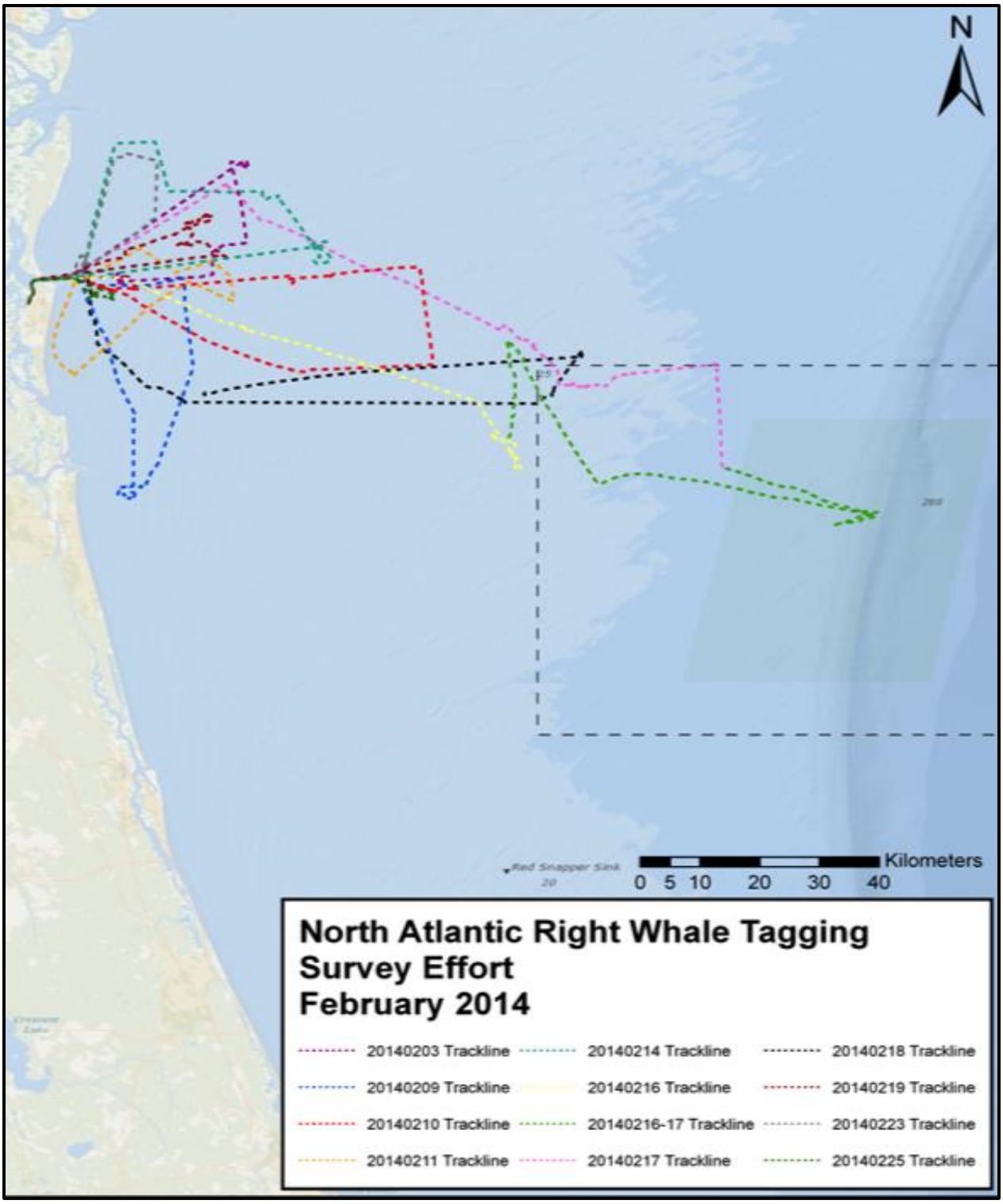

Figure 1. Survey effort (colored lines) in the Jacksonville Study Area (dashed-line box) and planned undersea warfare training range (shaded box), February 2014.

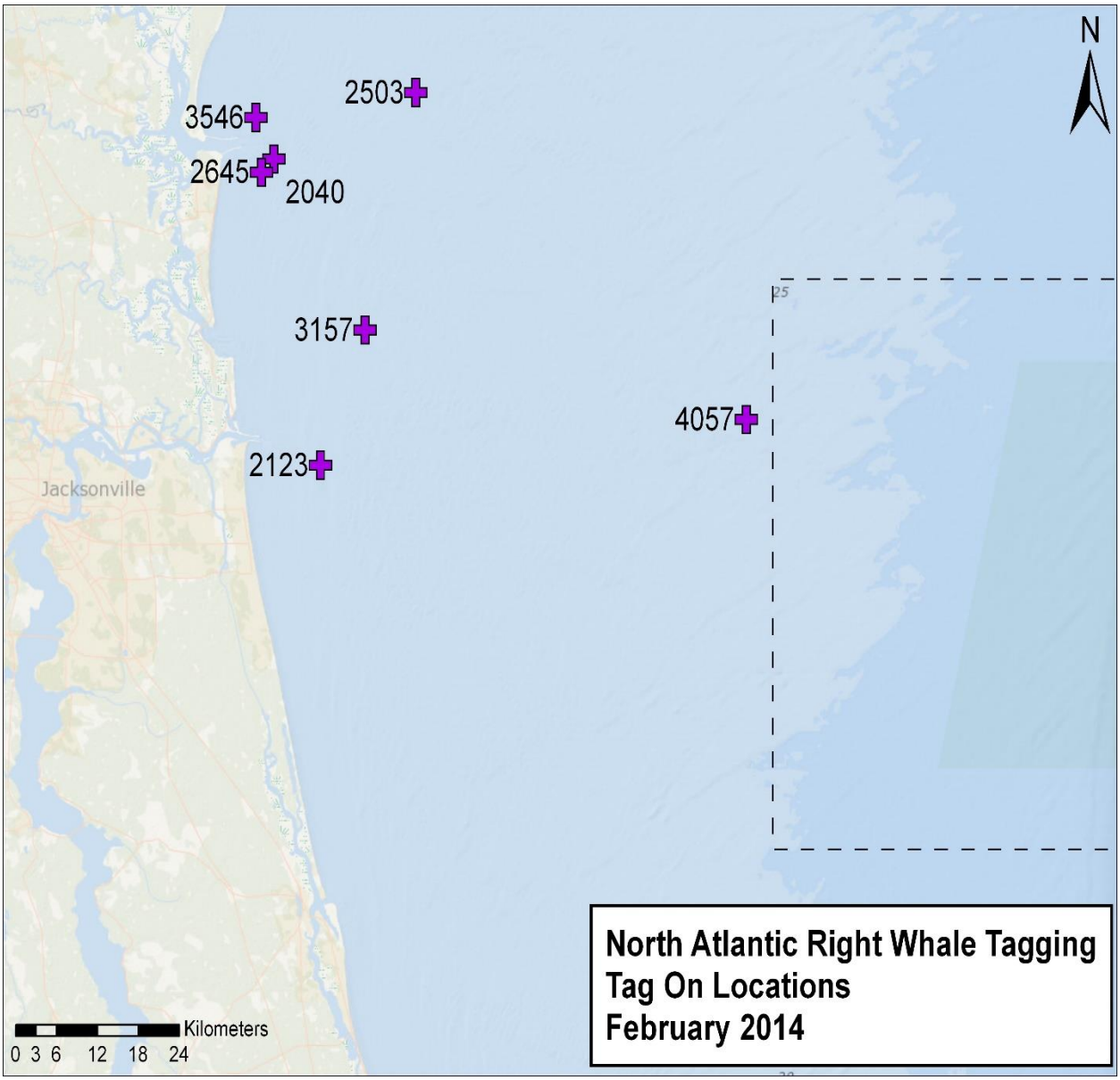

Figure 2. Plotted tag attachment positions (from Table 1) in the Jacksonville Study Area (dashed-line box) and planned undersea warfare training range (shaded box). Each position is marked with a purple plus sign, with the Whale ID listed next to the point.

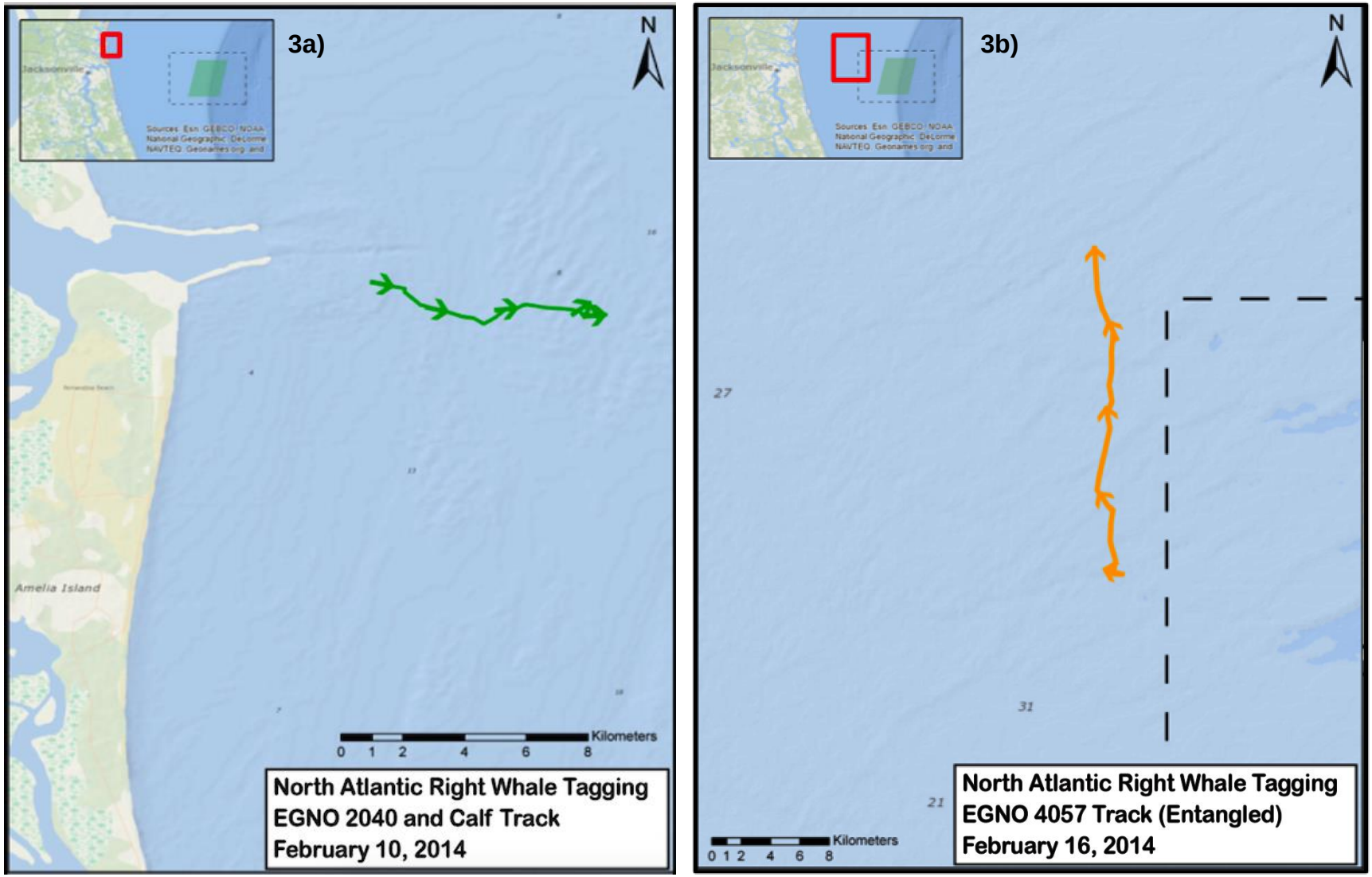

Figure 3. Fastloc GPS tag tracks from a) 10 February (green) and b) 16 February (orange) 2014. The inset map shows the position of the enlarged map in red, relative to the planned undersea training range (shaded box) in the Jacksonville Study Area (dashed-line box).

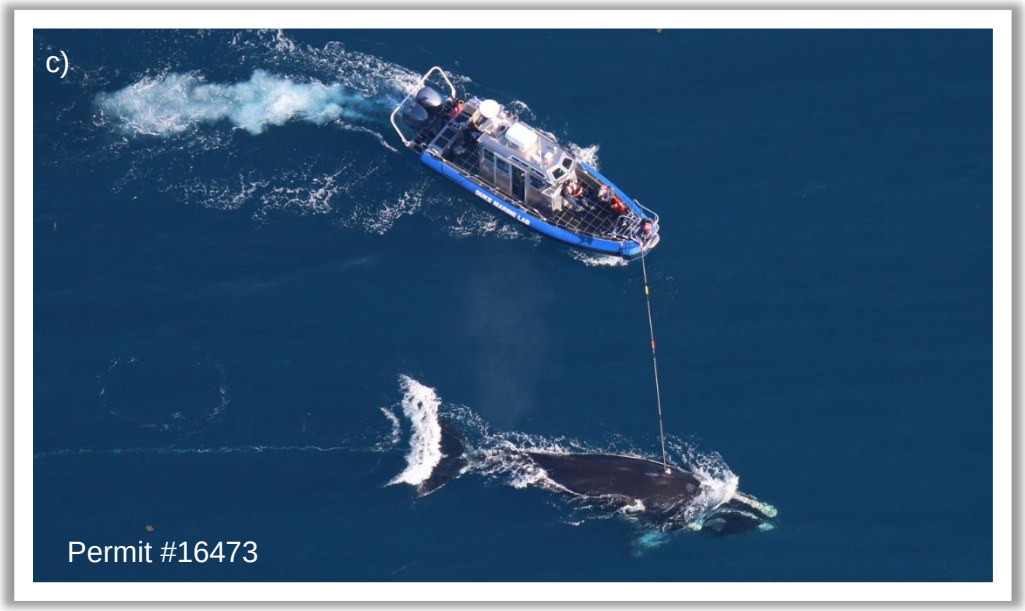

Figure 4. Images of tag attachments to whales in the southeastern United States during February 2014. Photos (a) and (b) collected under National Marine Fisheries Service Permit # 14791 to Douglas P. Nowacek, and (c) collected under National Marine Fisheries Service Permit #16473.

4. Summary of Findings

A brief summary of the tag data from 2014 indicates that individual whales show variable patterns of movement, both in north/south and east/west directions. The dive profiles indicate that right whales are using the entire water column; however, given the extremely shallow depths in the Jacksonville Study Area, the mean maximum dive depth for individuals was <10 meters in nearshore waters, with some mother/calf pairs not exceeding 6 meters in depth at their maximum point. These data suggest that whales may be just subsurface, where they are difficult to see, in much of the coastal waters off Florida. Overall, periods with detectable right whale calls were more common than anticipated, with call rates exceeding 100 calls per hour for some individuals. However, call rates were closely associated with the behavioral states of the animals. Call rates from whales involved in social interactions (~ 90 calls per hour) were significantly higher than rates from a solitary entangled whale that was tagged (0 calls per hour) and two mother/calf pairs with call rates < 2 calls per hour from multiple-hour tag deployments.

4.1 Dive Statistics

Nowacek (under a separate project) also collected tag data off the coast of Florida in 2006 from a total of six individual right whales. Those data were integrated into the current analyses to provide a broader perspective on right whale movement patterns and vocal behavior in the southeastern United States calving area.

The tagging records from the southeastern United States used for the statistical analyses included tags on adult nursing or pregnant females (*n*=5) as well as juveniles (*n*=2 males, *n*=1 female) (**Table 2**). An additional whale was tagged, but unable to be photo-identified and was excluded from analysis. Since all adult whales that were tagged were also nursing/pregnant females, the independent variables of age and sex were linked with reproductive condition and thus not separately analyzed. Dive parameters—dive duration, time at surface between dives, and maximum dive depth—were measured using TrackPlot™ version 3.0 (Ware et al. 2006).

Table 2. Summary of dive statistics from tag records from 2006 and 2014 in the Southeast United States.

Date	Tag ID	Dive record duration (hh:mm:ss)	Demographic	Number of dives per hour of tag data	Dive duration (s)	Mean time at surface between dives (s)	Mean maximum dive depth (m)
24-Jan-06	Eg06_024a	1:54:40	Juvenile male	13.60	158.64	55.05	7.13
24-Jan-06	Eg06_024b	0:36:42	Unknown	21.25	70.57	62.46	7.39
24-Jan-06	Eg06_024e	0:54:06	Juvenile female	6.65	226.97	71.43	14.74
28-Jan-06	Eg06_028a	18:30:00	Pregnant female	10.77	201.08	137.02	8.49
9-Feb-14	Eg14_040a	1:33:27	Nursing female	8.99	213.65	143.04	9.51
10-Feb-14	Eg14_041a	5:30:01	Nursing female	15.82	49.06	157.70	5.07
16-Feb-14	Eg14_047a	3:36:00	Juvenile male	11.67	166.21	120.80	10.68
18-Feb-14	Eg14_049a	11:36:27	Nursing female	11.98	140.09	154.35	6.02
25-Feb-14	Eg14_056a	5:34:18	Nursing female	13.10	129.72	138.26	5.49

Key: Eg = *Eubalaena glacialis* (North Atlantic right whale); m = meter(s); s = second(s)

A linear mixed-effects analysis of the relationship between reproductive condition (i.e., nursing female versus all others) and various dive parameters was performed using the *lme4* package (Bates et al. 2012) in R (www.rproject.org). Reproductive condition was entered as a categorical fixed effect, while individual, year, and dive number were added as random effects. Data were log-transformed for analysis to satisfy assumptions of normality. P-values (**Table 3**) were obtained using likelihood-ratio tests of the full model including reproductive condition against the model without reproductive condition. None of the dive parameters were significantly affected by reproductive condition at α=0.05; however, reproductive condition significantly affects maximum dive depth at α=0.10, a value that may be more appropriate to reduce Type II error given the small sample size of the analysis (*n*=8).

Table 3. Results of mixed effects model. Asterisk indicated significant effect of reproductive condition at α=0.10.

Dive parameter	Model estimate log(non-nursing – nursing) ± SE of estimate	Chi Square	df	p
Maximum depth (m)	0.334 ± 0.173	3.096	1	0.078*
Dive duration (s)	-0.329 ± 0.485	0.359	1	0.549
Time at surface between dives (s)	3.811 ± 0.119	1.448	1	0.229

Key: m = meter(s); s = second(s); SE = standard error

Two example figures (**Figures 5** and **6**) show TrackPlot screen captures of the dive and movement patterns of two individual right whales from 2006 and 2014, respectively.

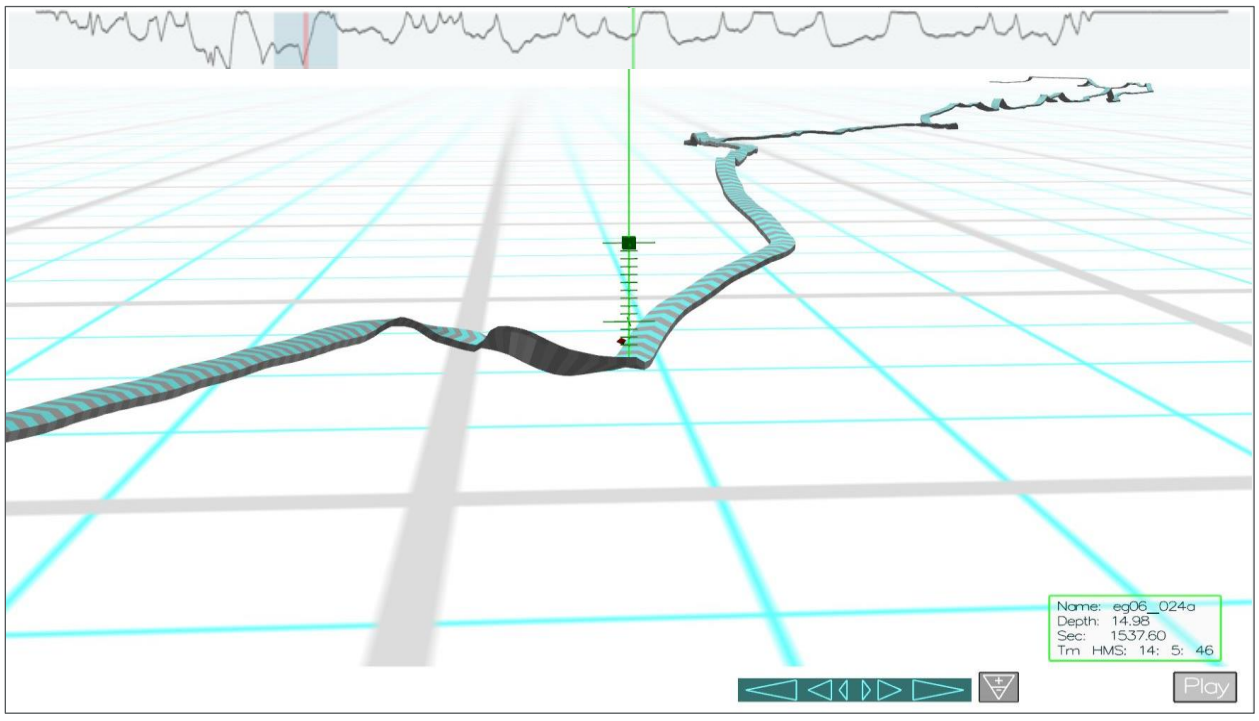

Figure 5. TrackPlot visualization of EGNO 3323, a juvenile male in 2006. In a qualitative comparison to the nursing females, there are fewer instances of multiple shallow (0.5 to 3.0-meter) dives between series of deeper dives.

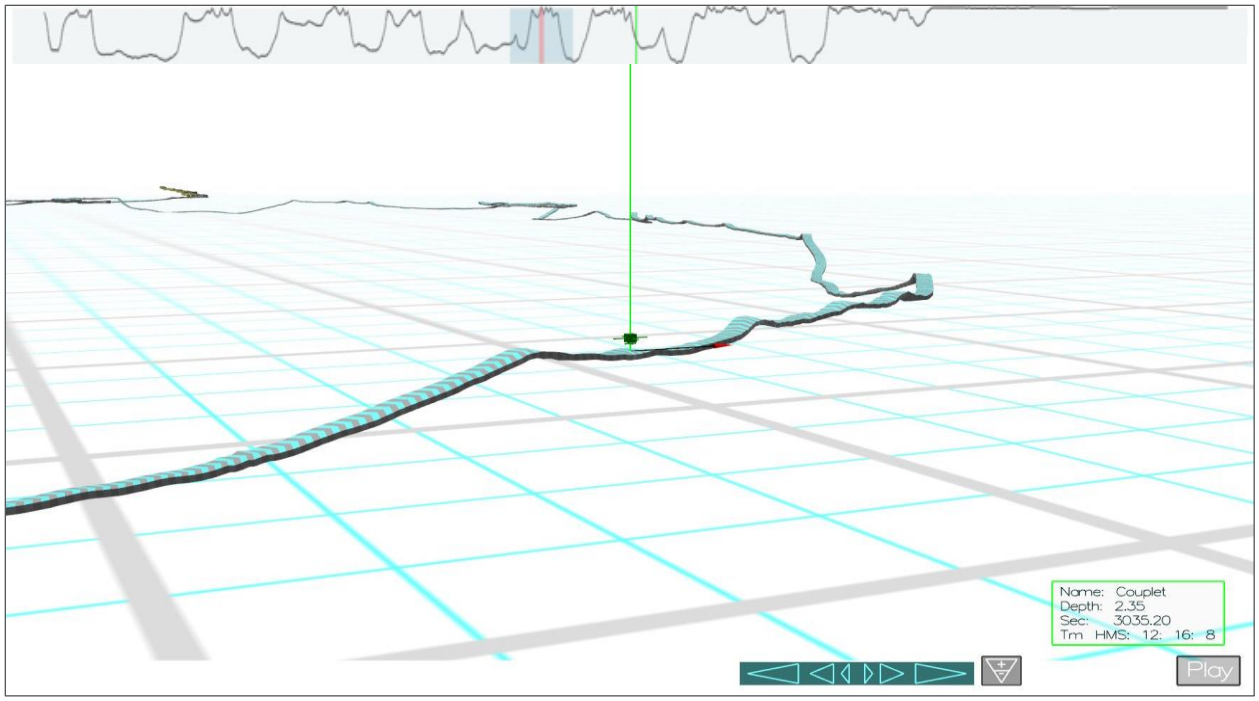

Figure 6. TrackPlot visualization of EGNO 2123 ("Couplet"), a nursing female in 2014. The ribbon track shows a series of shallow dives preceding a deeper dive.

4.2 Acoustic Analyses

Audio recordings were browsed visually and aurally in Raven Pro 1.5 (Cornell Bioacoustics Research Program) for evidence of any right whale vocalizations (**Table 4**). Additional sounds, such as anthropogenic noise from nearby ships and vocalizations from fish and other cetacean species, were also noted. Calls with a high signal-to-noise ratio (SNR) were pulled from the record to investigate the typical call types used in this habitat (**Figure 7**).

Table 4. Summary of all acoustic tag data from 2006 and 2014, with identification of calls from any right whale, not only that of the tagged whale, recorded on the tags.

Date	Tag ID	Acoustic record duration (hh:mm:ss)	Demographic	Right whale calls detected (all SNR including calls from other whales)	Estimated calls per hour of tag recording
21-Jan-06	Eg06_021a	1:21:07	Juvenile male	51	37.8
24-Jan-06	Eg06_024a	1:54:40	Juvenile male	267	140.5
24-Jan-06	Eg06_024b	0:36:42	Unknown	18	30
24-Jan-06	Eg06_024c	0:23:36	Unknown	102	266.1
24-Jan-06	Eg06_024e	0:54:06	Juvenile female	98	108.9
28-Jan-06	Eg06_028a	18:30:00	Pregnant female	8	0.43
09-Feb-14	Eg14_040a	1:33:27	Nursing female	36	24
10-Feb-14	Eg14_041a	5:30:01	Nursing female	108	19.6
16-Feb-14	Eg14_047a	3:36:00	Juvenile male	0	0
18-Feb-14	Eg14_049a	11:36:27	Nursing female	7	0.6
25-Feb-14	Eg14_056a	5:34:18	Nursing female	8	1.4

Key: Eg = *Eubalaena glacialis* (North Atlantic right whale); SNR = signal-to-noise ratio

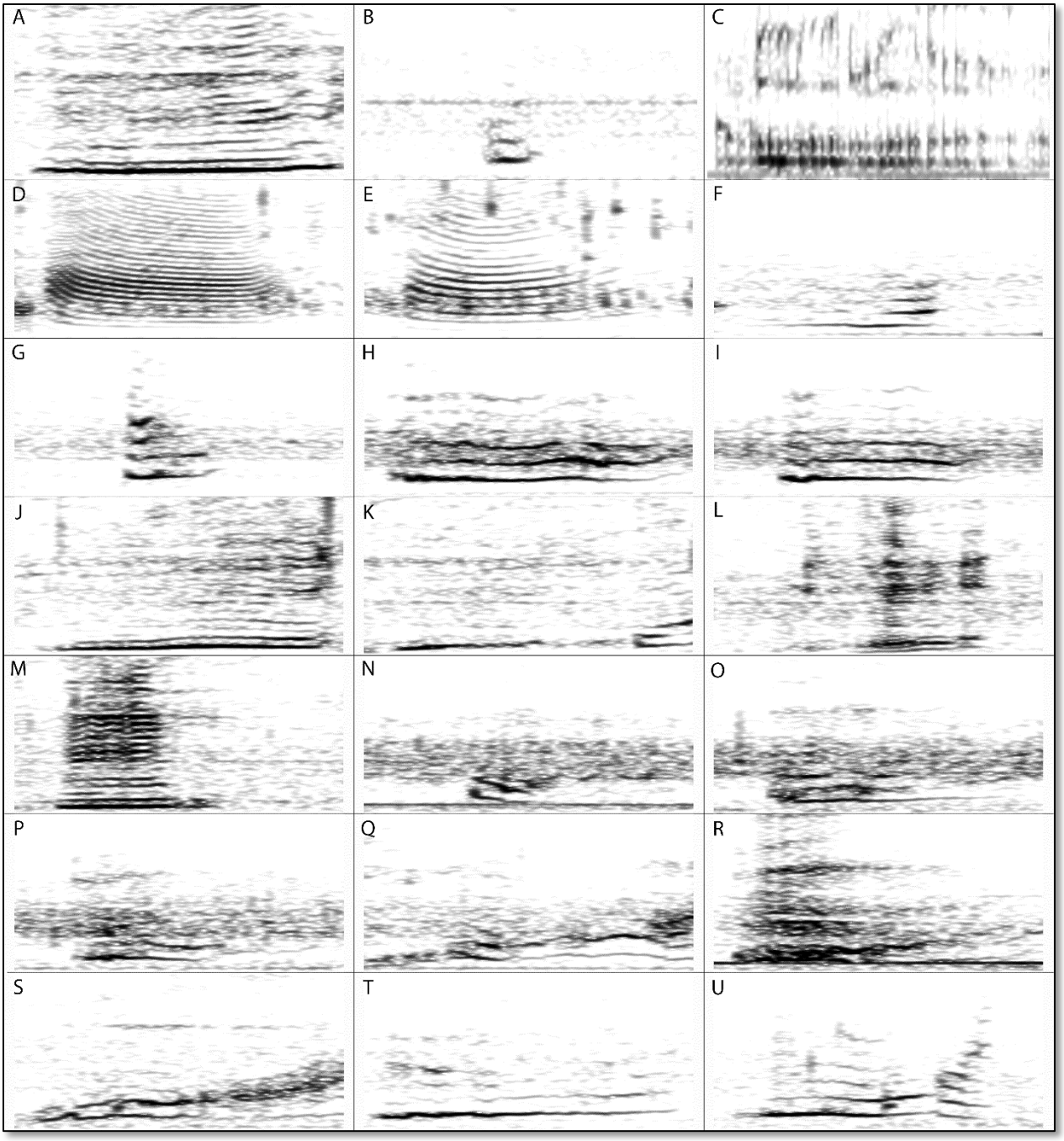

Figure 7. Spectrograms of high SNR calls showing the call types found in the 2014 acoustic tag records. (A) upcall, (B) grunt, (C) growl, (D-M) variable tonal calls, and (N-U) variable tonal calls presumed to be from a calf. For all spectrograms, frequency ranges from 0 to 2 kilohertz, and windows are 1.2 seconds in duration.

The most striking result from the acoustic analyses was the extremely high call rates recorded on some tags. In 2006, for tags with behavioral data, all high call rates (>100/hour) were associated with social surface-active group (SAG) activity in the vicinity of the tagged whale. For the 2014 data, we have behavioral data associated with all tags. Most tag records from 2014 contained few right whale vocalizations. There were two exceptions to this in 2014. The first

exception was tag record Eg14_040a on 9 February 2014, which showed no obvious behaviors associated with an increased call rate. The second tag record (Eg14_041a) had an increase in call rate coupled with high levels of surface activity and calf interaction with a small group of bottlenose dolphins (*Tursiops truncatus*). Many of these calls, based on call structure and amplitude, are presumably from the calf associated with the tagged nursing right whale female (**Figure 8**). This tag record also contained unidentifiable tonal sounds that could potentially be a novel right whale vocalization, an unknown fish vocalization, vessel-related, or a byproduct of water flow over the tag sensor (**Figure 9**).

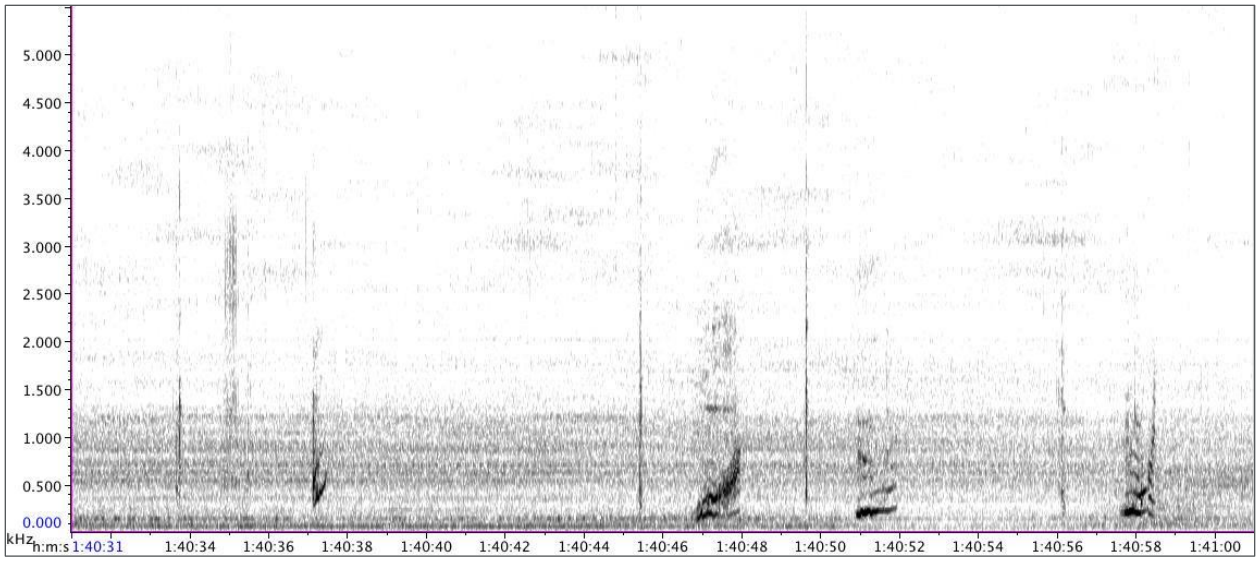

Figure 8. Right whale vocalizations, presumably produced by the calf based on the intensity and structure of the calls.

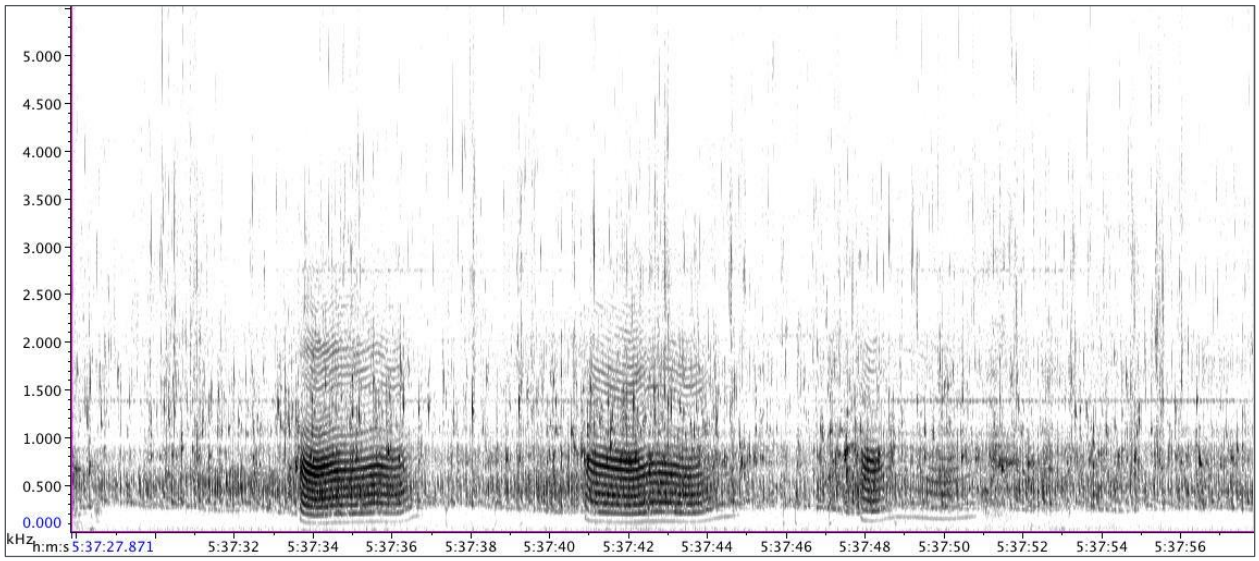

Figure 9. Examples of unidentified tonal-type sounds detected on the tag record.

4.3 Future Directions

Additional fieldwork is planned for 10 February through 10 March 2015. The emphasis in the second year of data collection will be whales closer to or within the Navy's planned undersea warfare training range. An effort to increase the sample size of data collected from whales other than mother/calf pairs will also be made in the second year of data collection. Pending whale availability, weather conditions, and tagging success in Year 2, a third year of data collection may be proposed to obtain sufficient data to assess variability in whale movement patterns, dive behavior, and acoustic activity.

5. Literature Cited

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Ware, C., R. Arsenault, and M. Plumlee. 2006. Visualizing the underwater behavior of humpback whales. *IEEE Computer Graphics and Applications* 26(4):14-18.