PROTECTED SPECIES MONITORING IN THE JACKSONVILLE OPAREA OFF JACKSONVILLE, FLORIDA
JANUARY 2012 - DECEMBER 2012

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Jacksonville Vessel Surveys

Methodology

Study Area

The study area within the Jacksonville OPAREA (JAX) is approximately 5728 km^2, surrounding the approximately 1700 km^2 proposed USWTR site. The survey area straddles the continental shelf break, including some of the Blake Plateau, and includes both shelf and pelagic waters (Figure 1).

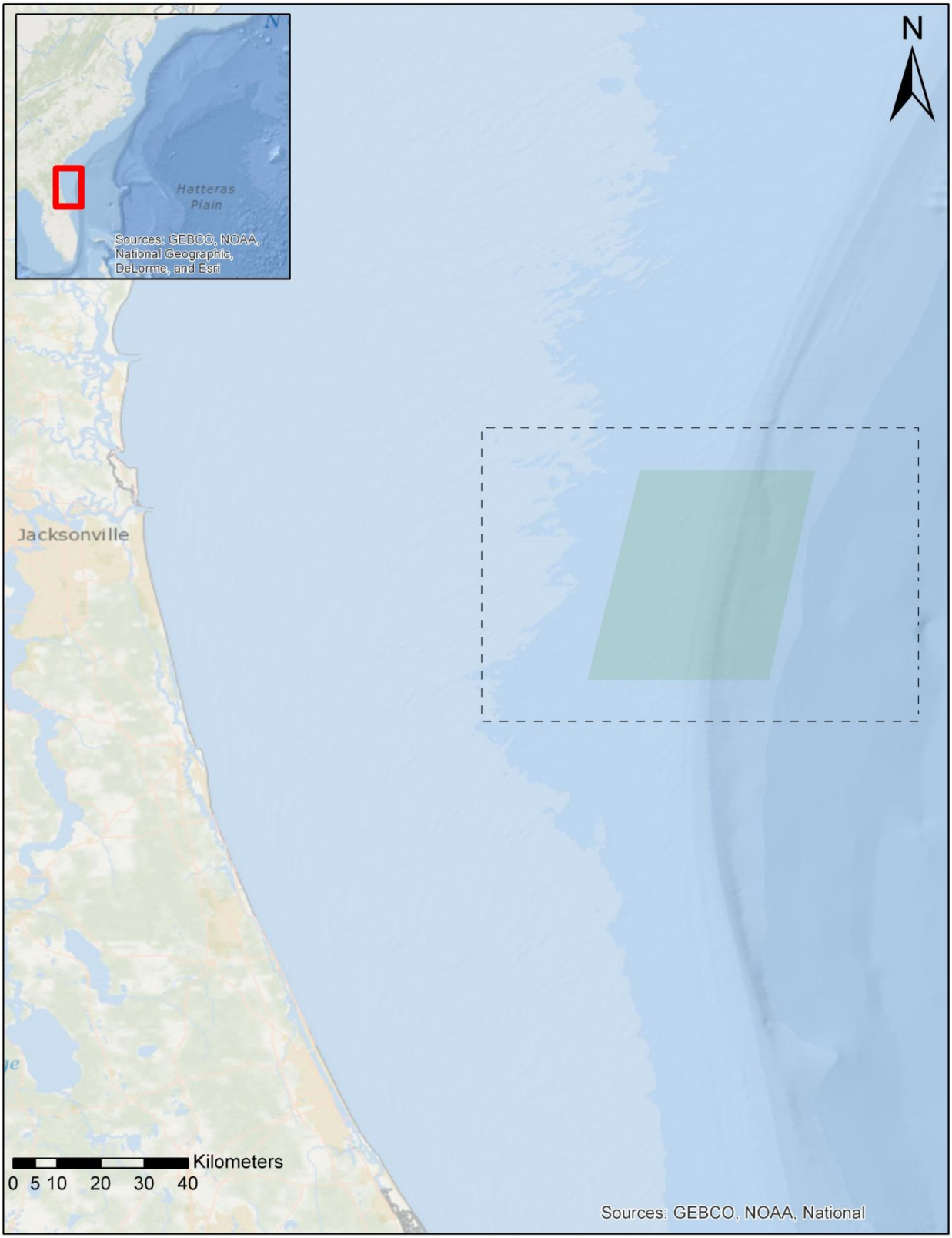

Figure 1. Map of the Jacksonville survey area and the proposed USWTR site (shaded box).

Vessel Survey Data Collection

Visual Surveys

Vessel survey effort in the Jacksonville study area during 2012 focused on questions of residency and population structure of cetaceans. Visual surveys were conducted at a speed of approximately 10 knots primarily from the R/V *Starbuck*, a 7 m rigid hull inflatable, and the R/V *Stellwagen* (Figures 2a and b). The F/V *Wahoo II*, the F/V *Madame Butterfly* and the F/V *Jodie Lynn* were used on occasions when the R/V *Starbuck* and the R/V *Stellwagen* were unavailable. Observations were made from the rigid hull inflatable or from the vessel's flying bridge by naked eye and 7x50 binoculars. Two observers (one port and one starboard) scanned constantly from straight ahead to 90° abeam either side of the trackline. The location, species and behavior of each cetacean group were recorded. If turtles were encountered, the location and species were recorded. Environmental conditions (weather, sea state, depth and sea surface temperature) were recorded at each sighting and whenever sighting conditions changed. Sighting and environmental data were recorded using an iPad tablet and linked GPS unit. In addition, use of the survey area by individual cetaceans was examined using photo-identification and biopsy techniques. We also use photographs to confirm species identification at each sighting and to

Figure 2. Vessel survey platforms, the R/V *Starbuck* (a), and the R/V *Stellwagen* (b).

compare identification features with those used by the aerial survey team. Photographs were taken with Canon or Nikon digital SLRs (equipped with 100-400 mm zoom lenses) in 24-bit color at a resolution of 3072 X 2048 pixels and saved in .jpg format. Remote biopsy sampling methods were employed to collect small skin and blubber samples using a variety of 27 kg – 68 kg pull crossbows, depending on the species and sampling distance. Biopsy samples were obtained with a specialized 2.5 cm stainless biopsy tip attached to a modified bolt, typically fired from the bow of the survey vessel.

Passive Acoustic Monitoring

To collect time-series of acoustic data in the Jacksonville survey area, autonomous High-frequency Acoustic Recording Packages (HARPs; Wiggins and Hildebrand 2007) were utilized. The HARP moored data-logging system includes a 16-bit A/D converter, a hydrophone suspended approximately 12 m above the seafloor, an acoustic release system, ballast weights, and flotation. The data-loggers are capable of sampling up to 200 kHz and can be set to record continuously or on a duty cycle to accommodate variable deployment durations. A combination of high and low frequency hydrophone elements allows detection of both odontocete and mysticete whale vocalizations, and sample rates are high enough to capture the echolocation clicks of most odontocete species.

The HARP deployed at Site A on 24 January 2012 in 91 m at 30.28501^{o} N, 80.22142^{o} W (Table 1, Figure 3) was unable to be recovered and has now been abandoned. A retrieval trip was made on 23 August 2012, but there was no response from the acoustic releases despite several attempts

to communicate at various distances around the drop site. The most likely explanation for this lack in communication is that the acoustic release batteries were dead; although it is possible a component of the mooring failed and released the instrument early. Another trip was made on 5 February 2013 to search for this HARP. A Hummingbird 998c side-scan sonar was used to search the area and screen shots were taken of possible targets. The images were passed on to two experts, neither of whom were convinced the images showed the presence of the HARP. Because there are no other communication systems on the HARP, a decision was made to cease recovery efforts.

Table 1. HARP deployments in the Jacksonville survey area.

Site	Deployment Date	Retrieval Date	Latitude	Longitude	Depth (m)	Sampling Rate	Duty Cycle	Amount of data
1A	30-Mar-09	16-Sep-09	30.27710	-80.21580	80	200 kHz	5-min on/10-min off	0.8 TB
1B	30-Mar-09	16-Sep-09	30.25820	-80.42820	40	200 kHz	5-min on/10-min off	2 TB
2A	16-Sep-09	21-Feb-10	30.28050	-80.21600	80	200 kHz	5-min on/10-min off	1.3TB
2B	23-Sep-09	21-Feb-10	30.25800	-80.42800	40	200 kHz	5-min on/10-min off	0.0 TB
3A	21-Feb-10	26-Aug-10	30.28110	-80.21530	90	200 kHz	5-min on/10-min off	2.0 TB
4B	9-Mar-10	26-Aug-10	30.25920	-80.42570	40	200 kHz	5-min on/10-min off	2.0 TB
5A	26-Aug-10	1-Feb-11	30.26819	-80.20894	90	200 kHz	5-min on/10-min off	2.0 TB
5B	26-Aug-10	1-Feb-11	30.25708	-80.43269	35	200 kHz	5-min on/10-min off	2.0 TB
6A	1-Feb-11	14-Jul-11	30.27818	-80.22085	91	200 kHz	5-min on/10-min off	2.0 TB
6B	2-Feb-11	14-Jul-11	30.25768	-80.42782	37	200 kHz	5-min on/10-min off	2.0 TB
7A	24-Jan-12		30.28480	-80.22110	77	200 kHz	Continuous	

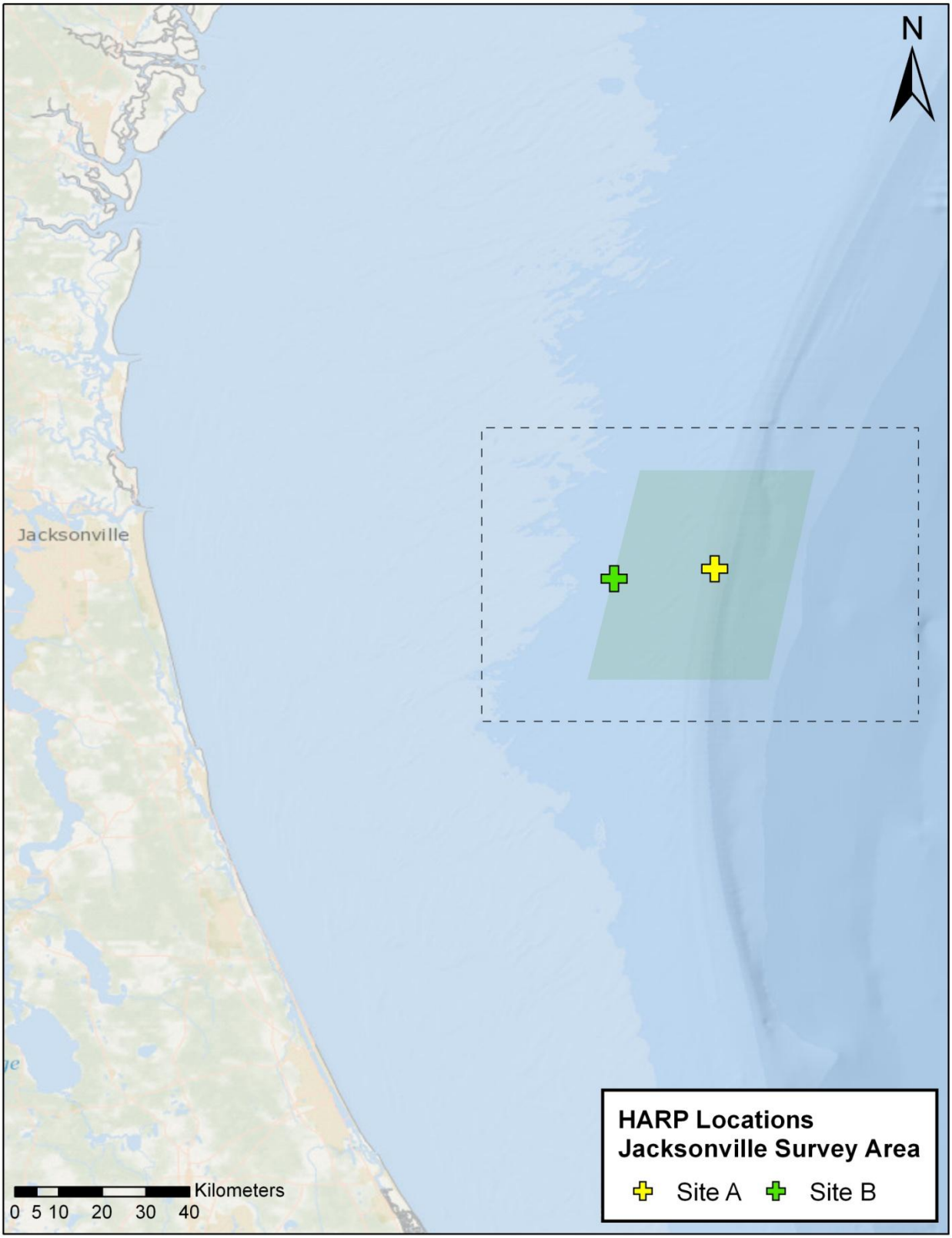

Figure 3. Location of HARP deployment sites in the Jacksonville survey area.

Data Analysis

Vessel survey effort and sighting data were compiled and mapped using *ArcGIS* 10.1 to illustrate the location of effort and sightings within the study area. All vessel sighting data collected from January 2012 through December 2012 have been posted on the data repository OBIS-SEAMAP (http://seamap.env.duke.edu/).

Acoustic Analysis

HARP Analysis

HARP data require processing prior to analysis, including backing up data in original format, converting data to wav format, decimating wav data by a factor of 100 to aid in baleen whale detection, and creating long-term spectral averages (LTSAs). New compression code was implemented starting in July 2010 which allowed for greater than two TB of data to be collected after the raw data were decompressed. This amount of data is impractical to analyze manually, so these data were compressed for visual overview by using a *MATLAB*-based acoustic program called Triton (Hildebrand Lab at Scripps Institution of Oceanography, CA) to create LTSAs from the wav files, which allowed for rapid review of the data. LTSAs are effectively compressed spectrograms created using the Welch algorithm (Welch 1967) by coherently averaging 500 spectra created from 2000-point, 0%-overlapped, Hann-windowed data and displaying these averaged spectra sequentially over time.

The following methods are a summary of Debich *et al.* (2013). See Appendix A for a more detailed description of analysis methods. Members of the Scripps Whale Acoustics Lab manually scanned the data from the August 2010 – July 2011 HARP deployments at Sites A and

B (Figure 3, Table 1) for marine mammal vocalizations and anthropogenic sounds (sonar, explosions, and shipping) using LTSAs. As a first pass for data analysis, segments of data that did not allow for further analysis due to disk malfunctions or strumming noise were identified (Table 2). For effective analysis of marine mammal and anthropogenic sounds, the usable data were divided into three frequency bands ((1) low frequencies, between 10 – 1000 Hz, (2) mid frequencies, between 500 – 5000 Hz, and (3) high frequencies, between 1 – 100 kHz). The resulting LTSAs had resolutions of 5 s in time and 1 Hz in frequency (for the data decimated by a factor of 100: 10-1000 Hz band), 5 s in time and 10 Hz in frequency (for the data decimated by a factor of 20: 500-5000 Hz band), and 5 s in time and 100 Hz in frequency (for the data not decimated: 1-100 kHz). Each LTSA was analyzed for the sounds of an appropriate subset of species or sources. Blue, fin, sei, Bryde's, and North Atlantic right whale and a subset of minke sounds were classified as low frequency; humpback, minke, shipping, explosions, and mid-frequency active sonar were classified as mid-frequency; and the remaining odontocete and sonar sounds were considered high-frequency. Low- and mid-frequency sounds were analyzed in hourly bins; high-frequency vocalizations were analyzed in one-minute bins. Vocalizations were assigned to species when possible.

Table 2. Time periods when acoustic data were not available or amenable to analysis.

Deployment	**Gaps In Data for High-Frequency Analysis**	**Too Much Noise for High-Frequency Analysis**	**Gaps in Data for Mid- and Low-Frequency Analysis**
JAX 05A	11/23/2010 22:48 – 11/24/2010 8:09		
JAX 05B		9/1/2010 23:49 – 9/3/2010 5:49 9/17/2010 20:17 – 9/21/2010 17:17 9/30/2010 18:30 – 10/1/2010 12:30 11/12/2010 17:15 – 11/15/2010 11:15	entire deployment
JAX 06A	2/12/2011 7:02 – 2/22/2011 5:16		2/12/2011 9:16 – end
JAX 06B	2/9/2011 7:00 – 2/12/2011 5:02		2/2/2011 14:20 – 2/12/2011 5:02

Data Storage

All acoustic, visual survey and photographic data are archived on digital media, and backed up on a Duke University network server.

Results

Vessel Survey Effort

Ten vessel surveys were conducted in 2012, totaling 937.4 km, or 58.6 hours, of survey effort (Table 3, Figure 4). Vessel surveys were conducted in Beaufort Sea States (BSS) 1 to 4, with most effort (82.2 %) performed in BSS 2 to 3 and 14.9 % in optimal (BSS 1) sighting conditions (Figure 5).

Table 3. Dates, kilometers, and hours surveyed during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Date	Distance Surveyed (km)	Survey Time
7-Jan-12	55.6	4:54
8-Jan-12	148.2	9:36
9-Jan-12	75.4	5:18
24-Jan-12	111.3	6:36
25-Jan-12	111.0	6:54
30-Mar-12	131.0	7:18
3-Apr-12	111.0	6:24
19-Apr-12	72.1	4:48
23-Aug-12	80.2	3:36
24-Aug-12	41.6	3:12

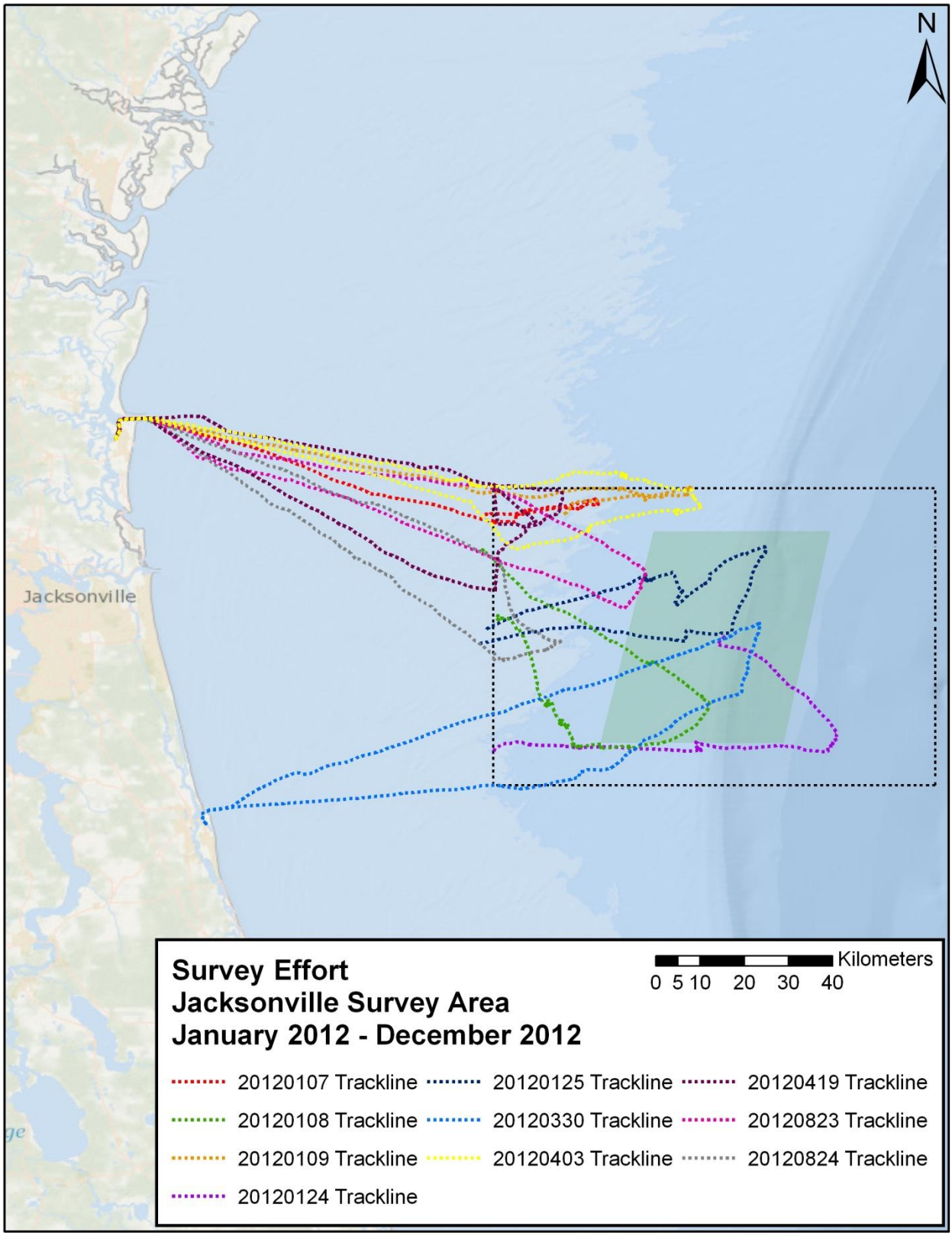

Figure 4. Survey effort during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

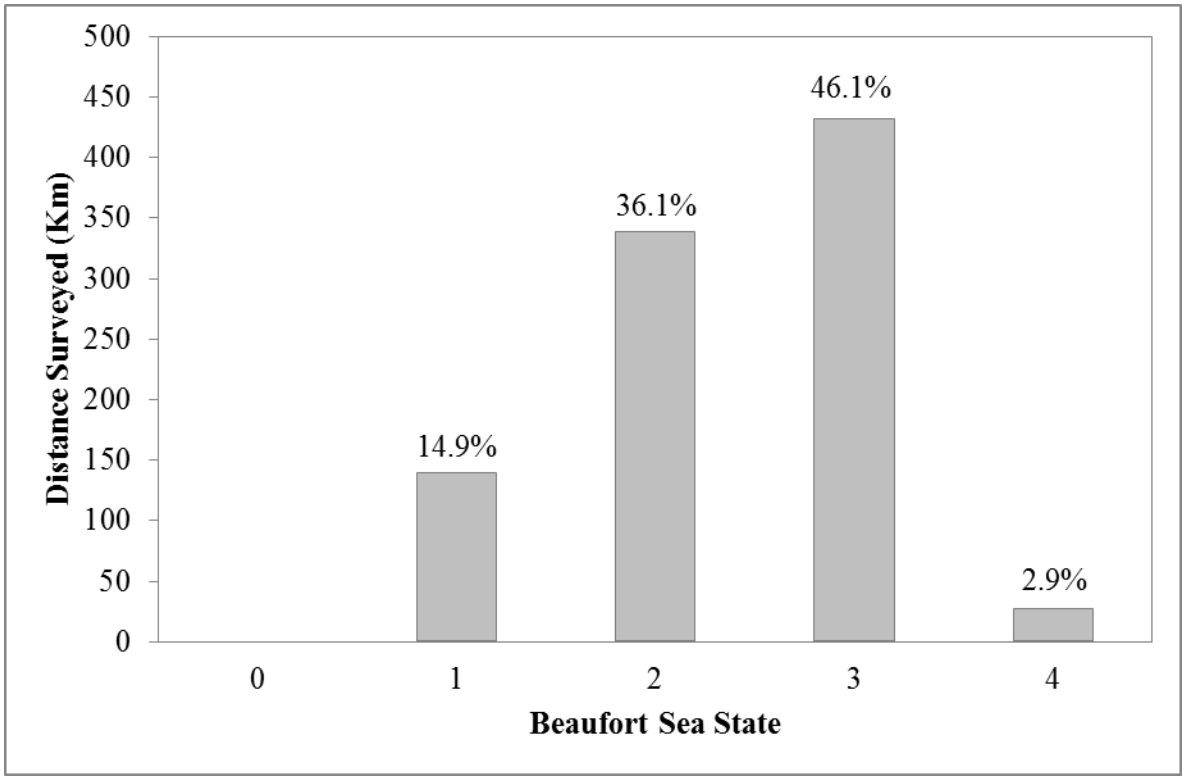

Figure 5. Total distance surveyed by Beaufort Sea State during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Marine Mammal and Sea Turtle Sightings

Forty-one cetacean sightings were recorded during vessel surveys. Two species were encountered: Atlantic spotted dolphins (*Stenella frontalis*; n = 14) and bottlenose dolphins (*Tursiops truncatus*; n = 23). In addition, unidentified delphinids were recorded on four occasions (Tables 4 and 5). No mixed species groups were observed. Sightings per unit effort was highest in a BSS 1, with no sightings observed in BSS 4 (Figure 6). Forty-nine sea turtles were observed in the study area during 2012 (Table 6). Loggerhead sea turtles (*Caretta caretta*, n = 41) were most frequently recorded, followed by leatherbacks (*Dermochelys coriacea*; n = 4) and Kemp's ridley sea turtles (*Lepidochelys kempii*; n = 1). In addition, three unidentified sea turtles were recorded (Tables 6 and 7).

Table 4. Cetacean sightings from vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Date	Time	Latitude	Longitude	Depth (m)	Temp (C^o)	Species	Group Size	Biopsy Samples	Images
07-Jan-12	11:34	30.501830	-80.711135	31.0	19.5	*T. truncatus*	2	0	0
07-Jan-12	12:25	30.499440	-80.666240	32.0	19.4	*S. frontalis*	15	1	98
07-Jan-12	14:17	30.526950	-80.530070	34.7	20.5	Unid. delphinid	3	0	0
07-Jan-12	14:46	30.535050	-80.487540	35.6	20.7	*T. truncatus*	3	0	21
08-Jan-12	8:27	30.302510	-80.692110	34.1	24.0	*T. truncatus*	2	0	0
08-Jan-12	10:04	30.129170	-80.598160	39.4	23.4	*T. truncatus*	2	0	2
08-Jan-12	11:02	30.090920	-80.562920	42.5	23.1	*T. truncatus*	1	1	40
08-Jan-12	12:05	30.082710	-80.551950	43.6	22.8	*T. truncatus*	2	1	39
08-Jan-12	13:02	30.049128	-80.539590	39.6	22.2	*T. truncatus*	5	0	2
08-Jan-12	13:51	30.043610	-80.481190	no data	no data	*T. truncatus*	2	2	22
08-Jan-12	14:22	30.043800	-80.425060	no data	no data	*T. truncatus*	2	0	0
08-Jan-12	16:06	30.213870	-80.374605	36.4	22.3	*S. frontalis*	6	3	99
08-Jan-12	16:57	30.257300	-80.459550	39.0	24.4	*T. truncatus*	7	0	3
08-Jan-12	17:18	30.314706	-80.549449	38.9	22.9	Unid. delphinid	2	0	0
08-Jan-12	17:19	30.439300	-80.718710	39.3	22.3	Unid. delphinid	2	0	0
09-Jan-12	8:51	30.552327	-80.405027	38.7	22.2	*T. truncatus*	2	0	1
09-Jan-12	9:55	30.568610	-80.298770	41.5	23.1	*S. frontalis*	35	4	80
09-Jan-12	11:56	30.568020	-80.443080	36.3	21.4	*T. truncatus*	2	1	34
09-Jan-12	13:05	30.558680	-80.698080	no data	no data	*T. truncatus*	20	0	0
24-Jan-12	10:30	30.046740	-80.625285	38.7	22.1	*T. truncatus*	1	0	0
24-Jan-12	12:27	30.035810	-80.279440	64.9	23.2	*T. truncatus*	9	2	28
24-Jan-12	14:41	30.044770	-80.012910	304.8	25.0	*T. truncatus*	9	1	24
25-Jan-12	10:35	30.391806	-80.390716	41.2	23.2	*T. truncatus*	4	1	27
25-Jan-12	11:50	30.361248	-80.320116	42.7	23.7	*S. frontalis*	25	2	113
25-Jan-12	15:08	30.278380	-80.307960	47.5	23.6	*T. truncatus*	8	2	40
30-Mar-12	10:16	29.962724	-80.681119	36.5	23.1	*S. frontalis*	1	0	0
30-Mar-12	11:21	29.980474	-80.527658	40.0	23.0	*T. truncatus*	2	1	20
03-Apr-12	10:18	30.584986	-80.787704	29.8	23.7	*S. frontalis*	7	2	133
03-Apr-12	10:45	30.574974	-80.746964	41.7	24.8	*S. frontalis*	2	0	4
03-Apr-12	11:01	30.571681	-80.728924	31.2	23.0	*S. frontalis*	15	1	11
03-Apr-12	11:17	30.573406	-80.701239	36.2	25.4	*S. frontalis*	2	0	3
03-Apr-12	12:57	30.596718	-80.436993	32.3	23.0	*S. frontalis*	12	2	37
03-Apr-12	14:39	30.515093	-80.327668	30.1	23.3	*S. frontalis*	4	2	34
03-Apr-12	15:56	30.487704	-80.507851	36.5	23.5	*S. frontalis*	4	2	21
23-Aug-12	13:41	30.41099	-80.41034	no data	no data	*T. truncatus*	1	0	0
23-Aug-12	14:06	30.37717	-80.40121	no data	no data	*T. truncatus*	3	0	0
23-Aug-12	14:49	30.33732	-80.46228	no data	no data	*S. frontalis*	1	0	0
23-Aug-12	15:55	30.44585	-80.74868	no data	no data	Unid. delphinid	1	0	0

Table 4 cont. Cetacean sightings from vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Date	Time	Latitude	Longitude	Depth (m)	Temp (C^{o})	Species	Group Size	Biopsy Samples	Images
24-Aug-12	11:48	30.2284	-80.69776	no data	no data	*T. truncatus*	2	0	13
24-Aug-12	12:45	30.24054	-80.59054	35.8	27.4	*S. frontalis*	3	0	0
24-Aug-12	13:03	30.24542	-80.58164	35.6	27.5	*T. truncatus*	1	0	0

Table 5. Number of cetacean sightings and mean group size for each species observed during Year 1 (July 2009 – June 2010), Year 2 (July 2010 – December 2011), and Year 3 (January 2012 – December 2012) of vessel surveys in the Jacksonville survey area.

	Sightings			
Species	**Year 1**	**Year 2**	**Year 3**	**Mean Group Size**
Globicephala macrorhynchus	3	0	0	33.3±18.0
Grampus griseus	2	0	0	21.5±19.1
Stenella frontalis	24	17	14	9.49±10.1
Tursiops truncatus	15	10	23	5.19±4.9
Unid. delphinid	12	1	4	1.88±0.8
Total:	**56**	**28**	**41**	

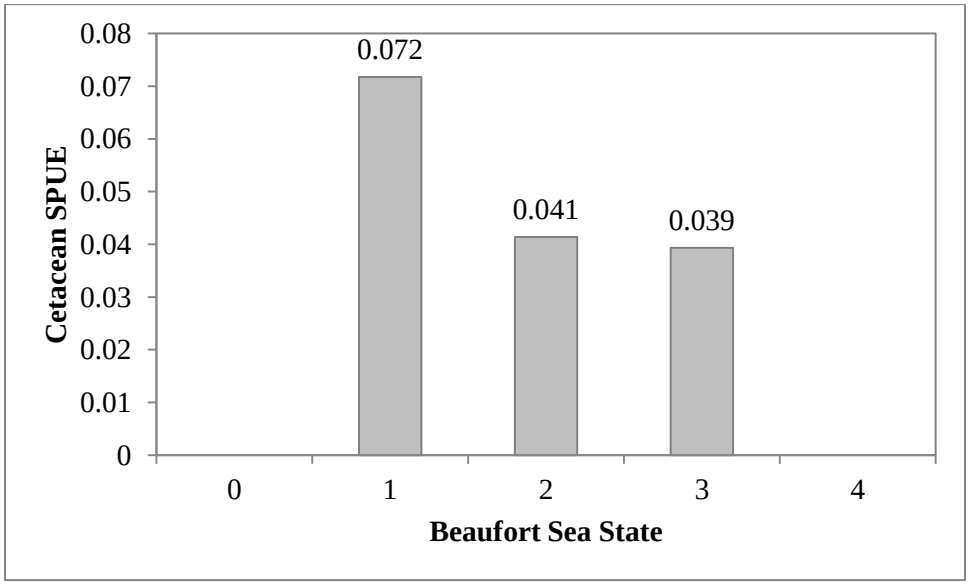

Figure 6. Number of cetacean sightings, corrected for kilometers on effort, observed in each Beaufort Sea State for vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Table 6. Sea turtle sightings from vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Date	Time	Latitude	Longitude	Depth (m)	Temp (C^o)	Species	Group Size
7-Jan-12	14:26	30.52881	-80.52291	34.7	20.5	*C. caretta*	1
7-Jan-12	14:56	30.53563	-80.48869	no data	20.7	Unid. sea turtle	1
7-Jan-12	16:46	30.51769	-80.63006	no data	no data	*C. caretta*	1
8-Jan-12	10:10	30.12728	-80.59263	36.4	22.3	*C. caretta*	1
8-Jan-12	10:28	30.13513	-80.59181	36.4	22.3	*D. coriacea*	1
8-Jan-12	11:10	30.08998	-80.56569	39.0	24.4	*C. caretta*	1
8-Jan-12	13:43	30.04635	-80.50339	no data	no data	*C. caretta*	1
8-Jan-12	13:46	30.04716	-80.49131	no data	no data	*C. caretta*	1
8-Jan-12	13:52	30.04313	-80.48047	39.4	23.4	*C. caretta*	1
8-Jan-12	14:22	30.04378	-80.42519	42.5	23.1	*C. caretta*	1
8-Jan-12	15:03	30.06384	-80.32413	no data	no data	*C. caretta*	1
8-Jan-12	15:52	30.18344	-80.32745	46.9	22.7	*C. caretta*	1
8-Jan-12	16:00	30.20237	-80.35318	43.8	22.9	*C. caretta*	1
9-Jan-12	10:56	30.55439	-80.30574	no data	no data	*C. caretta*	1
9-Jan-12	11:44	30.56025	-80.41771	no data	no data	*C. caretta*	1
9-Jan-12	13:01	30.55874	-80.67901	no data	no data	*C. caretta*	1
24-Jan-12	11:29	30.04120	-80.43899	42.7	23.1	*C. caretta*	1
25-Jan-12	10:24	30.37499	-80.42109	39.3	23.1	*C. caretta*	1
25-Jan-12	13:06	30.37451	-80.27050	48.0	23.4	*C. caretta*	1
30-Mar-12	12:41	30.08129	-80.34201	44.3	23.9	*C. caretta*	1
30-Mar-12	15:45	30.22590	-80.33625	44.9	24.4	*C. caretta*	1
30-Mar-12	16:11	30.19662	-80.42101	42.1	24.8	*C. caretta*	1
30-Mar-12	16:23	30.18517	-80.44653	40.0	24.8	*C. caretta*	1
30-Mar-12	16:41	30.08891	-80.77534	31.0	23.8	*D. coriacea*	1
3-Apr-12	11:26	30.56961	-80.68411	27.6	23.0	*C. caretta*	1
3-Apr-12	11:33	30.56991	-80.66811	30.0	23.0	*D. coriacea*	1
3-Apr-12	12:11	30.59251	-80.56103	31.8	23.1	*C. caretta*	1
3-Apr-12	13:33	30.58566	-80.40822	38.7	24.1	*C. caretta*	1
3-Apr-12	13:38	30.58131	-80.38930	38.5	24.2	*C. caretta*	3
3-Apr-12	13:54	30.56496	-80.32273	40.5	24.8	*C. caretta*	1
3-Apr-12	13:57	30.56408	-80.31120	42.0	24.8	*C. caretta*	1
3-Apr-12	14:06	30.54881	-80.29303	42.5	24.8	*C. caretta*	1
3-Apr-12	14:07	30.54684	-80.29203	42.5	24.8	*C. caretta*	1
3-Apr-12	14:12	30.53233	-80.27777	42.7	24.8	*D. coriacea*	1

Table 6 cont. Sea turtle sightings from vessel surveys in the Jacksonville survey area, January 2012 - December 2012.

Date	Time	Latitude	Longitude	Depth (m)	Temp (C^o)	Species	Group Size
3-Apr-12	14:37	30.51631	-80.32857	41.7	24.9	Unid. sea turtle	1
3-Apr-12	15:12	30.52234	-80.33443	41.2	25.2	*C. caretta*	1
3-Apr-12	15:14	30.52274	-80.34369	40.6	25.4	*C. caretta*	1
3-Apr-12	15:20	30.52077	-80.36923	40.0	25.6	*C. caretta*	1
3-Apr-12	15:45	30.50381	-80.45624	37.9	25.6	*C. caretta*	1
3-Apr-12	16:25	30.46851	-80.53420	36.5	25.6	*C. caretta*	1
3-Apr-12	16:34	30.46036	-80.57900	36.8	25.7	*C. caretta*	1
3-Apr-12	16:44	30.44787	-80.63764	36.1	25.6	Unid. sea turtle	1
19-Apr-12	12:13	30.49084	-80.62481	31.1	23.3	*C. caretta*	1
19-Apr-12	12:17	30.48970	-80.63243	31.1	23.3	*C. caretta*	1
23-Aug-12	13:39	30.56676	-80.69705	no data	no data	*L. kempii*	1
24-Aug-12	12:17	30.22151	-80.66546	35.5	27.3	*C. caretta*	1
24-Aug-12	12:35	30.23511	-80.61733	35.0	27.4	*C. caretta*	1
24-Aug-12	13:05	30.24702	-80.58249	36.0	27.5	*C. caretta*	2
24-Aug-12	17:46	30.27985	-80.62569	33.8	27.5	*C. caretta*	1

Table 7. Number of sea turtle sightings and mean group size for each species observed during Year 1 (July 2009 – June 2010), Year 2 (July 2010 – December 2011), and Year 3 (January 2012 – December 2012) of vessel surveys in the Jacksonville survey area.

	Sightings			
Species	**Year 1**	**Year 2**	**Year 3**	**Mean Group Size**
Caretta caretta	49	23	41	1.0±0.2
Dermochelys coriacea	5	7	4	1.0±0.0
Lepidochelys kempii	1	0	1	1.0±0.0
Unid. sea turtle	3	8	3	1.0±0.0
Total:	**58**	**38**	**49**	

Distributions and Habitat Associations of Cetaceans and Sea Turtles

The distribution of marine mammals and sea turtles in the Jacksonville study area is presented in Figures 7 through 11. Similar to observations made in previous years, Atlantic spotted dolphins were largely restricted to the relatively shallow shelf waters (Figure 8), whereas bottlenose dolphins were encountered throughout the survey area with one group detected in deeper offshore waters (Figure 9). All sea turtles were observed in relatively shallow waters over the continental shelf (Figure 11).

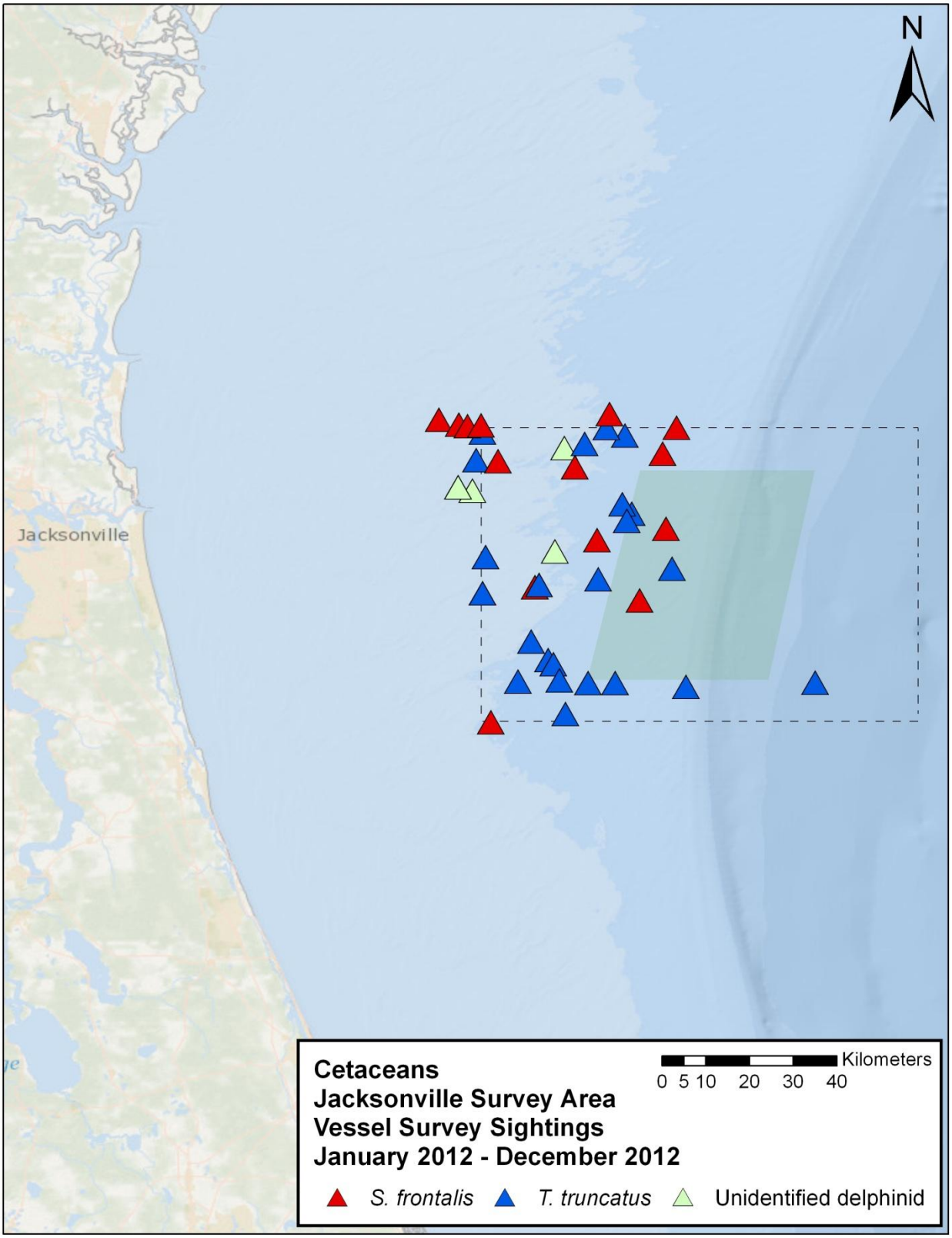

Figure 7. Distribution of all cetacean sightings made during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

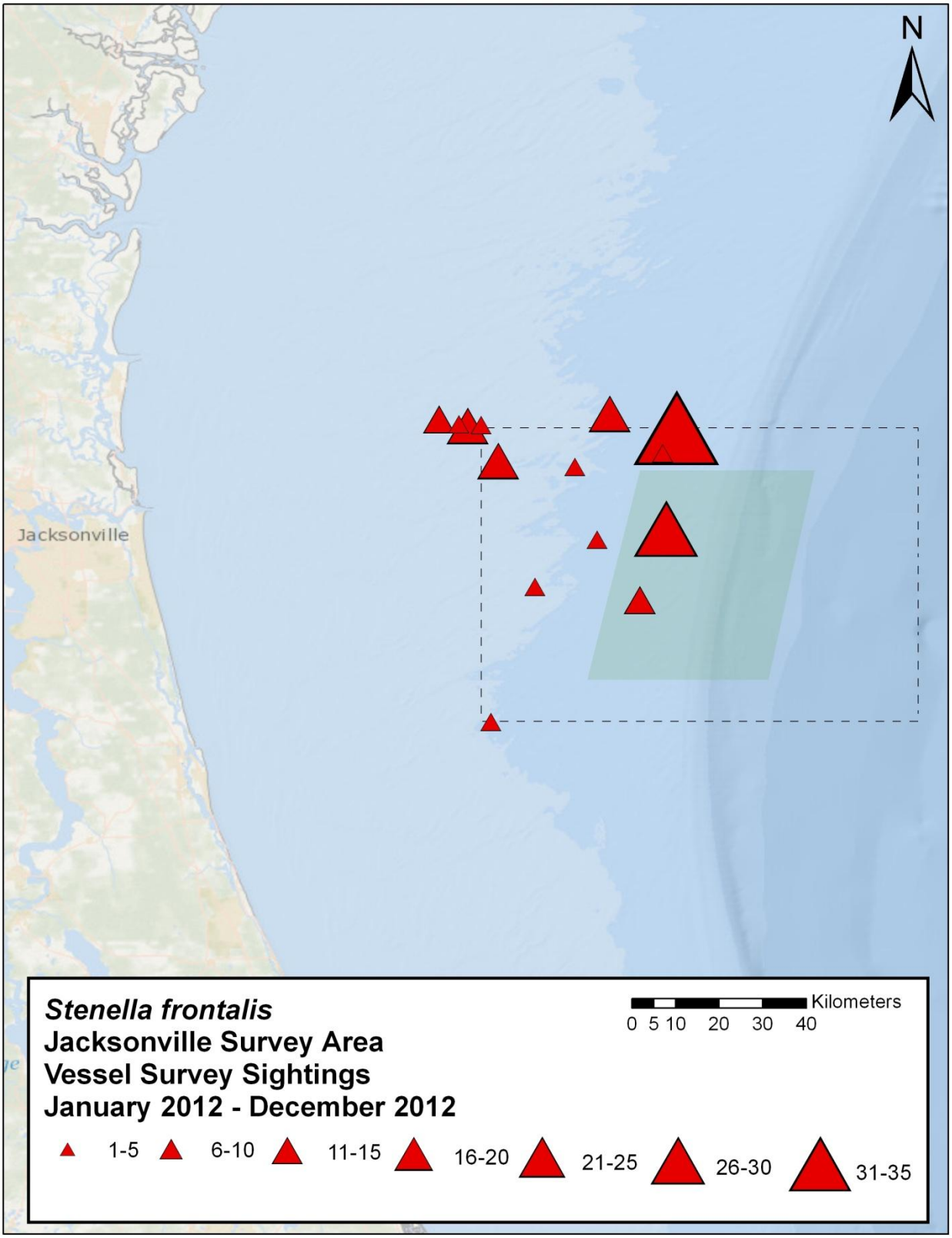

Figure 8. Distribution of Atlantic spotted dolphin sightings indicating group size made during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

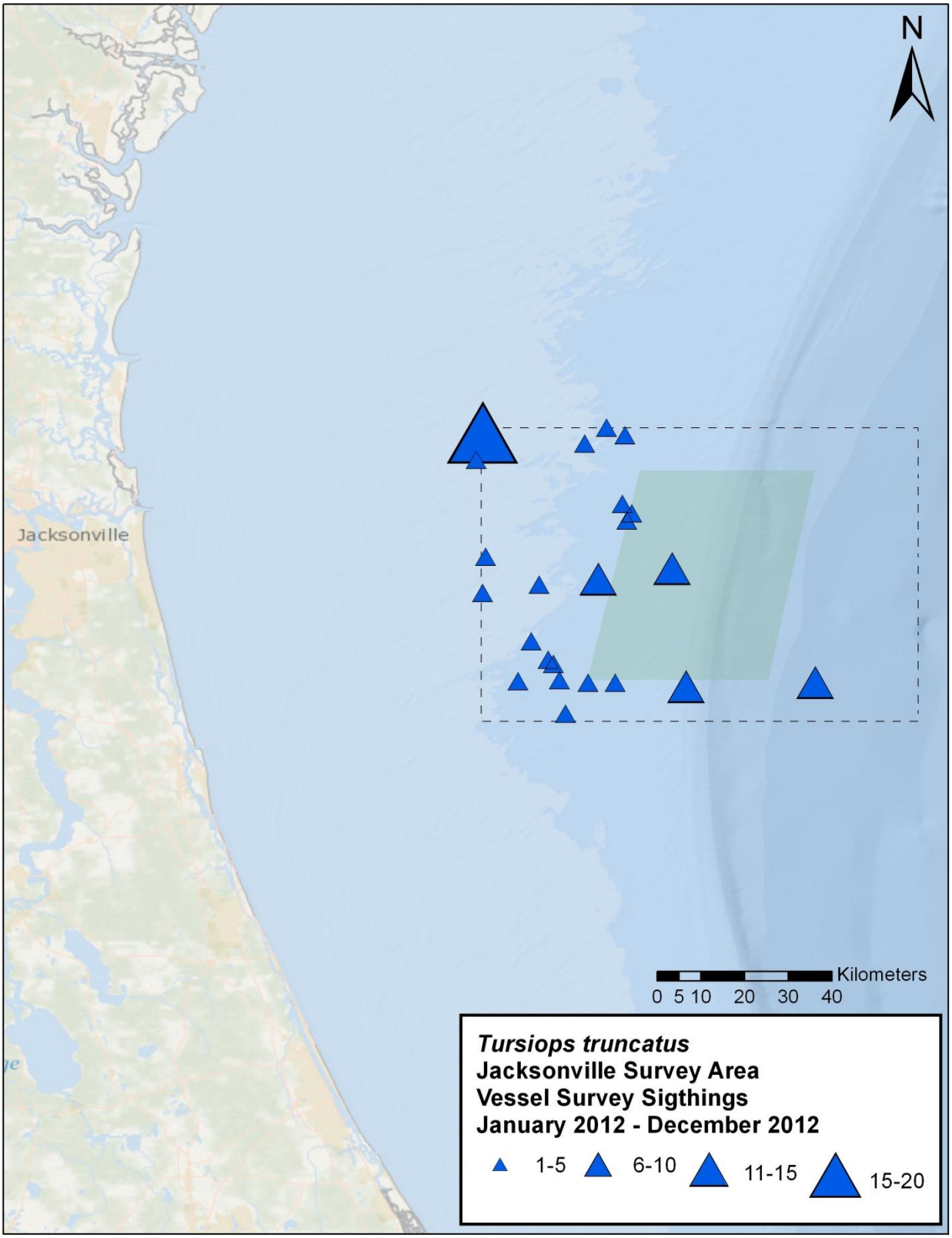

Figure 9. Distribution of bottlenose dolphin sightings indicating group size made during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

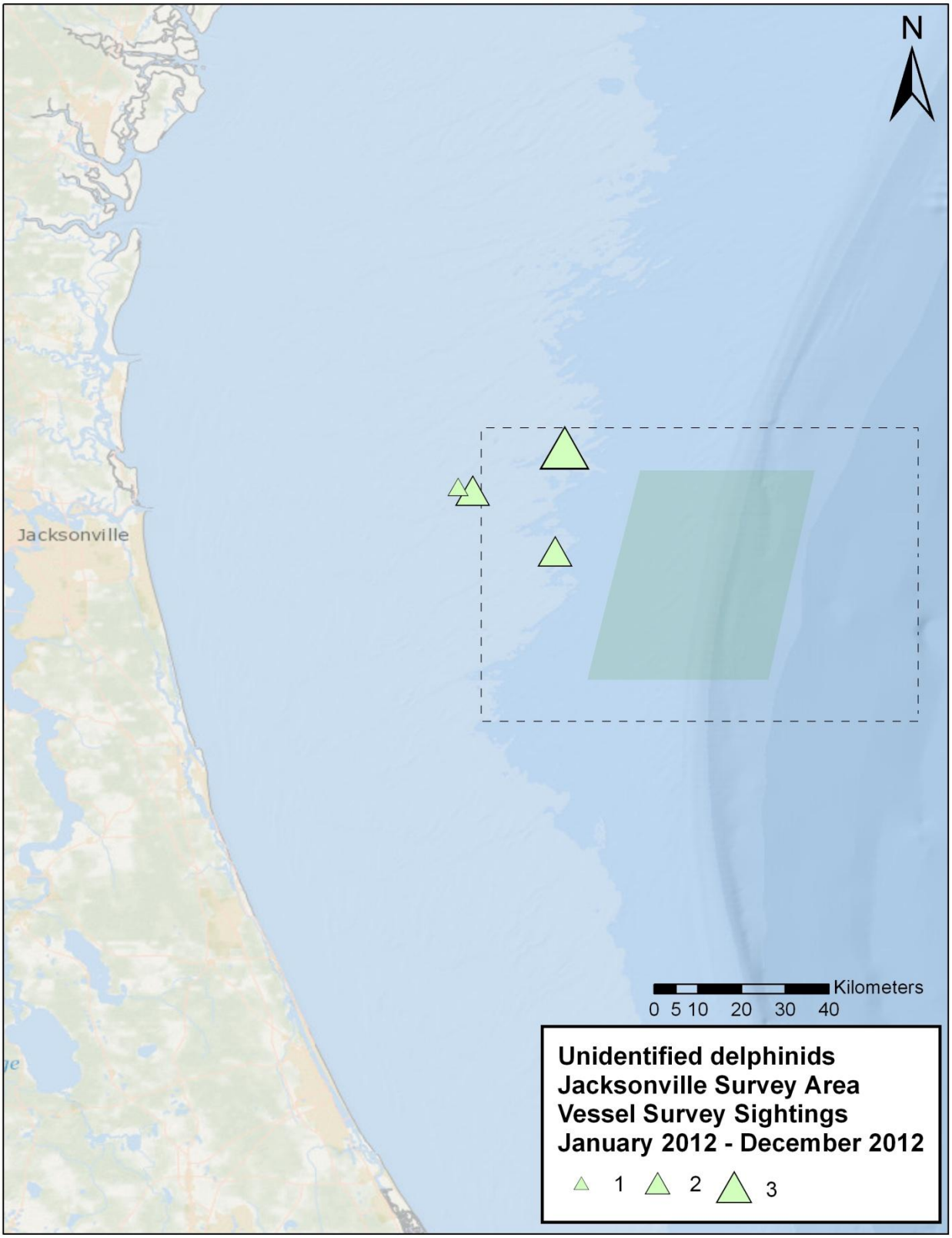

Figure 10. Distribution of unidentified delphinid sightings indicating group size made during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

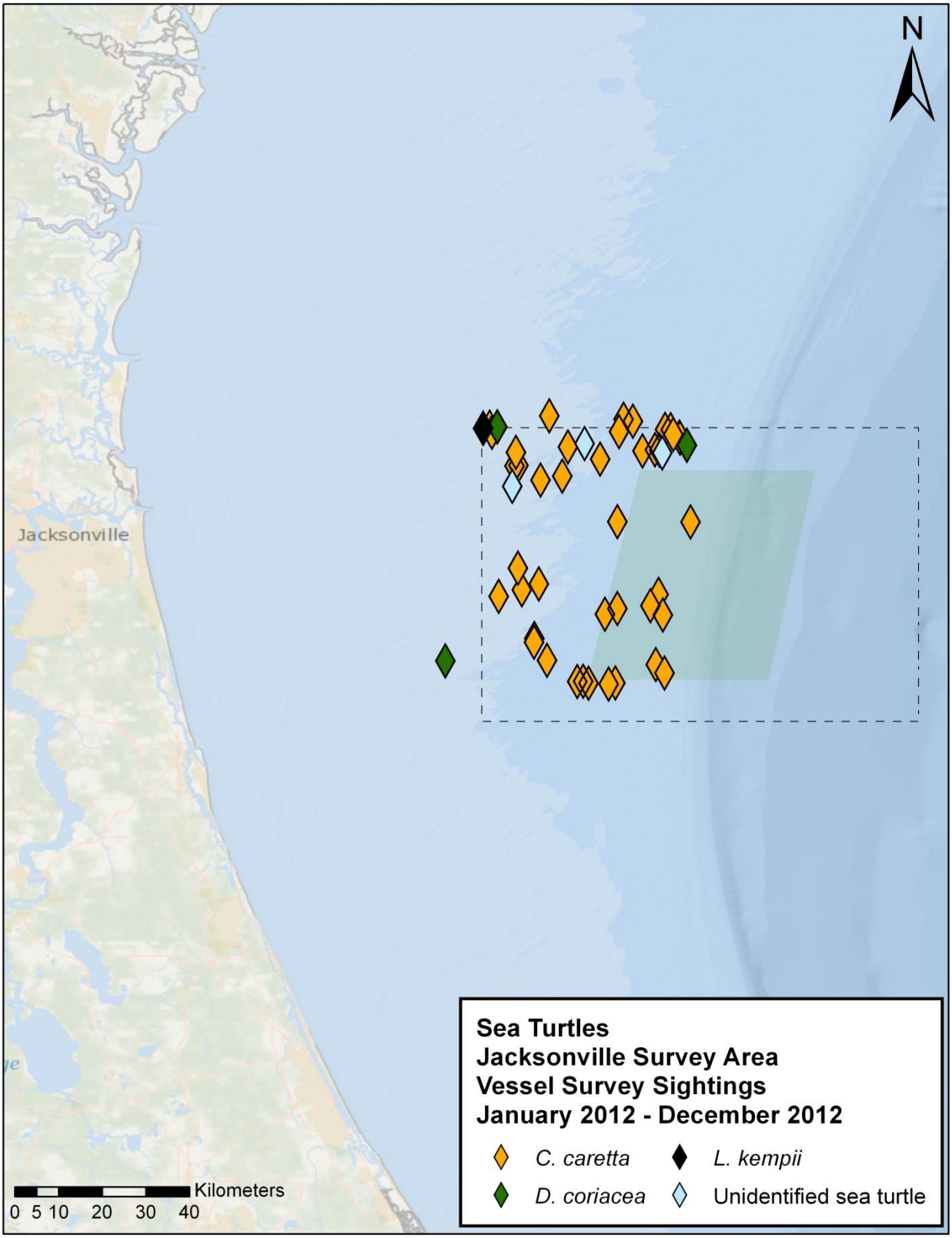

Figure 11. Distribution of sea turtle sightings made during vessel surveys in the Jacksonville survey area, January 2012 – December 2012.

Seasonality of Effort and Sightings

Due to unfavorable weather conditions, no survey effort was conducted in several months of the reporting period. It is, therefore, difficult to identify seasonal trends in cetacean or sea turtle distribution. The number of sightings is depicted below by species for both cetaceans and sea turtles during each month of surveys (Figures 12 and 13).

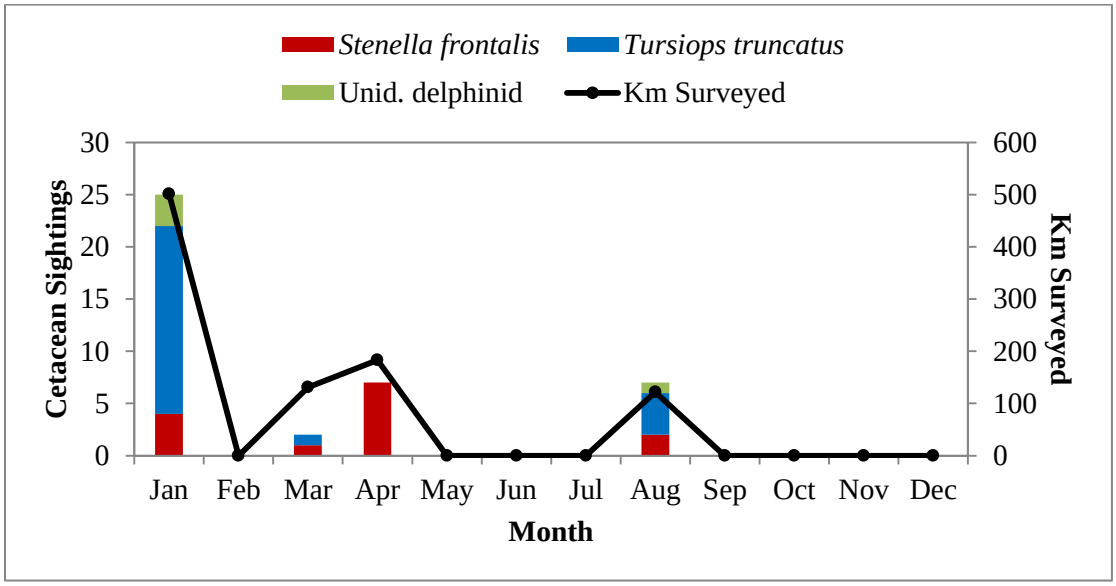

Figure 12. Number of cetacean sightings by month and effort (km surveyed) for vessel surveys conducted in the Jacksonville survey area, January 2012 – December 2012.

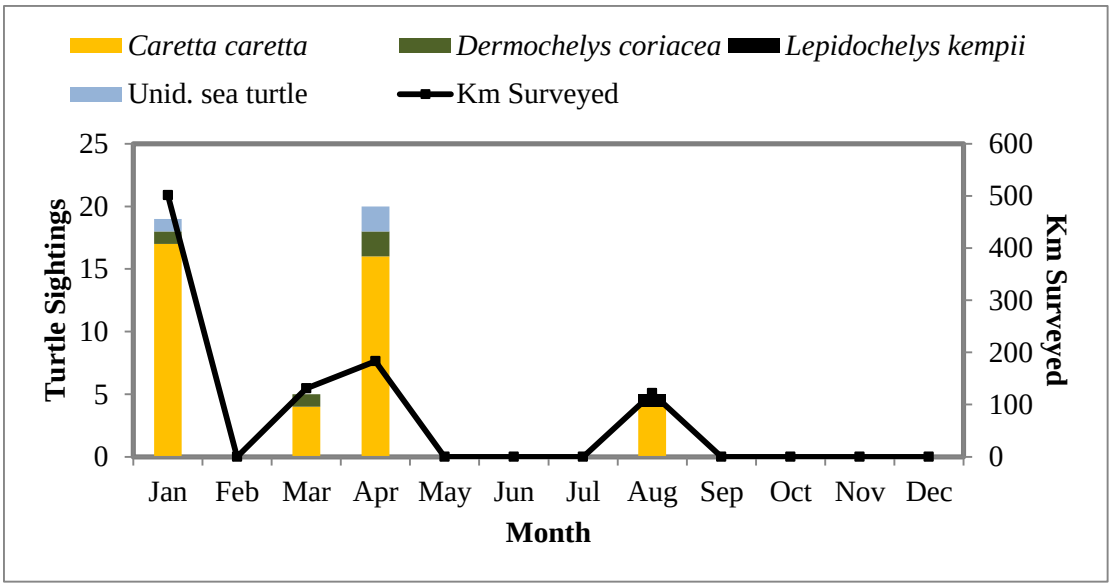

Figure 13. Number of sea turtle sightings by month and effort (kilometers surveyed) for vessel surveys conducted in the Jacksonville survey area, January 2012 – December 2012.

Biopsy Sampling

A total of 31 biopsy samples were collected in the Jacksonville survey area during 2012 from Atlantic spotted dolphins (n = 19) and bottlenose dolphins (n = 12)(Table 8, Figure 14). Skin samples will be analyzed for sex and population structure in the coming months. Voucher specimens of these samples are archived with the Southeast Fisheries Science Center in Lafayette, LA.

Table 8. Biopsy samples collected in the Jacksonville survey area, January 2012 – December 2012.

Date	Time	Latitude	Longitude	Species	Sample #
7-Jan-12	12:36	30.50247	-80.65608	*Stenella frontalis*	ZTS-12-001
8-Jan-12	11:39	30.09573	-80.56193	*Tursiops truncatus*	ZTS-12-002
8-Jan-12	12:14	30.08455	-80.55126	*Tursiops truncatus*	ZTS-12-003
8-Jan-12	13:58	30.03923	-80.48430	*Tursiops truncatus*	ZTS-12-004
8-Jan-12	14:02	30.03811	-80.48276	*Tursiops truncatus*	ZTS-12-005
8-Jan-12	16:24	30.21226	-80.38031	*Stenella frontalis*	ZTS-12-006
8-Jan-12	16:32	30.21042	-80.38461	*Stenella frontalis*	ZTS-12-007
8-Jan-12	16:35	30.21232	-80.38584	*Stenella frontalis*	ZTS-12-008
9-Jan-12	9:59	30.56845	-80.29752	*Stenella frontalis*	HJF-12-001
9-Jan-12	10:14	30.56838	-80.30261	*Stenella frontalis*	HJF-12-002
9-Jan-12	10:20	30.56763	-80.30446	*Stenella frontalis*	HJF-12-003
9-Jan-12	10:48	30.55512	-80.30578	*Stenella frontalis*	HJF-12-004
9-Jan-12	12:07	30.56538	-80.44226	*Tursiops truncatus*	ZTS-12-009
24-Jan-12	12:35	30.03811	-80.28133	*Tursiops truncatus*	ZTS-12-010
24-Jan-12	12:44	30.04162	-80.28565	*Tursiops truncatus*	ZTS-12-011
24-Jan-12	15:09	30.06070	-80.00417	*Tursiops truncatus*	HJF-12-005
25-Jan-12	10:40	30.38851	-80.39202	*Tursiops truncatus*	ZTS-12-012
25-Jan-12	11:52	30.35957	-80.31598	*Stenella frontalis*	ZTS-12-013
25-Jan-12	11:59	30.35317	-80.32049	*Stenella frontalis*	ZTS-12-014
25-Jan-12	15:14	30.27371	-80.30949	*Tursiops truncatus*	DMW-12-001
25-Jan-12	15:28	30.25899	-80.31058	*Tursiops truncatus*	DMW-12-002
30-Mar-12	11:27	29.98758	-80.52506	*Tursiops truncatus*	ZTS-12-020
3-Apr-12	10:24	30.58428	-80.77390	*Stenella frontalis*	ZTS-12-021
3-Apr-12	10:27	30.58594	-80.77408	*Stenella frontalis*	ZTS-12-022
3-Apr-12	11:05	30.57251	-80.73276	*Stenella frontalis*	HJF-12-006
3-Apr-12	13:11	30.59342	-80.44105	*Stenella frontalis*	HJF-12-007
3-Apr-12	13:16	30.59335	-80.44049	*Stenella frontalis*	HJF-12-008
3-Apr-12	14:46	30.51811	-80.32497	*Stenella frontalis*	ZTS-12-023
3-Apr-12	14:51	30.52029	-80.32563	*Stenella frontalis*	ZTS-12-024
3-Apr-12	16:02	30.48547	-80.50648	*Stenella frontalis*	HJF-12-009
3-Apr-12	16:09	30.48160	-80.50565	*Stenella frontalis*	HJF-12-010

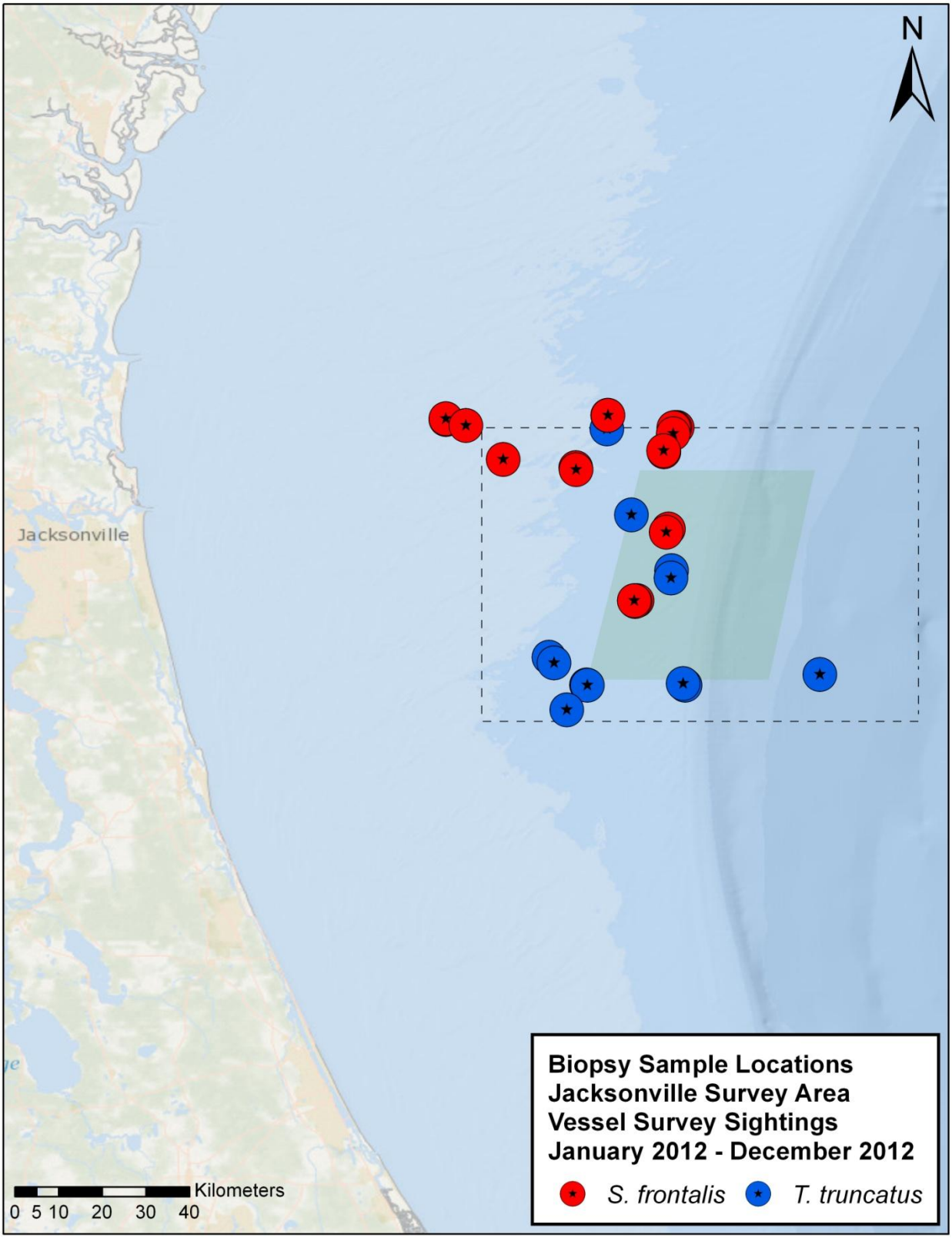

Figure 14. Locations of biopsy sample collections in the Jacksonville survey area, January 2012 – December 2012.

Photographic Effort

Approximately 949 digital images were taken for species confirmation and individual identification during 2012 vessel surveys. Images of newly identified dolphins were added to existing catalogs (Table 9); photo-identification analysis is now complete for all images taken through December 2012. Photo-identification catalogues for *Tursiops truncatus* and *Stenella frontalis* currently consist of 41 and 60 individuals, respectively. Two individual spotted dolphins have been resighted within the Jacksonville survey area (Figure 15). Sfr 3-001 was observed first on 10 October 2010 and again on 19 March 2011; Sfr 8-005 was photographed during surveys on two consecutive days: 18 March 2011 and 19 March 2011. No resightings of marked individuals were observed in 2012. The photo-identification catalogs of bottlenose dolphins and Atlantic spotted dolphins from Onslow Bay, NC and Jacksonville, FL were also compared; this analysis is complete, but no matches were identified between the two study areas. Future efforts include developing a short-finned pilot whale (*Globicephala macrorhynchus)* catalog for the Jacksonville survey area and comparing those individuals with the short-finned pilot whale catalogs from Onslow Bay and Cape Hatteras.

Table 9. Number of images taken and catalog size per species during vessel surveys in the Jacksonville survey area for Year 1 (July 2009 – June 2010), Year 2 (July 2010 – December 2011), and Year 3 (January 2012 – December 2012).

	Year 1		**Year 2**		**Year 3**		
Species	**Images**	**Catalog Size**	**Images**	**Catalog Size**	**Images**	**Catalog Size**	**Matches**
G. macrorhynchus	1368	0	0	0	0	0	0
G. griseus	405	1	0	1	0	1	0
S. frontalis	781	0	1267	41	633	60	2
T. truncatus	779	0	332	21	316	41	0

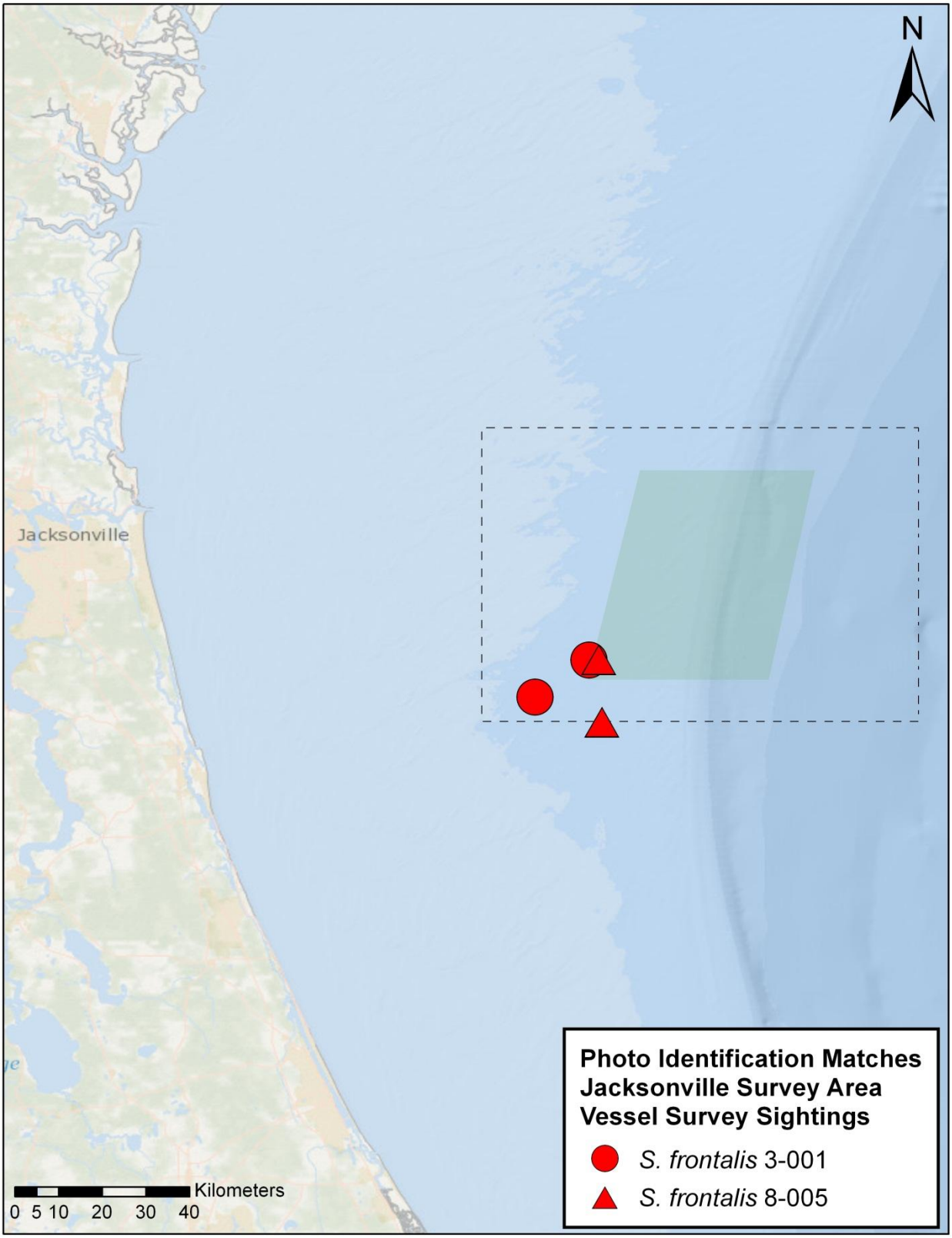

Figure 15. Locations of matched *Stenella frontalis* dolphins within the Jacksonville survey area.

Passive Acoustic Monitoring

HARP Analysis

The following is a summary of the analysis performed by Debich *et al.* (2013) at Scripps Institution of Oceanography. The full analysis report is found in Appendix A.

Underwater ambient noise during the August 2010 – July 2011 deployments at Sites A and B is shown in Figure 16. Tables 10 and 11 summarize the detected and identified marine mammal vocalizations for these deployments at Site A and at Site B, respectively. Figures 17 – 23 show the daily occurrence patterns for the different marine mammal groups (classified to species when possible). Figure 24 shows the occurrence of sonar.

Fin whale 20 Hz calls were detected at Site A in mid- to late January (Figure 17). Fin whale 40 Hz calls were not detected at either site, nor were there any 20 Hz calls at Site B.

Humpback whales were only detected at Site B (Figure 18). Only a few detections were made, likely because the migratory path of western North Atlantic humpbacks does not include the southeast US coastline, as they migrate from feeding areas in the Gulf of Maine (Katona & Beard 1990, Smith *et al.* 1999) to breeding areas in the Caribbean (Katona & Beard 1990, Stevick *et al.* 1998).

Minke whale slow-down/speed-up pulse trains were detected at both sites, with detections starting in December 2010 and continuing through the end of January 2011 at Site A and detections only in June 2011 at Site B (Figure 19). Minke whale regular pulse trains were only

recorded at Site A in mid-January 2011 (Figure 19). The general occurrence of minke whale pulse trains in the winter months is similar to previous findings. Pulse trains were only found at Site A previously. The June detection of a pulse train at Site B is a new finding in regard to season and site.

Downsweep calls similar to those ascribed to sei whales by Baumgartner *et al.* (2008) were detected at Site A, with detections occurring in November and December (Figure 20). No downsweep calls were detected at Site B.

The "5-pulse" call was detected late October through early December at Site A (Figure 21). No 5-pulse calls were recorded at Site B. The 5-pulse call is presumed to be produced by a mysticete due to its character, prevalence, and intensity.

Detected odontocete vocalizations included clicks and whistles (Figures 22-23). Most of these detections were assigned to the unidentified odontocete category, with clicks being divided into five main groups based on spectral patterns. Only a few detections were assigned to Risso's dolphins. Overall rates of unidentified odontocete detections were higher at Site A than B (Figure 22). Risso's dolphins were only detected at Site A, from the end of August until the end of November as well as the middle of January and beginning of March (Figure 23). A nighttime diel pattern is suggested from these detections. A greater number of Risso's click detections were observed during the August 2010 – July 2011 data sets than in previous data sets.

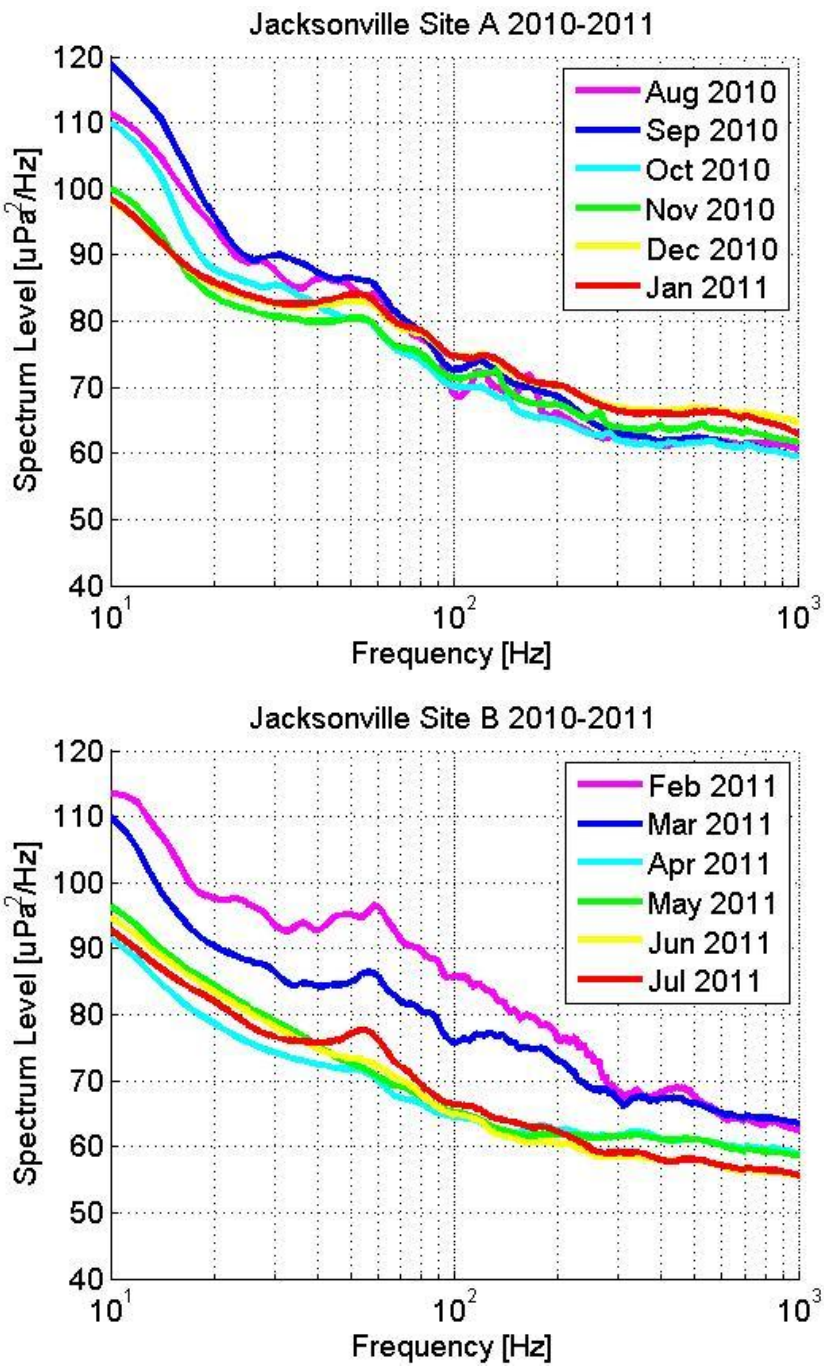

Figure 16. Monthly averages of ambient noise at Site A (top) and Site B (bottom) for August 2010 – July 2011 (for usable data).

Table 10. Summary of detections of marine mammal vocalizations at Site A. *For mysticetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in hourly bins; for odontocetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

Species	**Call type**	**Total duration of vocalizations (hours)***	**Percent of recording duration***	**Days with vocalizations**	**Percent of recording days**
Fin whale	20 Hz	39	0.25	6	0.90
Humpback whale	song or non-song (unspecified)	0	0	0	0
Minke whale	pulse train (slow-down, speed-up)	105	0.67	14	2.11
Minke whale	pulse train (regular)	2	0.01	1	0.15
Possible sei whale	downsweep	7	0.04	2	0.30
Possible mysticete	5-pulse sound	120	0.76	24	3.62
Unidentified odontocete	clicks, whistles	1524.1	58.69	302	45.55
Risso's dolphin	clicks	16.07	0.62	21	3.17

Table 11. Summary of detections of marine mammal vocalizations at Site B. *For mysticetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in hourly bins; for odontocetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

Species	**Call type**	**Total duration of vocalizations (hours)***	**Percent of recording duration***	**Days with vocalizations**	**Percent of recording days**
Fin whale	20 Hz	0	0	0	0
Humpback whale	song or non-song (unspecified)	1	0.01	1	0.15
Minke whale	pulse train (slow-down, speed-up)	1	0.01	1	0.15
Minke whale	pulse train (regular)	0	0	0	0
Possible sei whale	downsweep	0	0	0	0
Possible mysticete	5-pulse sound	0	0	0	0
Unidentified odontocete	clicks, whistles	655.35	24.13	287	43.29
Risso's dolphin	clicks	0	0	0	0

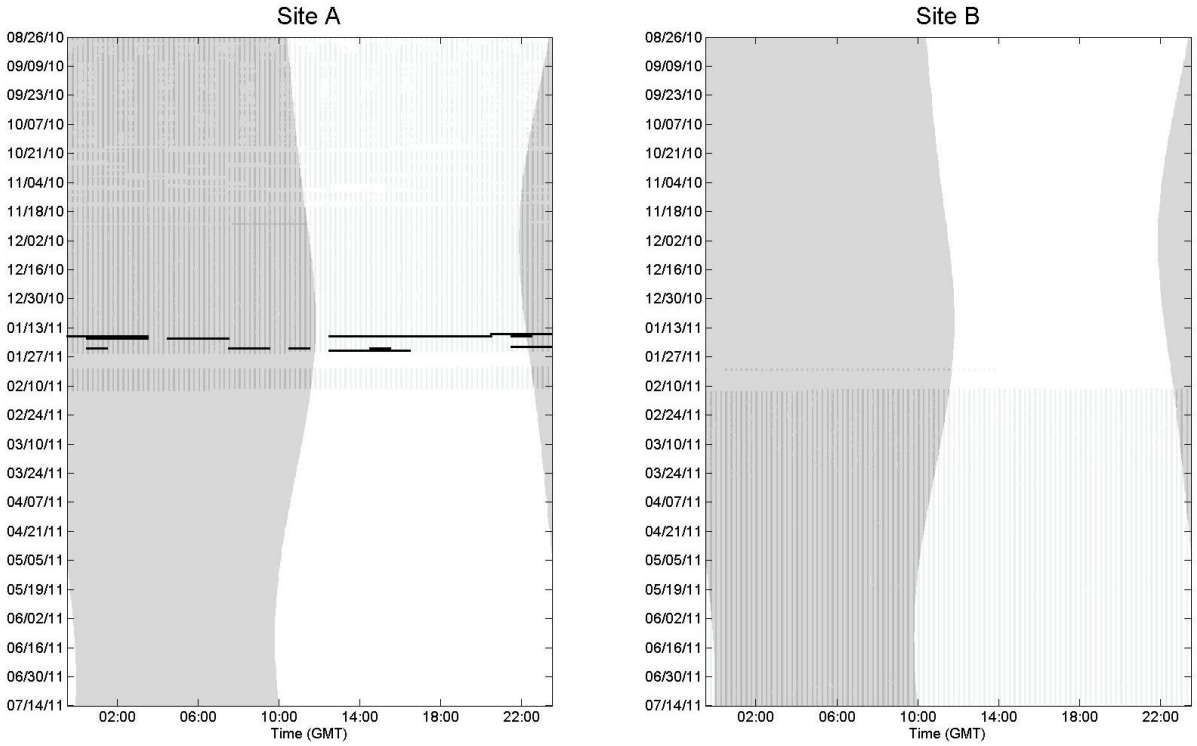

Figure 17. Fin whale detections (black bars) in hourly bins for the August 2010 – July 2011 Site A and B deployments. Note there were no detections at Site B. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1 and 2).

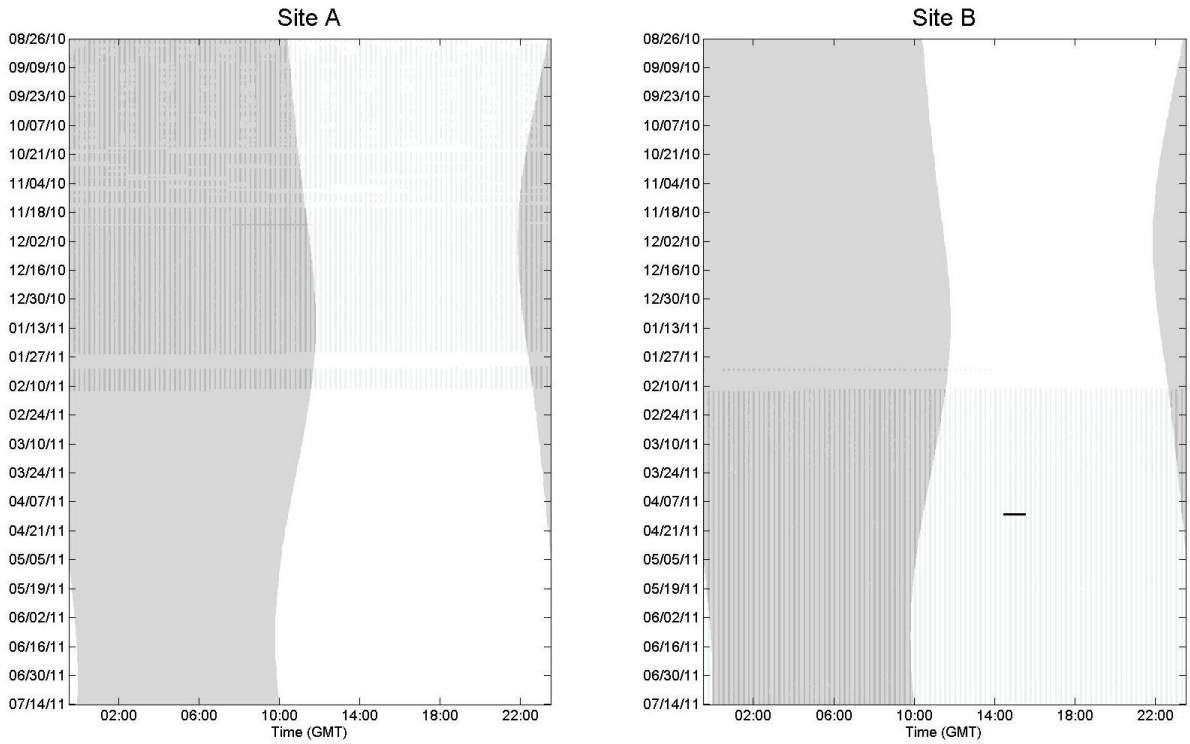

Figure 18. Humpback whale detections (black bars) in hourly bins for the August 2010 – July 2011 Site A and B deployments. Note there were no detections at Site A. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

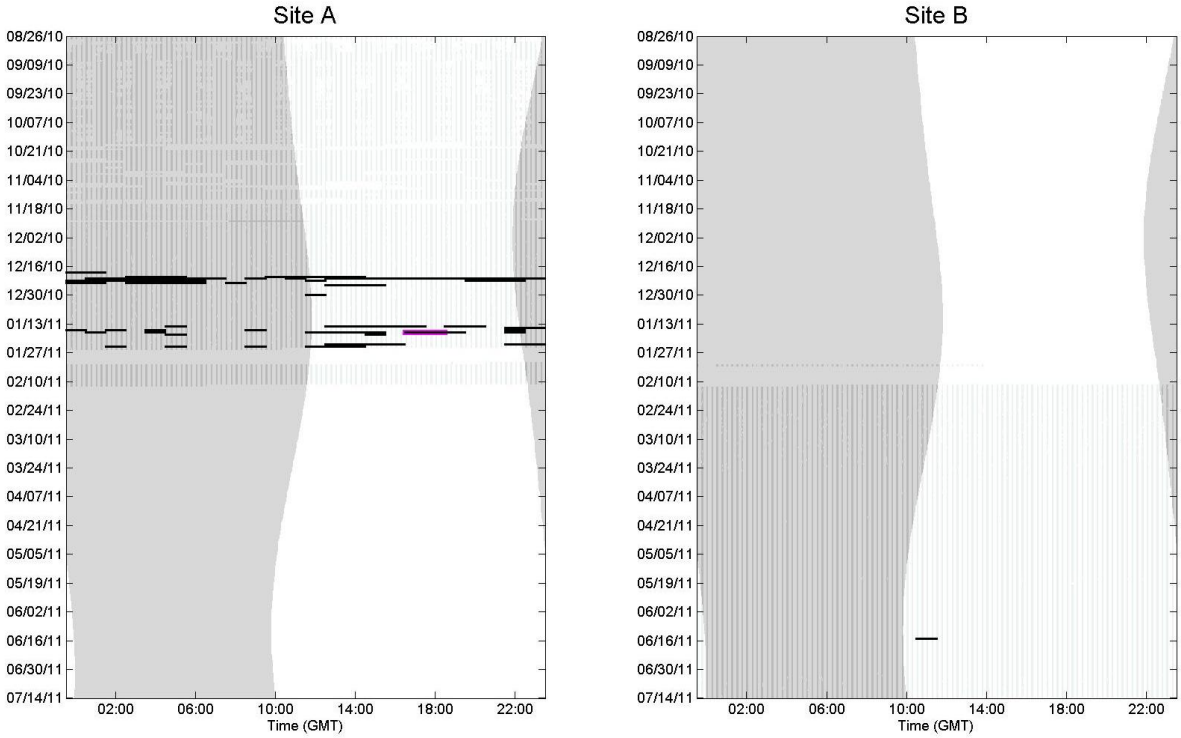

Figure 19. Minke whale slow-down/speed-up pulse train detections (black bars) and regular pulse train (pink bars) in hourly bins for the August 2010 – July 2011 Site A and B deployments. Note there were no regular pulse trains detected at Site B. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

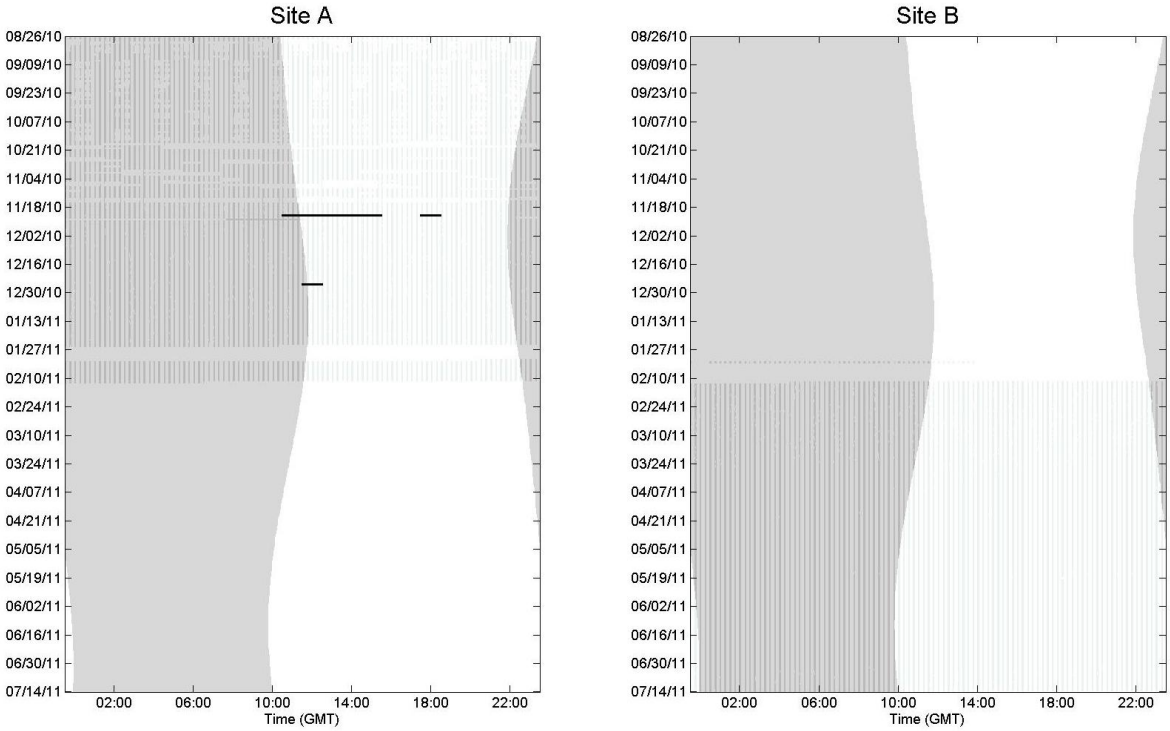

Figure 20. Hourly bins of downsweep detections (black bars) that may be produced by sei whales (Baumgartner *et al.* 2008) for the August 2010 – July 2011 Site A and B deployments. Note there were no detections at Site B. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

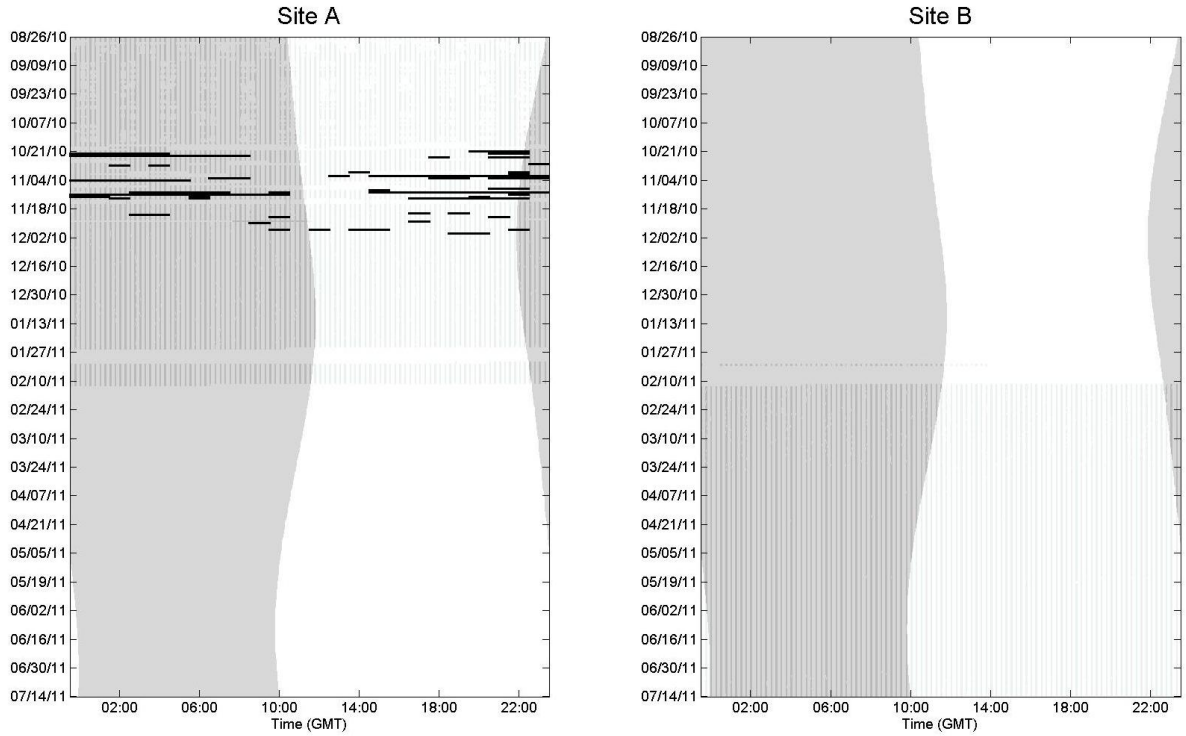

Figure 21. Hourly bins of 5-pulse call detections (black bars) that are likely produced by a mysticete for the August 2010 – July 2011 Site A and B deployments. Note there were no detections at Site B. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

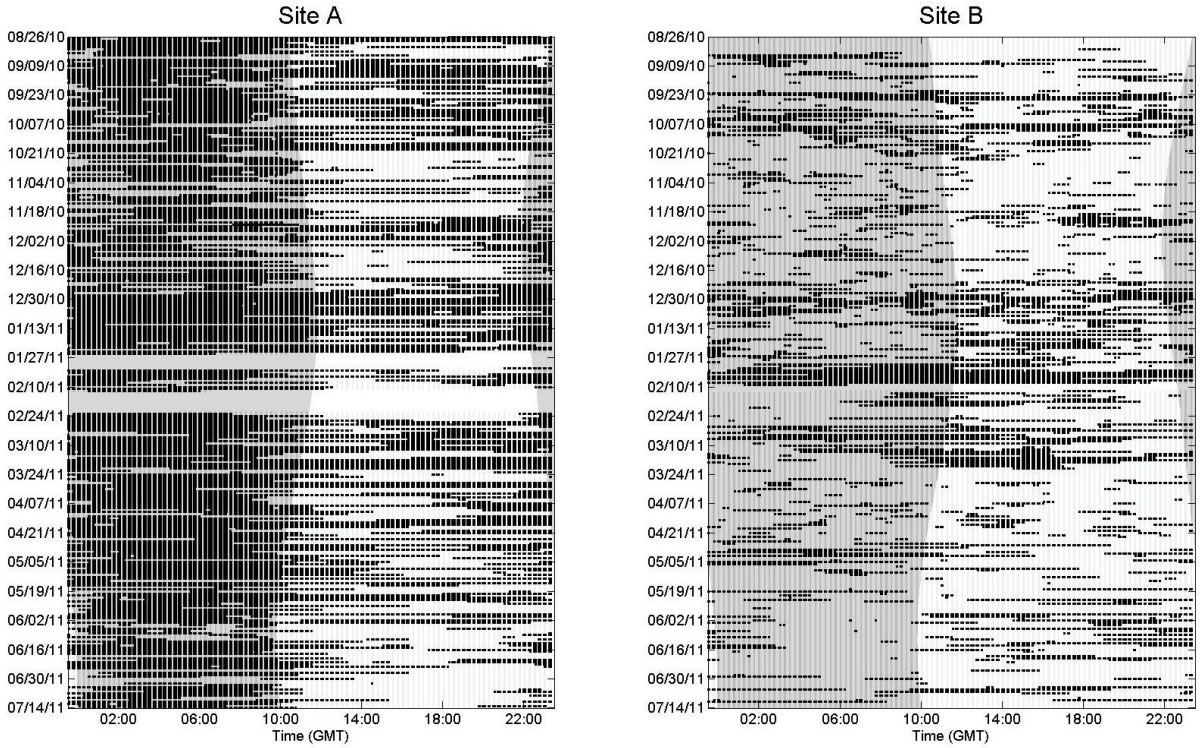

Figure 22. Unidentified odontocete vocalization detections (black bars) in minute bins for the August 2010 – July 2011 Site A and B deployments. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

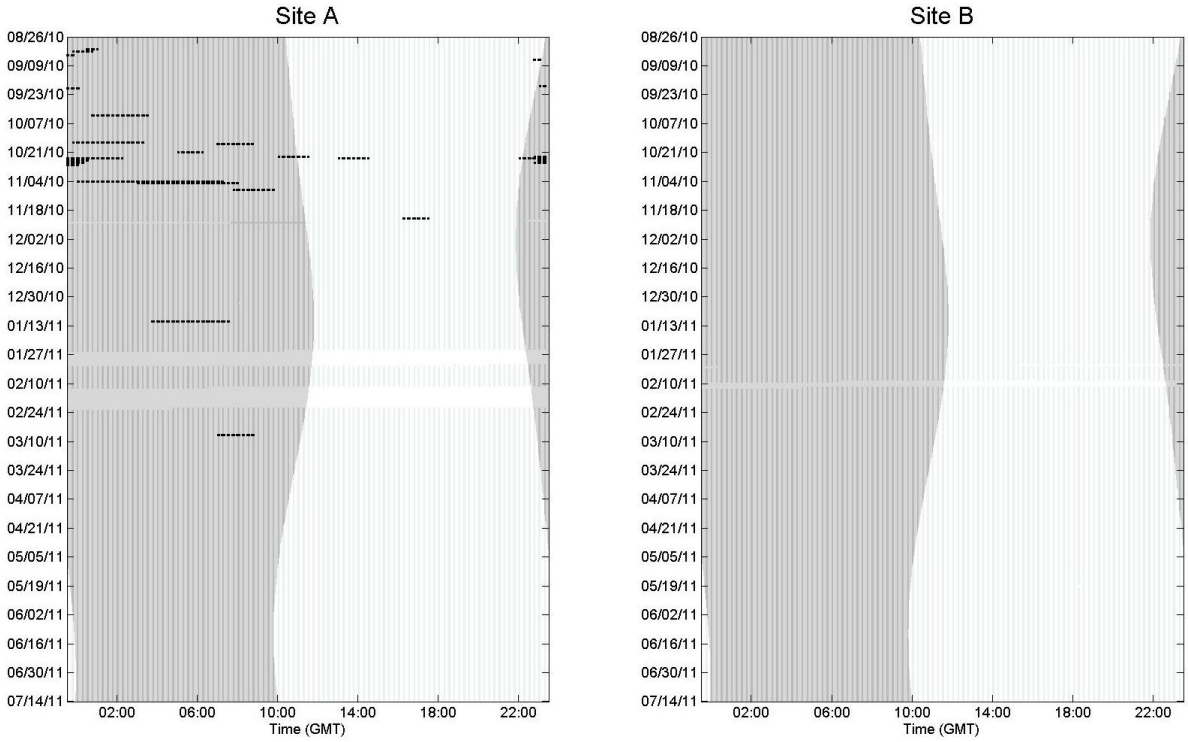

Figure 23. Risso's dolphin click detections (black bars) in minute bins for the August 2010 – July 2011 Site A and B deployments. Note there were no detections at Site B. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

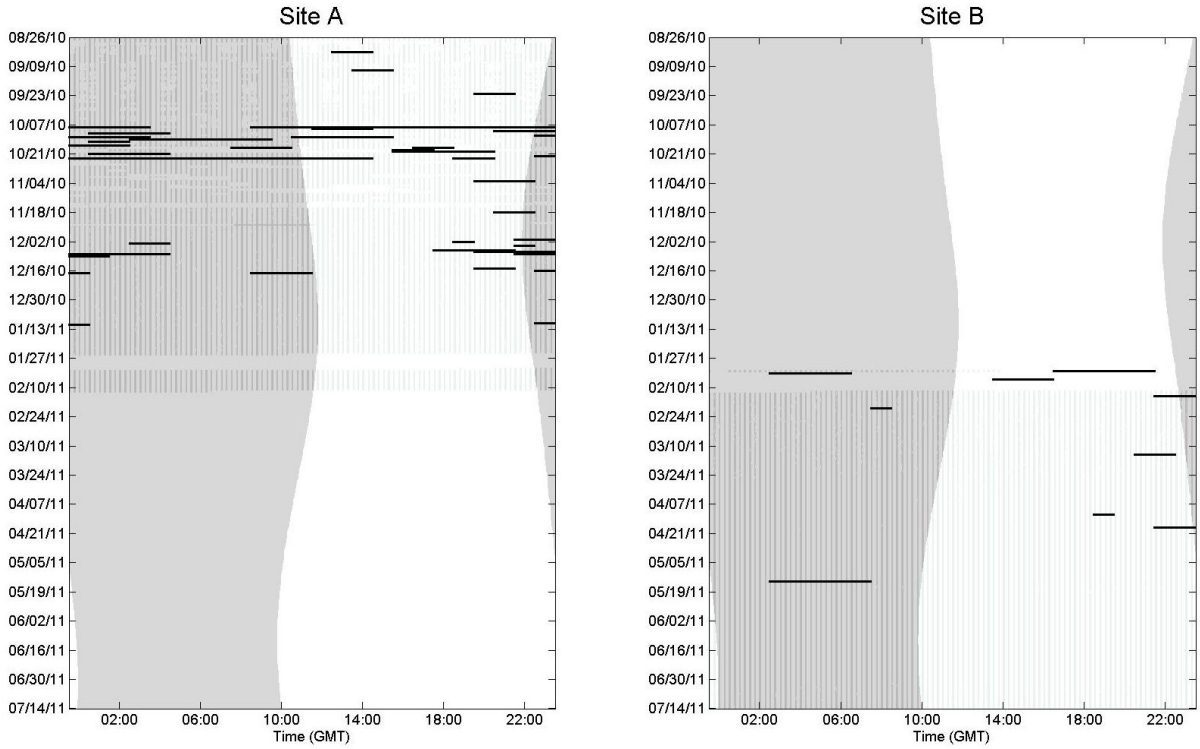

Figure 24. Mid-frequency active sonar (black bars) detected in hourly bins during the August 2010 – July 2011 Site A and B deployments. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort (detailed in Tables 1-2).

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Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex 2010-2011

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MPL TECHNICAL MEMORANDUM # 541

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Executive Summary

Passive acoustic monitoring was conducted at two sites in the US Navy's Jacksonville Range Complex during August 2010 – July 2011. These sites are located 50 and 61 nm east of the Florida coastline on the shelf and shelf break at water depths of 40 m – 90 m. Acoustic data collected at these sites provide information on the presence of marine mammals and anthropogenic sound sources. High-frequency Acoustic Recording Packages (HARPs) documented sounds between 10 Hz and 100 kHz with recording cycles of 5 minutes every 15 minutes. The data were divided into three frequency bands and data analysis was conducted with analyst scans of long-term spectral averages and spectrograms.

Four mysticete whale species were recorded: fin, minke, sei, and humpback. No blue whale, North Atlantic right whale, or Bryde's whale calls detected. A new call, designated the "5-pulse" was detected and is presumed to be produced by a mysticete whale due to its character, prevalence and intensity. Site A has more hours with calling mysticete whales than site B. However, humpback whale calls were detected only at site B, though these detections were few.

The largest number of odontocete detections were attributed to unidentified odontocetes, thought to be primarily bottlenose and Atlantic spotted dolphins. Unidentified odontocetes were detected throughout the year. Overall numbers of detections were higher at site A than site B. There was a diel acoustic activity pattern with greater numbers of echolocation clicks produced at night, likely due to nighttime foraging. Risso's dolphin echolocation clicks were only detected at site A and only occurred August through March. Five click types, yet to be associated to an odontocete species, were characterized and their seasonal and diel occurrence described.

Ship noise was the most common anthropogenic sound at both sites A and B. Both sites had Mid-Frequency Active (MFA) sonar events throughout the period of data collection. At site A, a total of 2,437 MFA sonar pings were detected with a maximum peak-to-peak received level of 173 dB re 1 µPa. Similarly, a total of 2,496 MFA sonar pings were detected at site B, reaching a maximum peak-to-peak level of 166 dB re 1 µPa. Echosounder pings with a variety of primary frequencies (4 – 80 kHz) were found at both sites A and B. Explosions were recorded at both sites, though were more prevalent at site B. A low-frequency tone, referred to as the 130 Hz tone, was recorded at site A. High noise levels, possibly caused by instrument strumming and fluid flow at the sensor, occurred intermittently at both sites and likely decreased the detection range for low-frequency sounds.

Project Background

The US Navy's Jacksonville Range Complex (JAX) is located within the South Atlantic Bight that extends from Cape Hatteras, North Carolina to the Florida Straits. The sea floor is relatively smooth and features a broad continental shelf, with an inner zone of less than 200 m water depth, and an outer zone extending to water depths of 2000 m. A diverse array of marine mammals are found in this region, including mysticete whales, dolphins and other toothed whales, and manatees.

In April 2009, an acoustic monitoring effort was initiated within the boundaries of JAX with support from the Atlantic Fleet under contract to Duke University. The goal of this effort was to characterize the vocalizations of marine mammal species present in the area, to determine their year-round seasonal presence, and to evaluate the potential for impact from Naval operations. This report documents the analysis of two High-frequency Acoustic Recording Packages (HARPs) that have been deployed within JAX during the time period August 2010 – July 2011. The JAX-B HARP site is 50 miles east of the Florida coastline and the JAX-A HARP site is approximately 11 nm further offshore (Figure **1**).

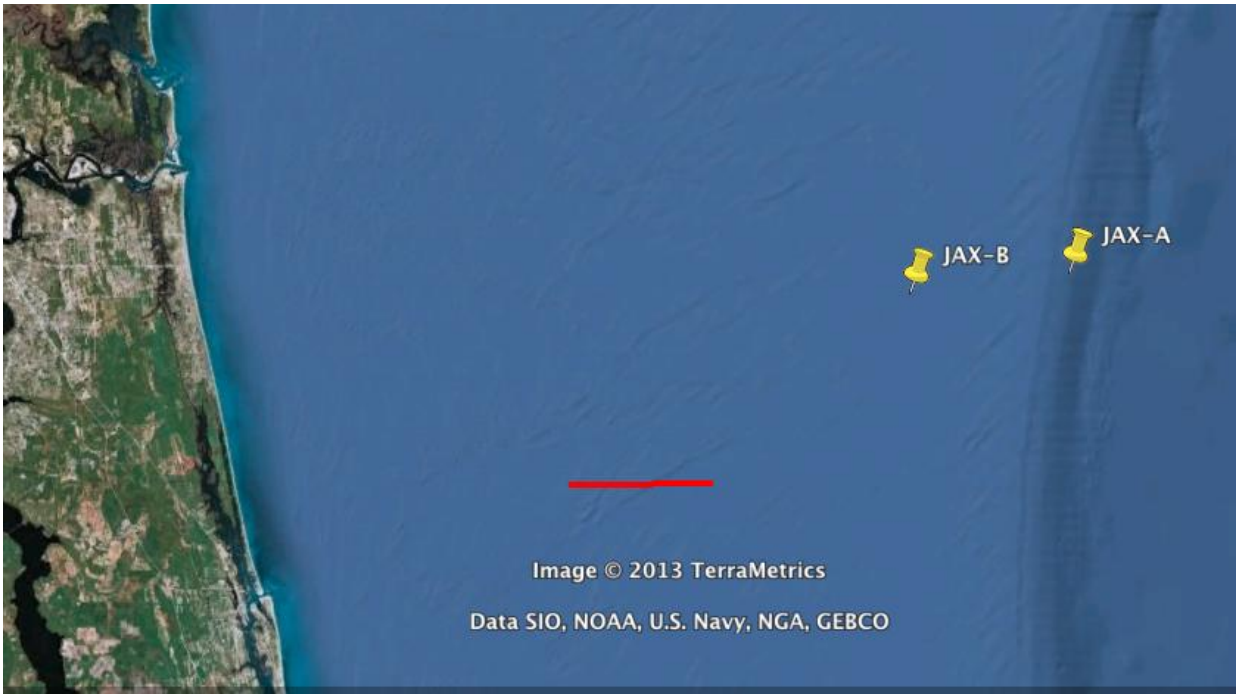

Figure 1. Locations of High-frequency Acoustic Recording Packages (yellow pins) at sites A and B in the Jacksonville Range Complex. The red bar represents 10 nm.

Methods

High Frequency Acoustic Recording Packages

High-frequency Acoustic Recording Packages (HARPs) were used to detect marine mammal species, anthropogenic noise, and ambient noise in the JAX Range Complex. HARPs record underwater sounds from 10 Hz to 100 kHz with approximately 110 days of continuous data storage. Recording a broad frequency range of 10 Hz - 100 kHz is required to detect both baleen whale (mysticetes), and toothed whale (odontocetes) species. The HARP sensor and mooring package are described in Wiggins and Hildebrand (2007). For the JAX range deployments, the HARP electronics package was located near the seafloor with the hydrophone suspended 10 m above. Each HARP is calibrated in the laboratory to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones are calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations.

Data Collected to Date

Acoustic data have been collected at two sites since April 2009 (Table 1). The two sites are designated site A (30° 16.6 N, 80° 13.0 W, depth 80-90 m) and site B (30° 15.5 N, 80° 25.7 W, depth 40 m). Site A was placed at the shelf break, site B was on the shelf, approximately 11 nm apart.

Table 1. JAX HARP data sets. Periods of acoustic data analyzed in this report are shown in bold.

Deployment Designation	Site A Recording Period	Site B Recording Period
JAX 01	4/2/2009-5/25/2009	4/2/2009-9/5/2009
JAX 02	9/16/2009-12/27/2009	--
JAX 03	2/22/2010-7/30/2010	--
JAX 04	--	3/9/2010-8/19/2010
JAX 05	**8/26/2010-1/25/2011**	**8/27/2010-2/1/2011**
JAX 06	**2/1/2011-7/14/2011**	**2/2/2011-7/14/2011**

Data Analysis

To assess the quality of the acoustic data, frequency spectra were calculated for all the data (over one-year at each of the two instruments) using a time average of 5 seconds and frequency bins of 1 Hz. These data, called Long-Term Spectral Averages (LTSA) were examined both for characteristics of ambient noise and also as a means to discover marine mammal and anthropogenic sounds. As a first pass for data analysis, segments of data that did not allow for further analysis due to disk malfunctions or strumming noise were identified (Table 2).

Table 2. Periods when acoustic data were not available or amenable to analysis.

Deployment Name	Gaps In Data for High-Frequency Analysis	Too Much Noise for High-Frequency Analysis	Gaps in Data for Mid- and Low-Frequency Analysis
JAX 05A	11/23/2010 22:48 – 11/24/2010 8:09		
JAX 05B		9/1/2010 23:49 – 9/3/2010 5:49 9/17/2010 20:17 – 9/21/2010 17:17 9/30/2010 18:30 – 10/1/2010 12:30 11/12/2010 17:15 – 11/15/2010 11:15	entire deployment
JAX 06A	2/12/2011 7:02 – 2/22/2011 5:16		2/12/2011 9:16 – end
JAX 06B	2/9/2011 7:00 – 2/12/2011 5:02		2/2/2011 14:20 – 2/12 5:02

The presence of acoustic signals from multiple marine mammal species was analyzed, along with the presence of anthropogenic noise such as sonar, explosions, and shipping. All data were analyzed by visually scanning LTSAs in appropriate frequency bands. When a sound of interest was identified in the LTSA, the waveform or spectrogram at the time of interest was examined to further classify particular sounds to species or source. Acoustic classification was carried out either by comparison to species-specific spectral characteristics or by analysis of the time and frequency character of individual sounds.

To document the data analysis process, we describe the major classes of marine mammal calls and anthropogenic sounds in the JAX region, and the procedures used to test for their presence in the HARP data. For effective analysis, the data were divided into three frequency bands and each band was analyzed for the sounds of an appropriate subset of species or sources. The three frequency bands are as follows: (1) low frequencies, between 10 – 1000 Hz, (2) mid frequencies, between 500 – 5000 Hz, and (3) high frequencies, between 1 – 100 kHz. Blue, fin, sei, Bryde's, and North Atlantic right whale and a subset of minke sounds were classified as low frequency; humpback, minke, shipping, explosions, and mid-frequency active sonar were classified as mid-frequency; while the remaining odontocete and sonar sounds were considered high-frequency. We describe the calls and procedures separately for each frequency band.

Low Frequency Marine Mammals

For the low frequency data analysis, the 200 kHz sampled raw-data were decimated by a factor of 100 for an effective bandwidth of 1 kHz. Long-term spectral averages (LTSAs) of these data were created using a time average of 5 seconds and frequency bins of 1 Hz. The presence of each call type was determined in hourly bins. A subset of each call type was measured for start and end frequencies and duration (**Table 3**).

Table 3. Low-frequency whale calls in JAX data. Mean values (± one standard deviation) are presented. Calls for the 5-pulse were separated by a minimum of 24 hours to obtain calls from multiple animals. Other call types occurred in clusters and therefore measurements may represent an individual animal more than once.

Species/Call	Call Type	Start Frequency (Hz)	End Frequency (Hz)	Duration (s)
Fin whale	20 Hz pulse *(n=30)*	27.2 ± 2.0	16.4 ± 0.6	1.6 ± 0.3
Minke whale	50 Hz pulse *(n=2)*	56.5 ± 2.1	54.5 ± 2.1	64.5 ± 14.8
	150 Hz speed-up/ slow-down *(n=18)*	166.2 ± 5.0	163.6 ± 5.2	36.6 ± 7.9
Sei whale	Downsweep *(n=23)*	120.8 ± 14.6	46.2 ± 4.4	1.5 ± 0.2
5-pulse	5-pulse *(n=30)*	178.5 ± 22.3	185.9 ± 22.2	2.7 ± 0.5

Whale calls for which low frequency effort was expended include: blue whale A, B and arch calls, fin whale 20 and 40 Hz pulses, Bryde's whale Be7 and Be9 calls, North Atlantic right whale upcall, in addition to sei whale calls, and the "5- pulse" call type of unknown origin (presumably baleen whale). The same LTSA and spectrogram parameters were used to detect all call types. For spectrogram scrolling, the LTSA frequency was set to display between 1-500 Hz. To observe individual calls, spectrogram parameters were typically set to 120 seconds by 200 Hz. The FFT was generally set between 1500 and 2000 data points (yielding about 1 Hz frequency resolution), with an 85-95% overlap of data in the input time series. **Table 3** presents measurements of frequency and duration for each recorded call type.

Blue Whales

Several different calls were used to test for the presence of blue whales. Detection effort included call types A, B, and arch from Mellinger and Clark (2003) (Figure **2**). The A call is a constant 18-19 Hz tone lasting approximately 8 seconds while the B call is an 18-15 Hz downsweep lasting approximately 11 seconds. Individual A and B calls are readily detected in an LTSA, owing to their long duration. The third call, the arch call, starts at a frequency of 56 Hz, ascends to a peak frequency of 69 Hz, then descends to 35 Hz over a period of 6.3 seconds (Figure **3**). Manual scanning of the LTSA was the primary means to search for blue whale calls, however, no blue whale calls of any type were detected in the JAX data.

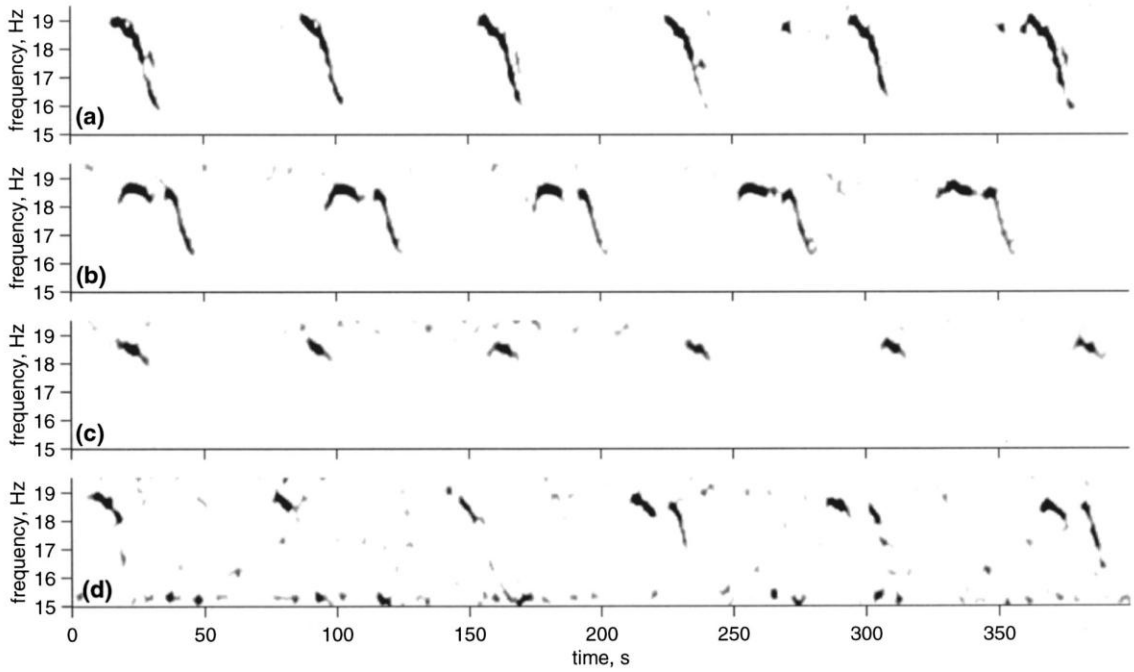

Figure 2. Blue whale A and B calls from Mellinger and Clark (2003).

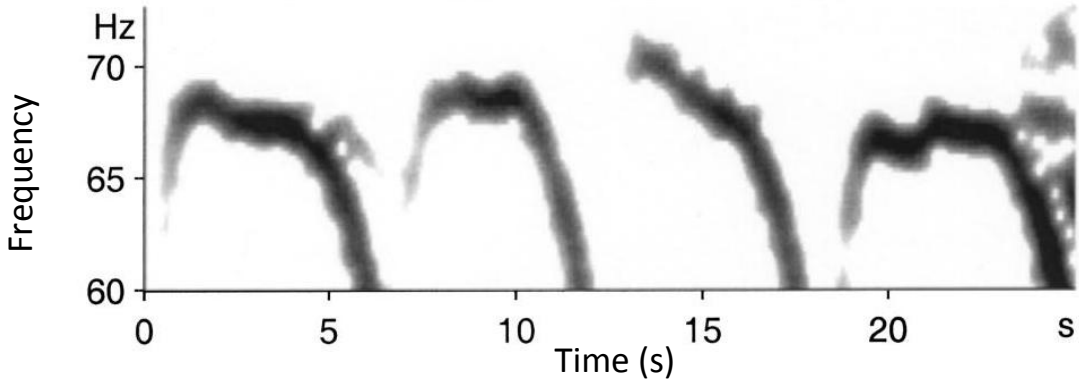

Figure 3. Blue whale arch calls from Mellinger and Clark (2003).

Fin Whales

Fin whales produce a variety of calls, most are less than 100 Hz, short in duration, and frequency-modulated. The best known fin whale call is the 20 Hz pulse, downswept at 30 - 15 Hz (Figure 4). These pulses occur at regular intervals as song (Thompson *et al.* 1992), and at irregular intervals as counter-calling between multiple animals (McDonald *et al.* 1995). In this report we indicate the presence of 20 Hz pulses, but do not categorize them as either song or irregular interval calls. Watkins (1981) and Širović *et al.* (2012) also report a fin whale 40 Hz pulse which sweeps down in frequency from 75 to 40 Hz (Figure 5). While there was logging effort for these calls, however, no 40 Hz pulses were detected in the JAX acoustic data.

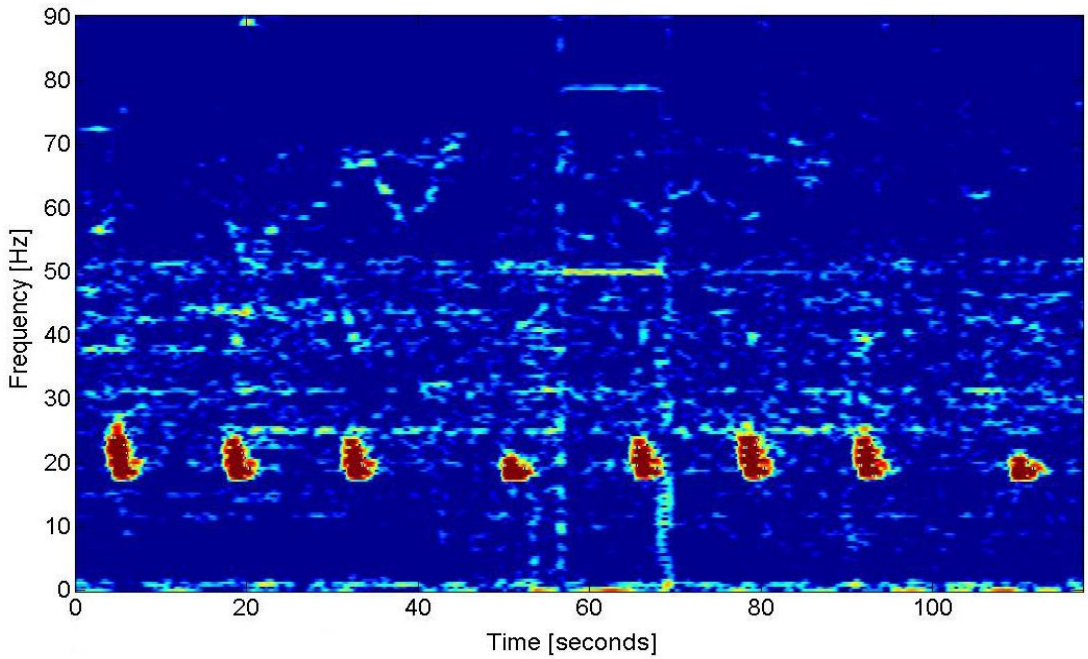

Figure 4. Fin whale 20 Hz pulse, created in regular pattern or song. Site A on January 24, 2011.

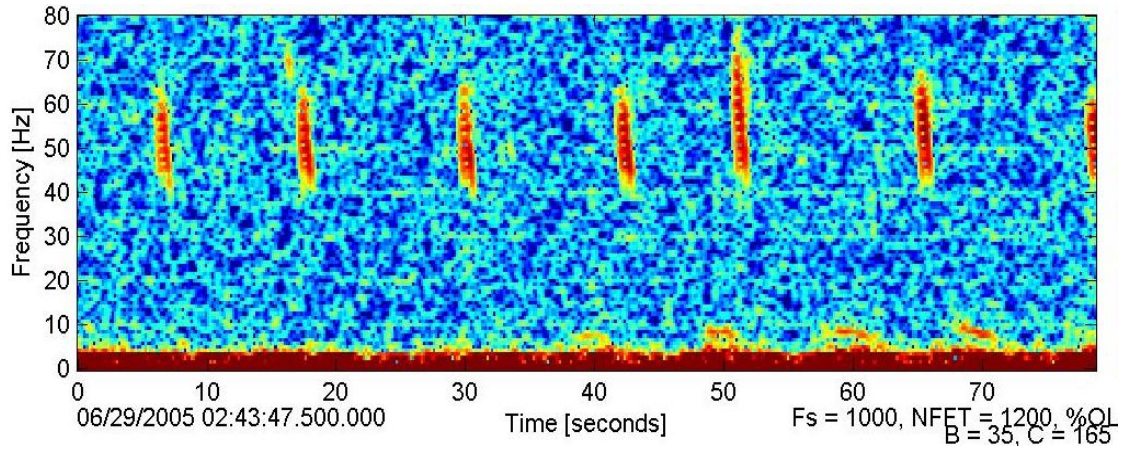

Figure 5. Fin whale 40 Hz pulse, from Bering Sea HARP data.

Minke Whales

Minke whales in the North Atlantic produce long pulse trains. Mellinger *et al.* (2000) describe minke whale pulse sequences as speed-up and slow-down pulse trains (increasing and decreasing pulse rate), centered around 150 Hz (Figure **6**). Another type of pulse train centered around 50 Hz (50 Hz pulse) has also recently been found in the North Atlantic (Figure **7**).

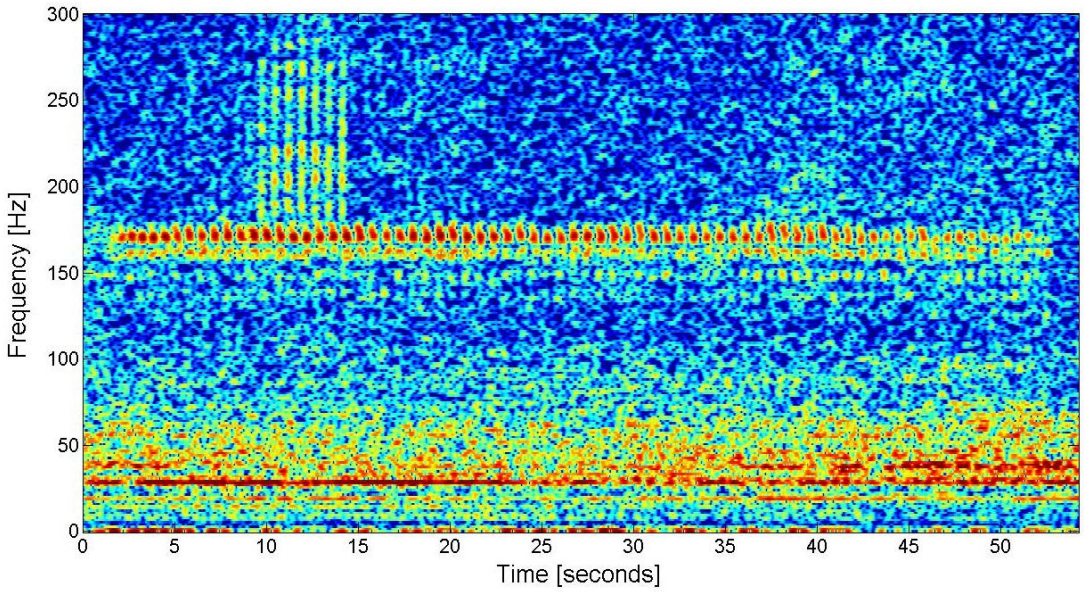

Figure 6. Minke whale speed-up/slow-down pulse train. Site A on February 10, 2011.

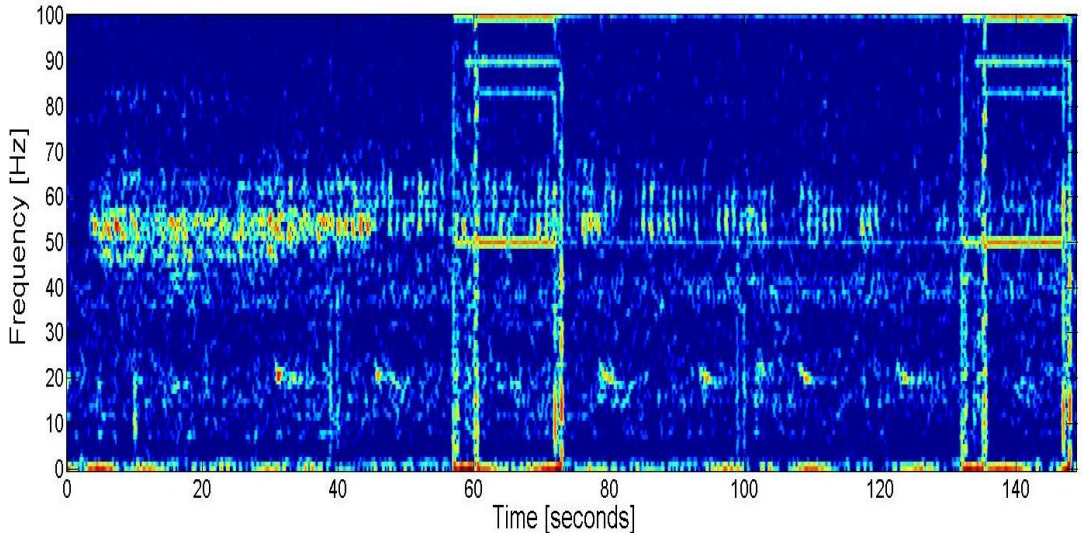

Figure 7. Minke whale 50 Hz pulses. Site A on January 17, 2011.

Bryde's Whales

Bryde's whales inhabit tropical and subtropical waters worldwide (Omura 1959, Wade & Gerrodette 1993), and the JAX region is considered their northerly range limit. The Be7 call is one of several call types in the Bryde's whale repertoire, first described in the Southern Caribbean (Oleson *et al.* 2003). The Be7 call has a fundamental frequency of 44 Hz and ranges in duration between 0.8 and 2.5 seconds with an average intercall interval of 2.8 minutes (Figure **8**). The Be9 call type, described for the Gulf of Mexico (Sirovic *et al.* 2013), is a downswept pulse ranging from 143 to 85 Hz, with each pulse approximately 0.7 seconds long (Figure **9**). Neither Bryde's whale call type was detected in the JAX data.

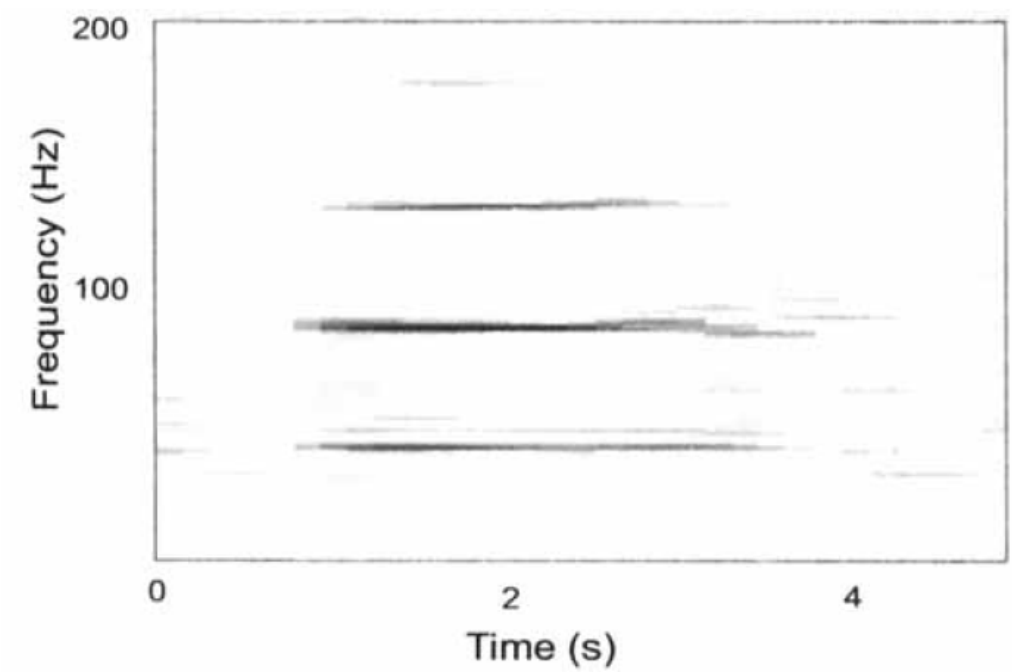

Figure 8. Spectrogram of Bryde's whale Be7 call type, from Oleson et al. (2003).

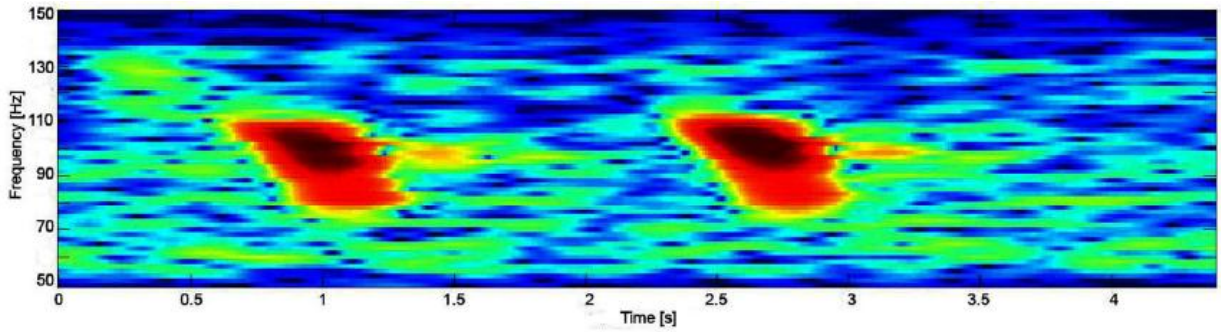

Figure 9. Bryde's whale Be9 call type from Sirovic et al. (2013).

Sei Whale

Sei whales are found primarily in temperate waters and undergo annual migrations between lower latitude winter breeding grounds and higher latitude summer feeding grounds (Mizroch *et al.* 1984, Perry *et al.* 1999). While several sounds have been attributed to sei whales, we report on a low frequency downsweep call similar to those Baumgartner reports as sei whale calls (Baumgartner *et al.* 2008). These calls typically sweep from a starting frequency around 100 Hz to an ending frequency around 40 Hz (Figure **10**).

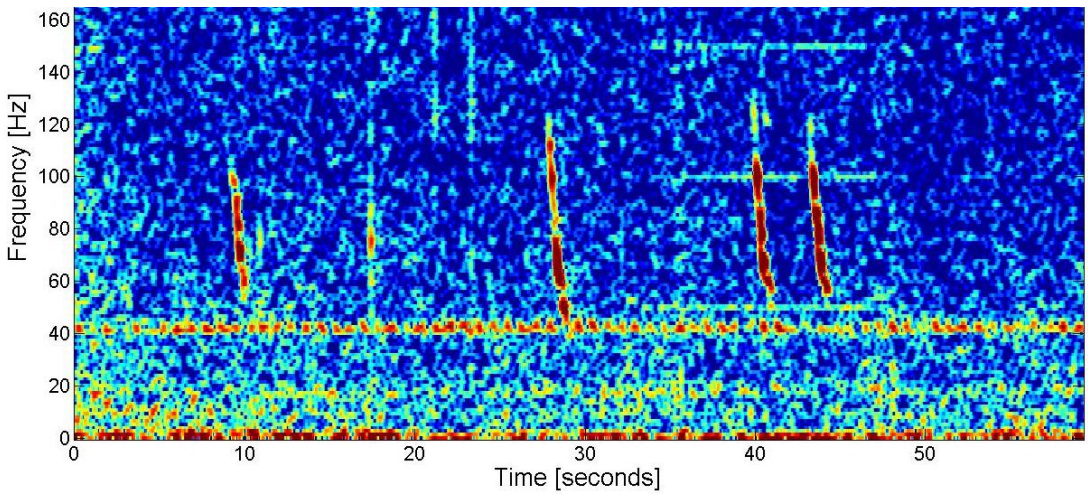

Figure 10. Downsweep calls believed to be from Sei whales. Site A on December 26, 2010.

North Atlantic Right Whale

The North Atlantic right whale is a critically endangered whale found in the Western North Atlantic. Several call types that have been described for the North Atlantic right whale including the scream, gunshot, blow, upcall, warble, and downcall (Parks & Tyack 2005). For low-frequency analysis, we examined the data for upcalls, which are approximately 1 second in duration and range between 80 Hz and 3 kHz (Figure 11). No right whale upcalls were detected.

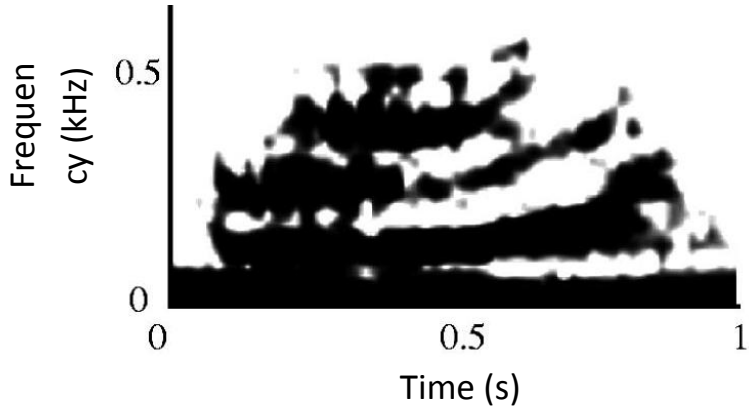

Figure 11. Right whale upcall call from Parks and Tyack (2005).

Five pulse calls

One call type that has not been described previously, 5 pulse (Figure 12), was recorded commonly at site A. While we do not know which species is responsible for the production of this call, its frequency and temporal characteristics, as well as relatively loud levels, leads us to believe they were likely produced by a baleen whale and thus we included it in this analysis.

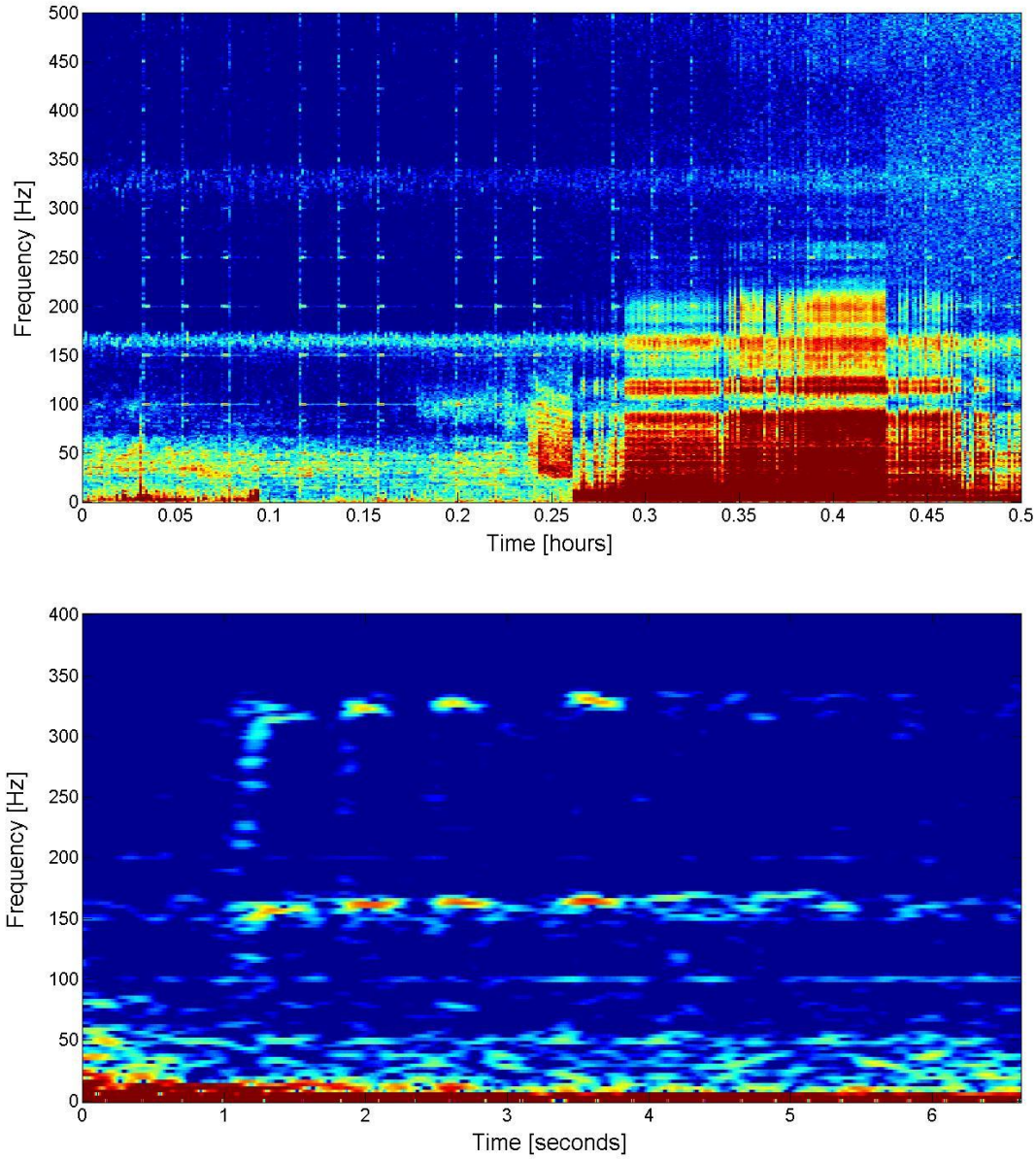

Figure 12. LTSA (top) of a band of 5 pulse calls and a spectrogram (bottom) of a single 5 pulse call (750-point FFT, 98% overlap) recorded on 26 August 2010 at site A.

Mid-Frequency Marine Mammals

For mid-frequency data analysis, the raw 200 kHz HARP data were decimated by a factor of 20 for an effective bandwidth of 5 kHz. The LTSAs for mid-frequency data analysis are created using a time average of 5 seconds, and a frequency bin size of 10 Hz. The presence or absence of each call type was determined in hourly bins.

Mid-frequency sounds monitored in this report include: humpback whale, minke whale speed-up/slow-down pulses, North Atlantic right whale gunshot calls, and killer whale whistles. LTSA search parameters used to search for each sound are given in Table 4.

Table 4. Mid-frequency data analysis search parameters.

	LTSA Search Parameters	
Species	**Plot Length (Hr)**	**Frequency Range (Hz)**
N Atlantic Right Whale (gunshot calls)	0.75	1000-5000
Killer Whale (whistles)	3.0	0-5000

Humpback Whale

Humpback whales song is categorized by the repetition of units, phrases and themes as defined by Payne and McVay (1971). Non-song vocalizations such as social sounds and feeding sounds consist of individual units that can last from 0.15 to 2.5 seconds (Dunlop *et al.* 2007, Stimpert *et al.* 2011). Most humpback whale vocalizations have acoustic energy between 100-3000 Hz (Figure **13**). For this report we detected humpback calls (both song and non-song) using the generalized power-law algorithm (Helble *et al.* 2012), and then used a trained analyst to verify the accuracy of the detected signals.

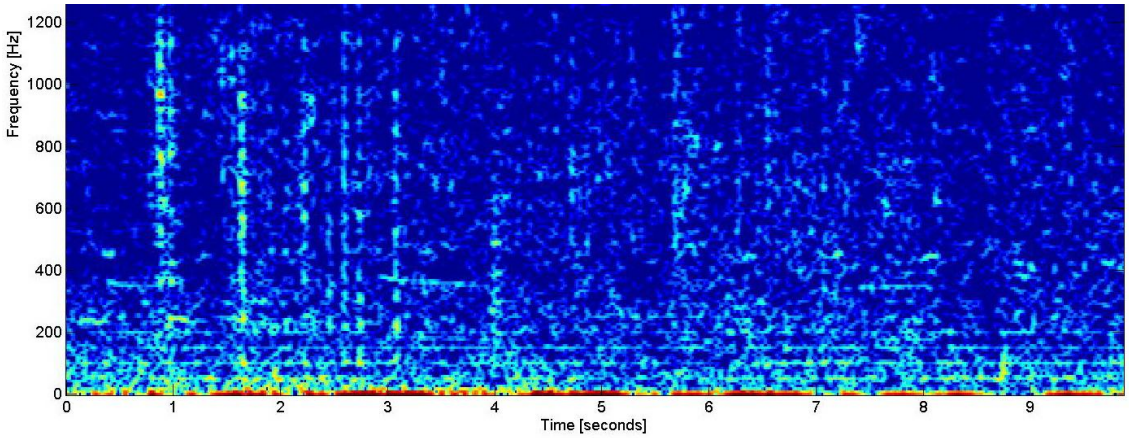

Figure 13. Humpback whale calls recorded at site A on April 13, 2011.

North Atlantic Right Whale

North Atlantic right whale gunshot calls are high intensity (~196 dB pp re 1 µPa) and broadband (20 Hz – 20 kHz) (Parks *et al.* 2005) and were therefore included in mid-frequency analysis. Gunshot calls exhibit an initial signal followed by prolonged reverberation (Figure **14**). Although these calls are capable of being detected at a several miles range, no right whale gunshot calls were detected in the JAX data.

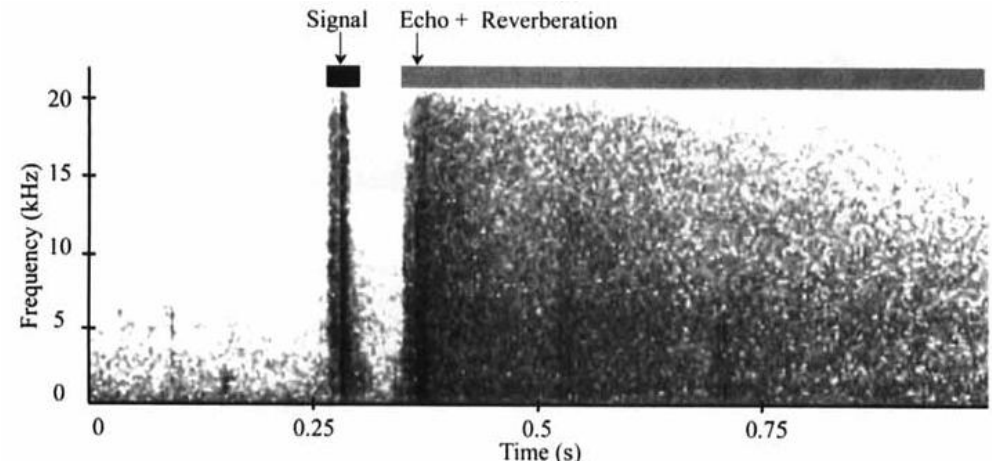

Figure 14. North Atlantic Right whale gunshot call from Parks et al, 2005.

Killer Whale

Killer whales are a cosmopolitan species, though little is known about killer whales off the east coast of the United States (Gormley 2000). Few sightings of killer whales have ocurred on the shelf (Katona *et al.* 1988). Acoustic parameters from known Western Atlantic killer whale calls were used to search for killer whale calls (Figure **15**). Neither killer whale whistles, calls nor clicks were detected in the JAX data.

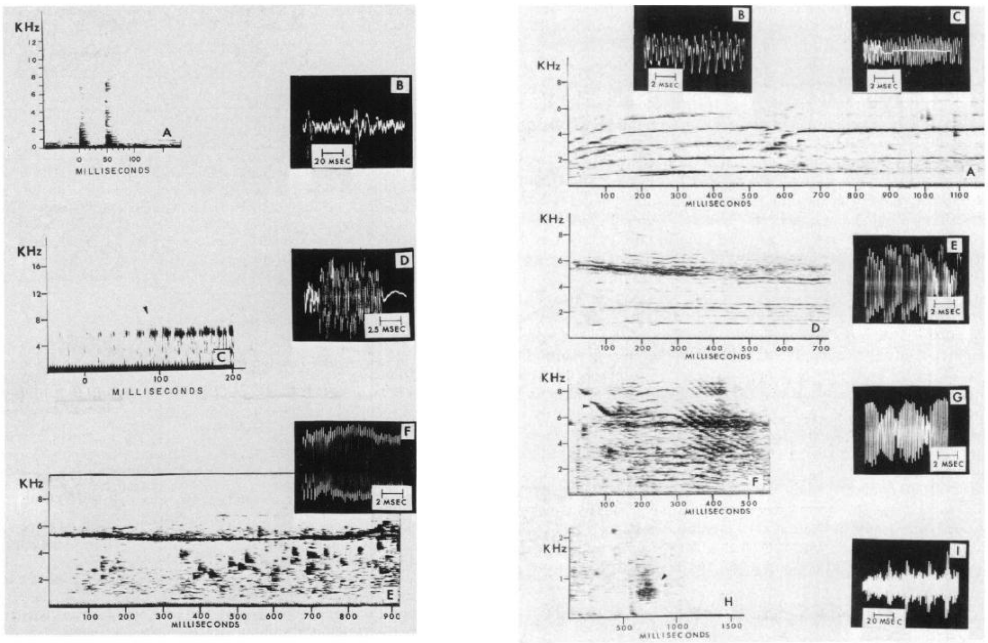

Figure 15. Killer whale vocalizations from Steiner *et al.* (1979).

High-Frequency Marine Mammals

For the high frequency data analysis, spectra were calculated for the full effective bandwidth of 100 kHz. The LTSAs were created using a time average of 5 seconds and a frequency bin size of 100 Hz. The presence of call types was determined in one-minute bins.

Unidentified Dolphin

Delphinid sounds can be categorized as either: (1) echolocation clicks, (2) buzz pulses, or (3) whistles. Dolphin echolocation clicks are broadband impulses with the majority of energy between 20 and 80 kHz. Buzz pulses are rapidly repeated clicks that have a creak or buzz-like sound quality; they are in approximately the same frequency band as the echolocation clicks. Dolphin whistles are tonal calls predominantly between 5 and 25 kHz that vary in their degree of frequency modulation as well as duration. These signals are easily detectable in an LTSA as well as the spectrogram (Figure 16). Only some delphinid sounds are distinguishable by species based on the character of their clicks, buzz pulses or whistles (Roch *et al.* 2011, Roch *et al.* 2007).

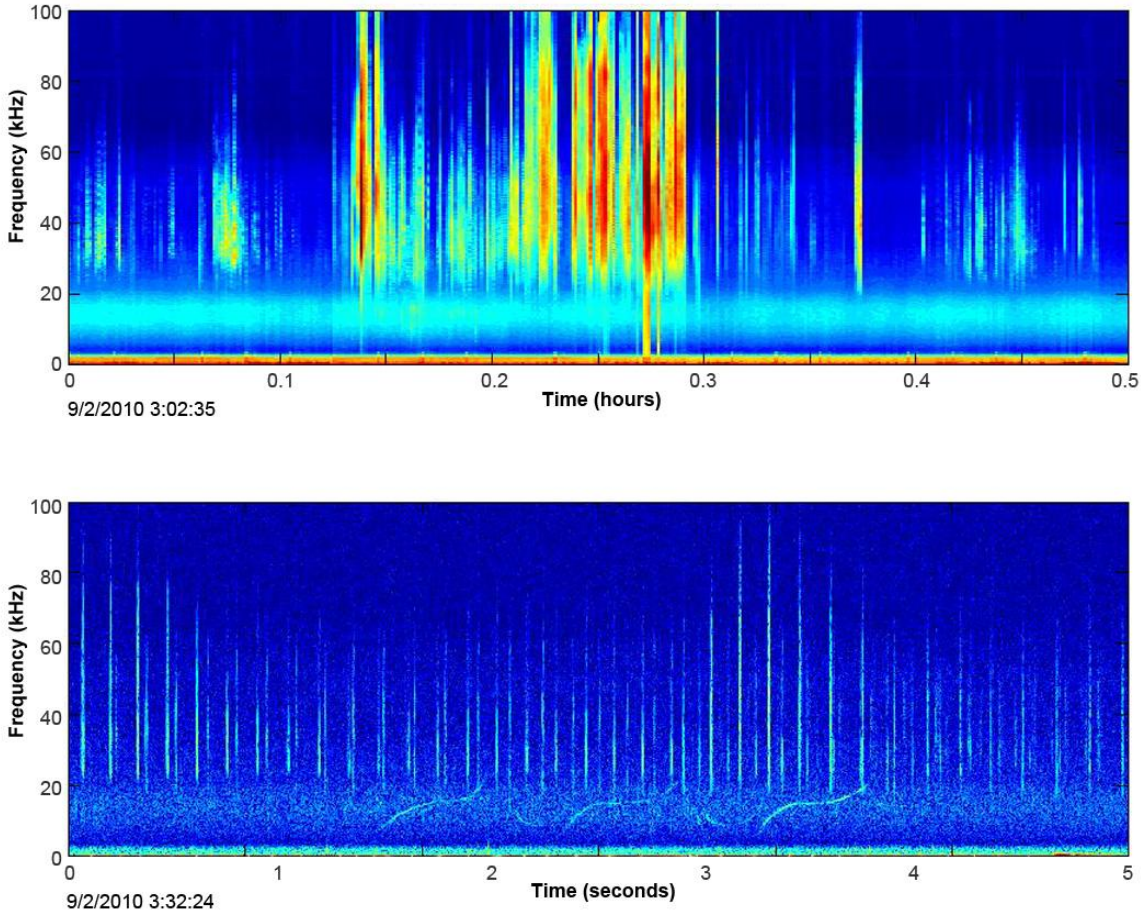

Figure 16. LTSA (top) and spectrogram (bottom) of odontocete echolocation clicks and whistles.

Risso's Dolphin

Risso's dolphin echolocation clicks can be identified to species by their distinctive banding patterns in the LTSA (Figure 17). Risso's dolphin echolocation clicks in southern California are known to have energy peaks at 22, 26, 30, and 39 kHz (Soldevilla *et al.* 2008). Our analysis found Risso's dolphin energy peaks at 23, 26, 35, 44 kHz (Figure **18**), similar to that reported for the JAX area (Soldevilla et al. 2011).

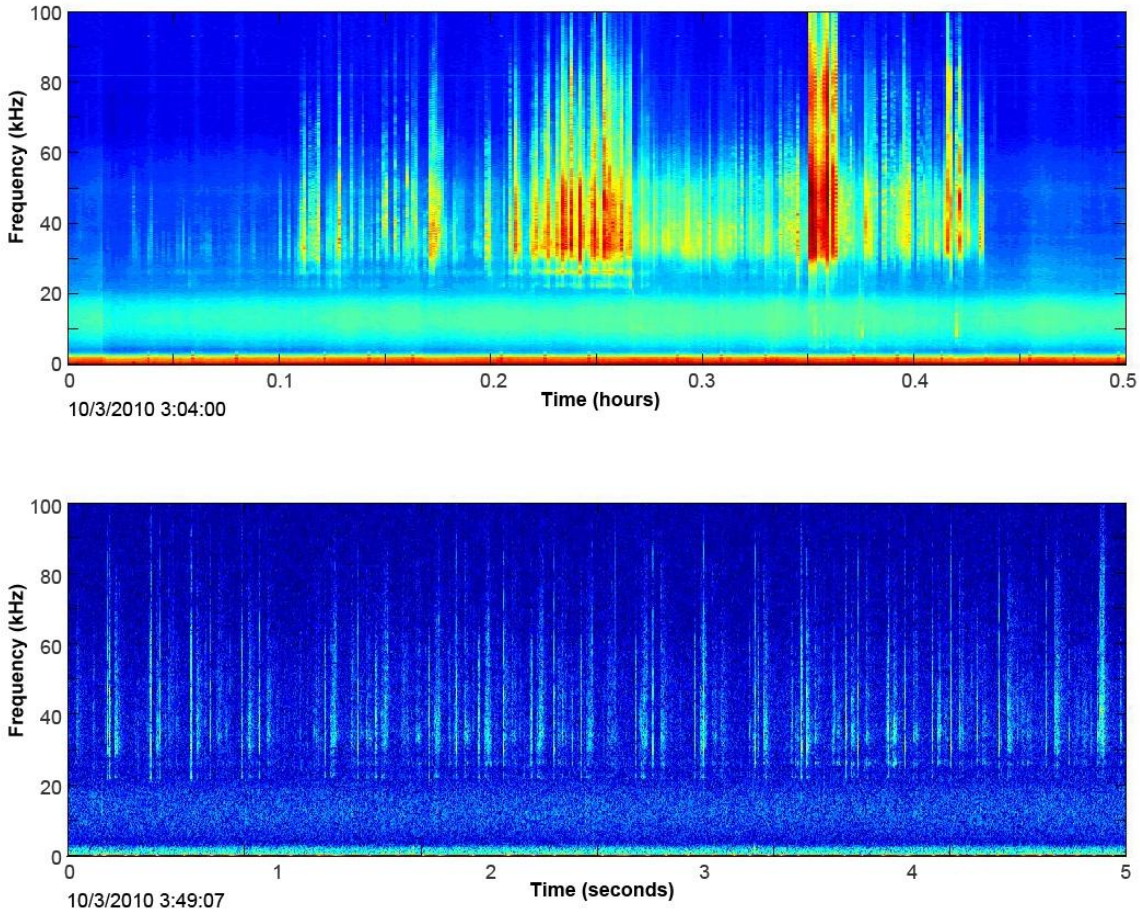

Figure 17. Risso's dolphin click bout in LTSA (above) and spectrogram (below). A distinctive banding pattern is seen in the LTSA.

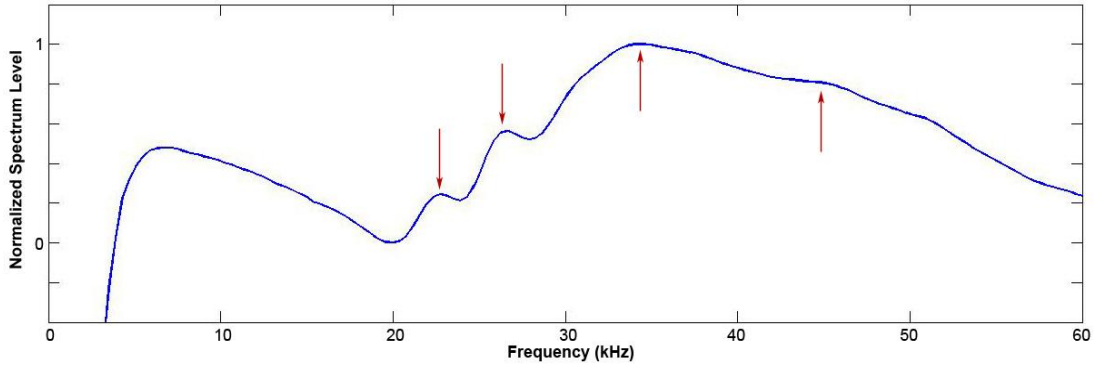

Figure 18. Risso's dolphin echolocation click mean spectra. Arrows show locate spectral peaks.

Echolocation Click Types

An analysis was conducted to describe echolocation clicks from unidentified odontocetes (UO). Click type (CT) mean spectra from HARP recordings in the Gulf of Mexico, analyzed and defined by Kait Frasier, and off the coast of North Carolina, analyzed and defined by Lynne Williams, were used as templates. These previous analyses were combined and provided thirteen distinct mean click spectra. All click types had dominant energy above 20 kHz. They differed in the prominence of spectral peaks below 20 kHz, and in the slope and onset of the lower frequency bound in their main spectral energy band. A custom software routine displayed mean click templates and overlaid novel spectra of manually detected acoustic encounters in JAX. A trained analyst determined, based on spectral content, whether an acoustic encounter remained UO or was classified as a CT. Based on a complete analysis of all deployments reported here, five CT (Figure **19**) were identified at least ten times within one deployment and will be described below. CT were then assigned names based on the frequency at which their spectra reached 50% of maximum energy (e.g CT25 = 25 kHz for the 50% energy level).

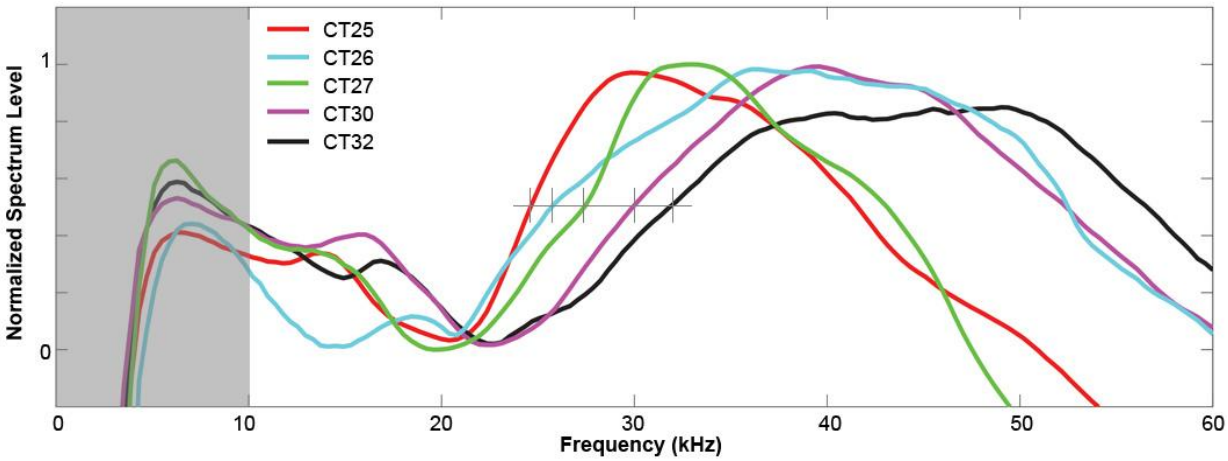

Figure 19. Echolocation click types (CT) that occurred in JAX recordings repeatedly. Numerical values (e.g. CT25 = 25 kHz) refers to low end of 50% energy bandwidth.

Click Type 25

CT 25 (Figure **20**) reaches its 50% maximum energy at approximately 25 kHz and has a peak frequency of about 33 kHz. It has a smaller peak at 15 kHz with troughs at 12 and 20 kHz (Figure **21**).

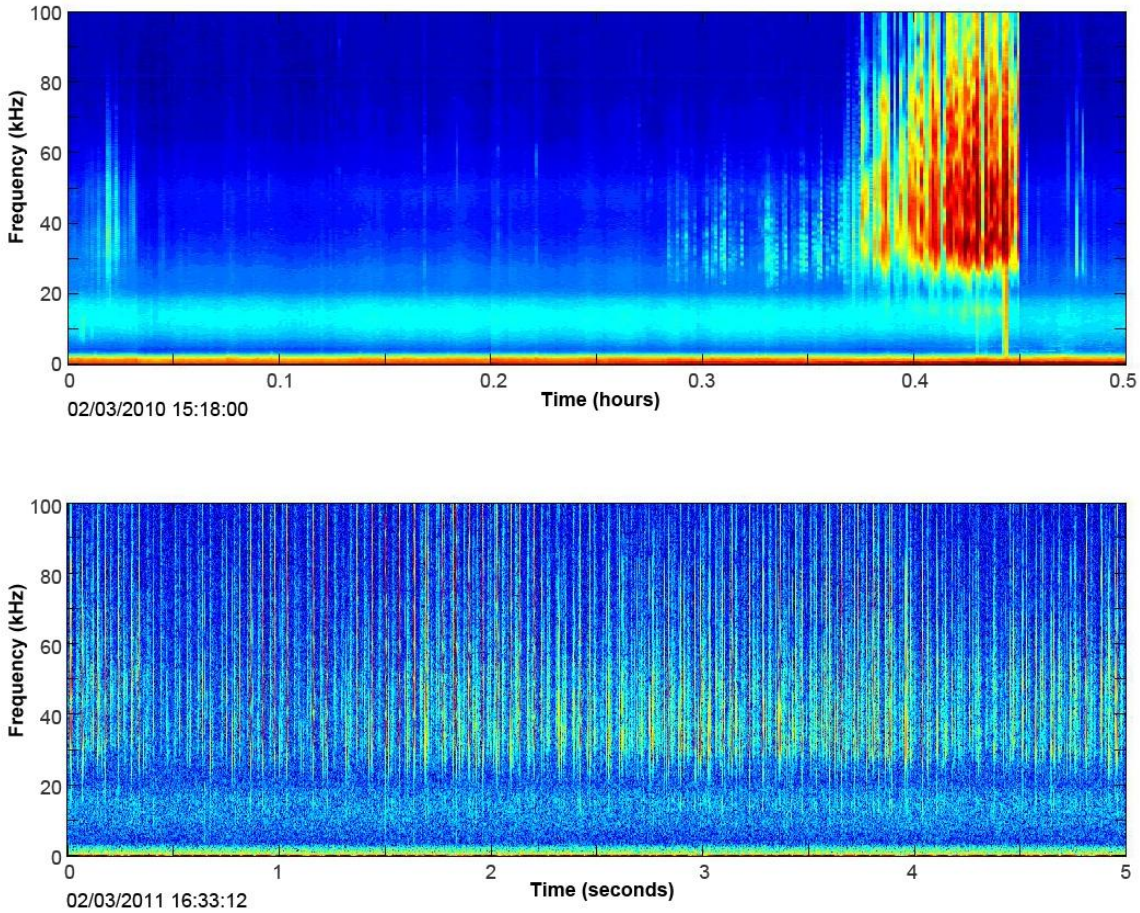

Figure 20. CT25 in the LTSA (above) and spectrogram (below).

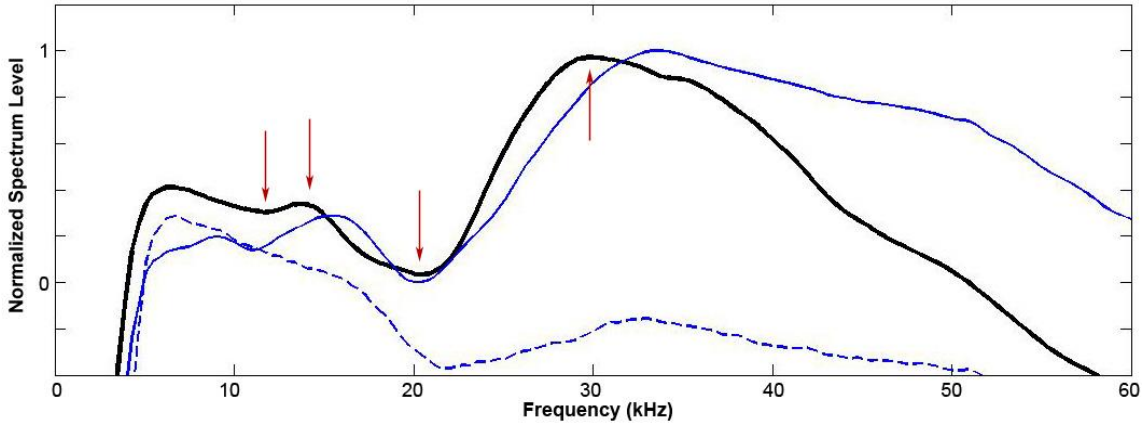

Figure 21. Mean Spectra of clicks for CT25. Example encounter (black line), template for CT (blue line; from G of Mex and/or North Carolina), noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 26

CT 26 (Figure **22**) reaches its 50% maximum energy at approximately 26 kHz and has a peak frequency of about 35 kHz. It has a smaller peak at 18 kHz with troughs at 15 and 21 kHz (Figure **23**).

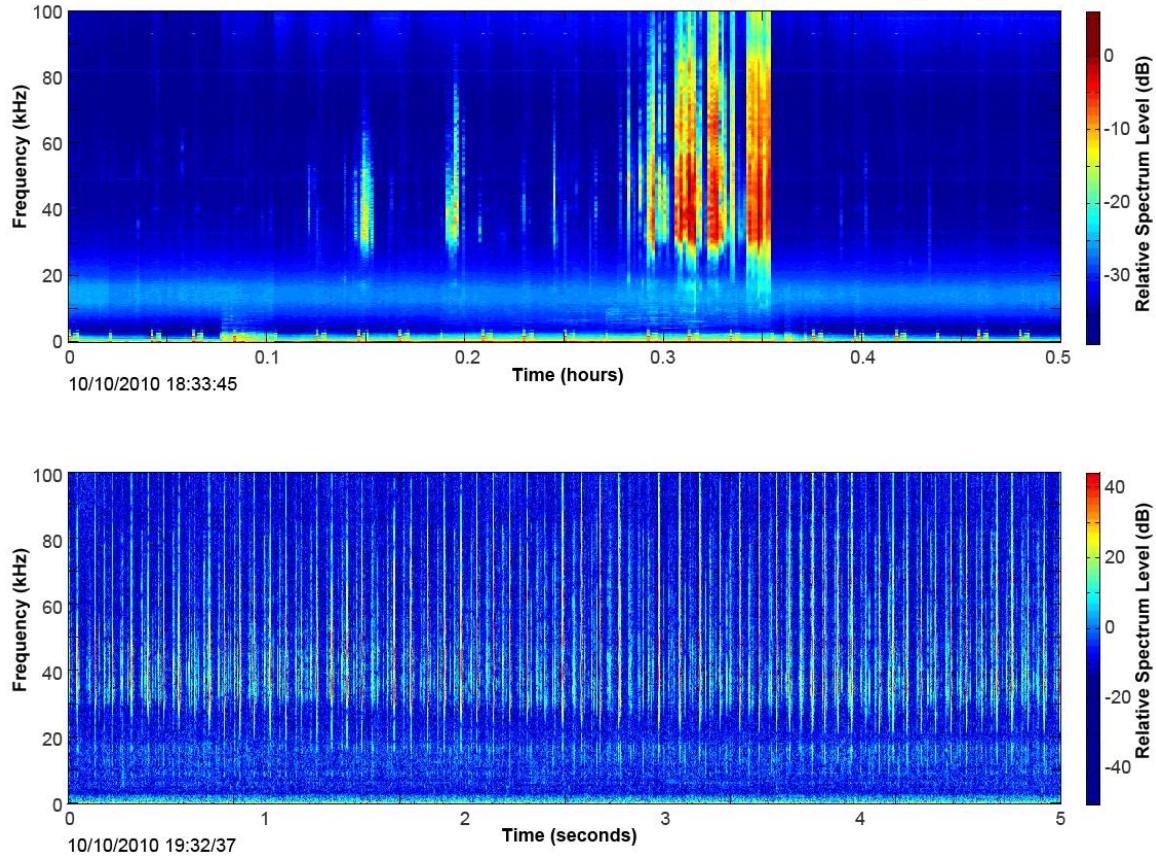

Figure 22. CT26 in the LTSA (above) and spectrogram (below).

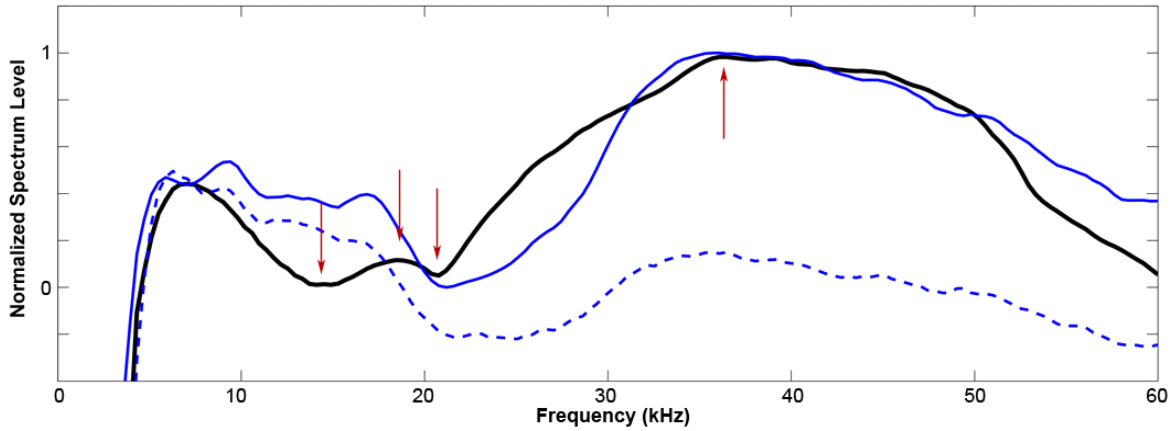

Figure 23. Mean Spectra of clicks for CT26. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 27

CT 27 (Figure **24**) reaches its 50% maximum energy at approximately 27 kHz and has a peak frequency of about 35 kHz. It has a smaller peak at 16 kHz ranging with troughs at 11 and 20 kHz (Figure **25**).

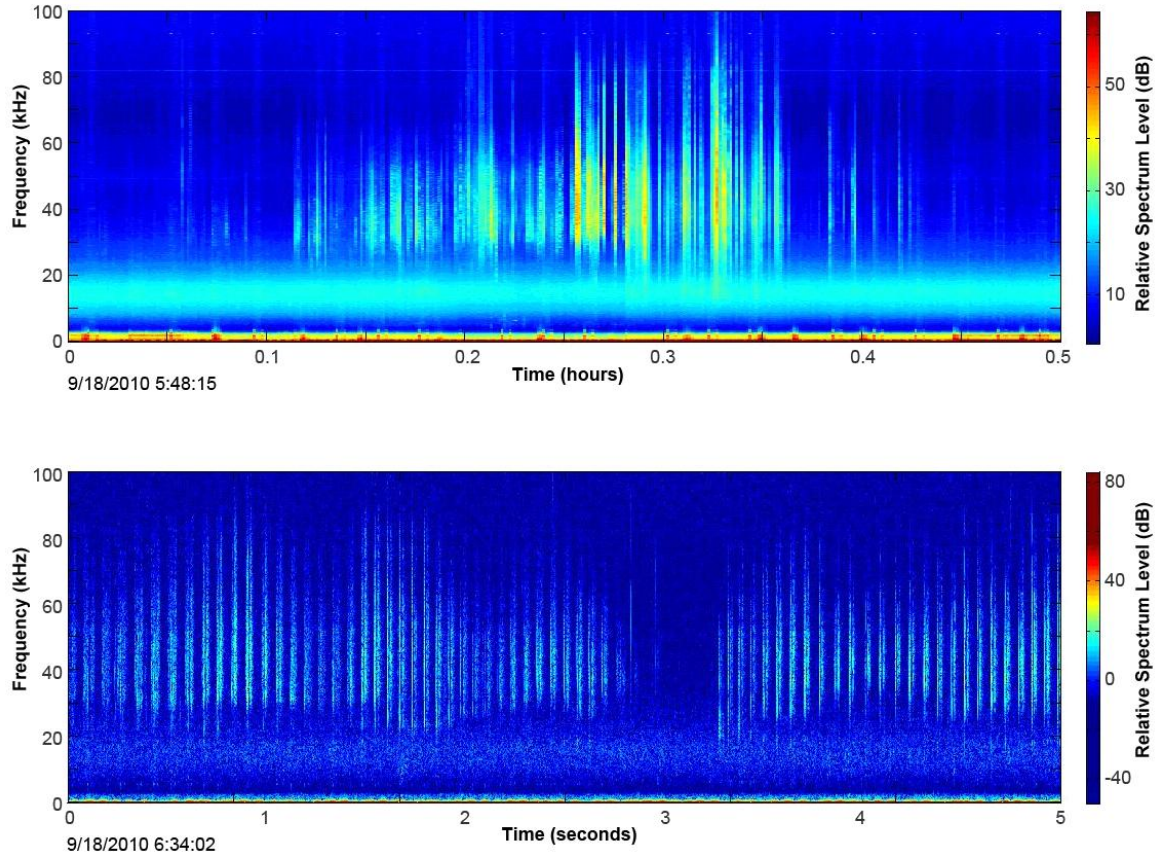

Figure 24. CT27 in the LTSA (above) and spectrogram (below).

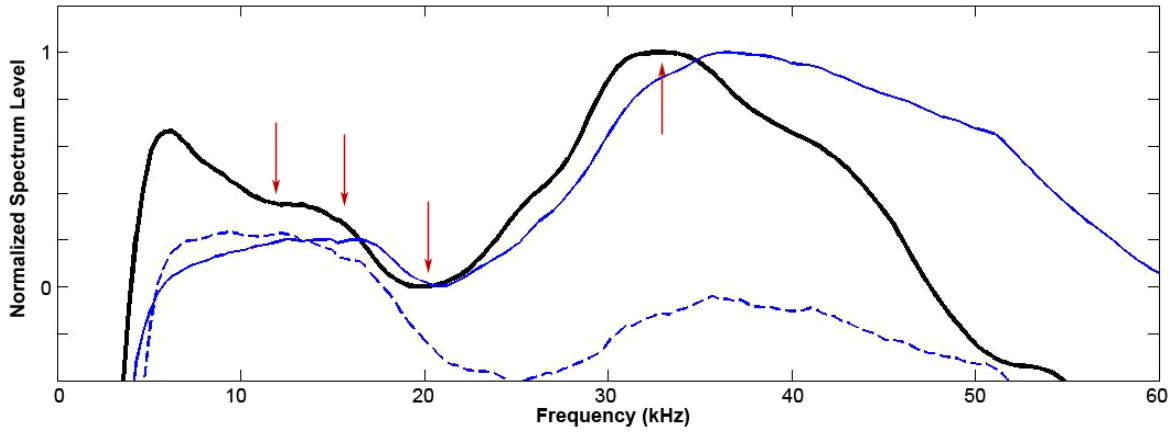

Figure 25. Mean spectra of CT27. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 30

CT 30 (Figure **26**) reaches its 50% maximum energy at approximately 30 kHz and has a peak frequency of about 37 kHz. It has a smaller peak at 16 kHz with troughs at 12 and 22 kHz (Figure **27**).

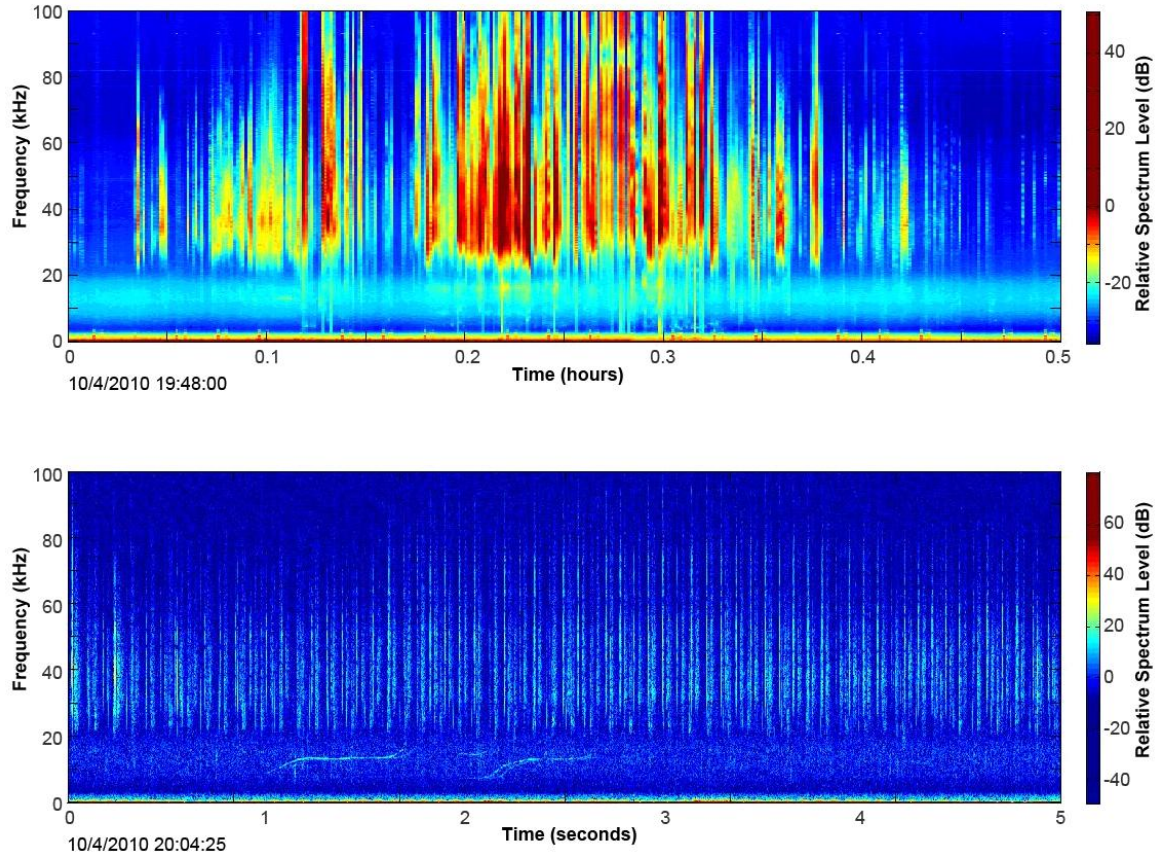

Figure 26. CT30 in the LTSA (above) and spectrogram (below).

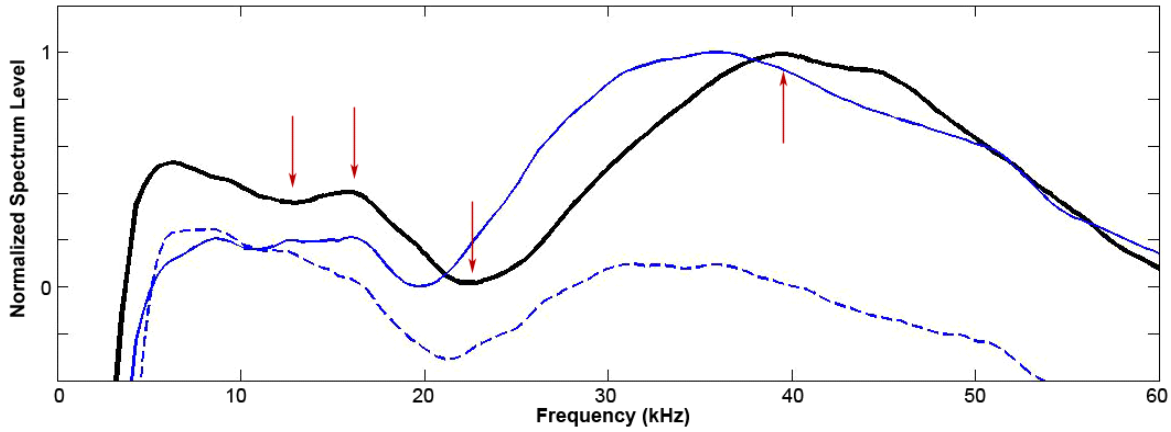

Figure 27. Mean Spectra of CT30. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 32

CT 32 (Figure 28) reaches its 50% maximum energy at approximately 32 kHz and has a peak frequency of about 39 kHz. It has a smaller peak at 17 kHz with troughs at 15 and 22 kHz (Figure 29). Clicks with high received level (Figure **30**) show a peak between 4-6 kHz (Figure **31**). This low peak becomes apparent in LTSAs but a high pass filter cuts it out in the mean spectra.

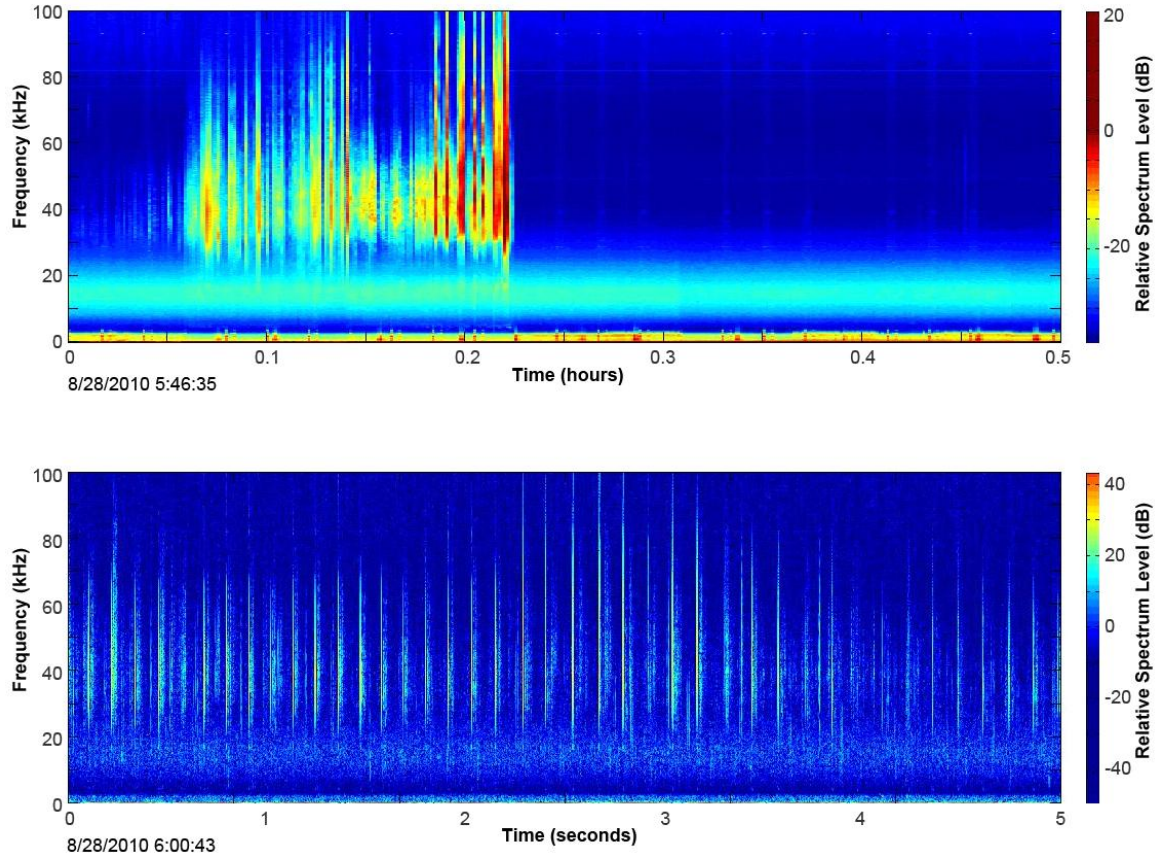

Figure 28. CT32 in the LTS A (above) and spectrogram (below).

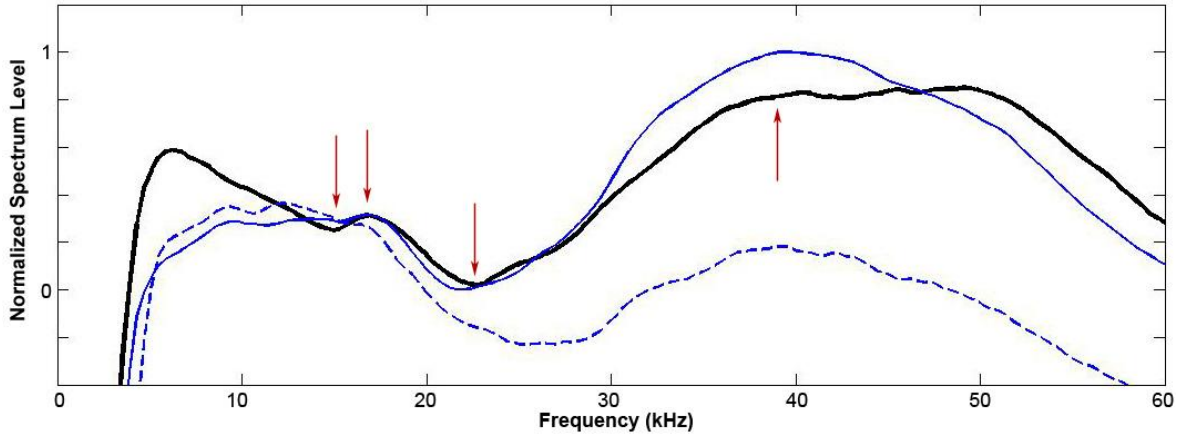

Figure 29. Mean Spectra of CT32. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

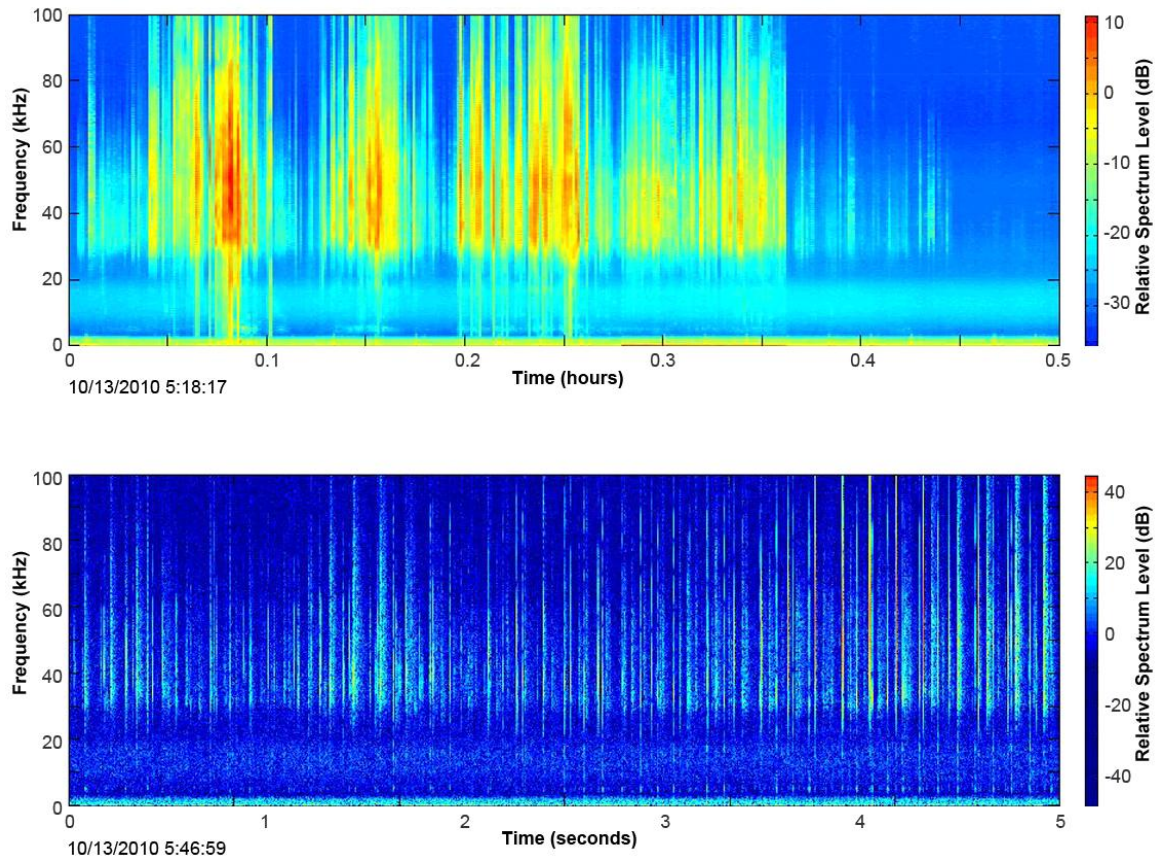

Figure 30. CT32 (emphasizing 4-6 peak) in the LTSA (above) and spectrogram (below).

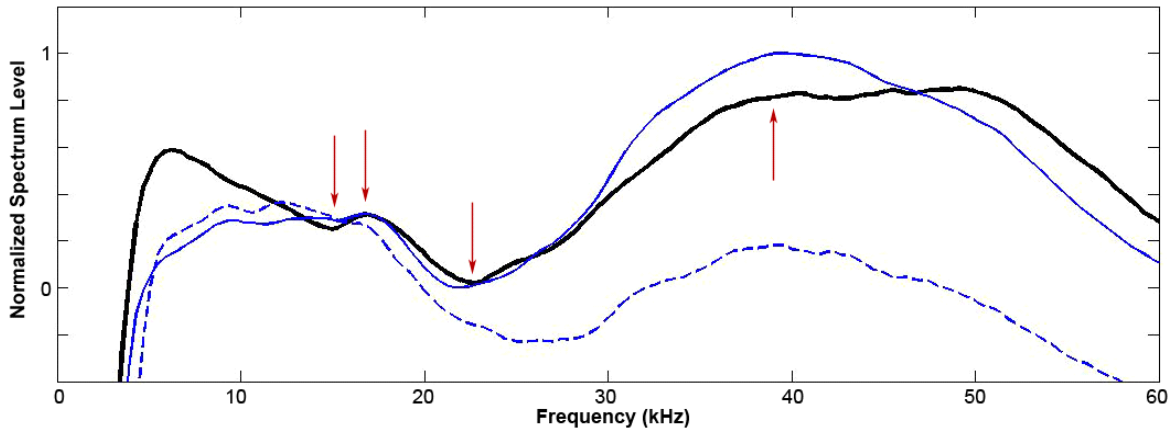

Figure 31. Mean Spectra of CT32. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Sperm Whale

Sperm whales produce echolocation clicks in the frequency range 5 – 20 kHz. Care must be taken not to misclassify impulsive anthropogenic sounds that maintain a similar frequency to sperm whales. No definitive sperm whale encounters were found in the JAX data. Similar findings were reported by Soldevilla et al. (2011).

Anthropogenic Sounds

Broadband Ship Noise

Broadband ship noise occurs when a ship passes relatively close to the HARP. Ship noise can occur for many hours at a time, but broadband ship noise typically lasts from 10 minutes up to 3 hours. Ship noise has a characteristic interference pattern in the LTSA. Combination of direct paths and surface reflected paths produce constructive and destructive interference (bright and dark bands) in the spectrogram that vary by frequency and distance between the ship and the HARP (Figure **32**). This noise can extend to well above 10 kHz, though typically falls off above a few kHz.

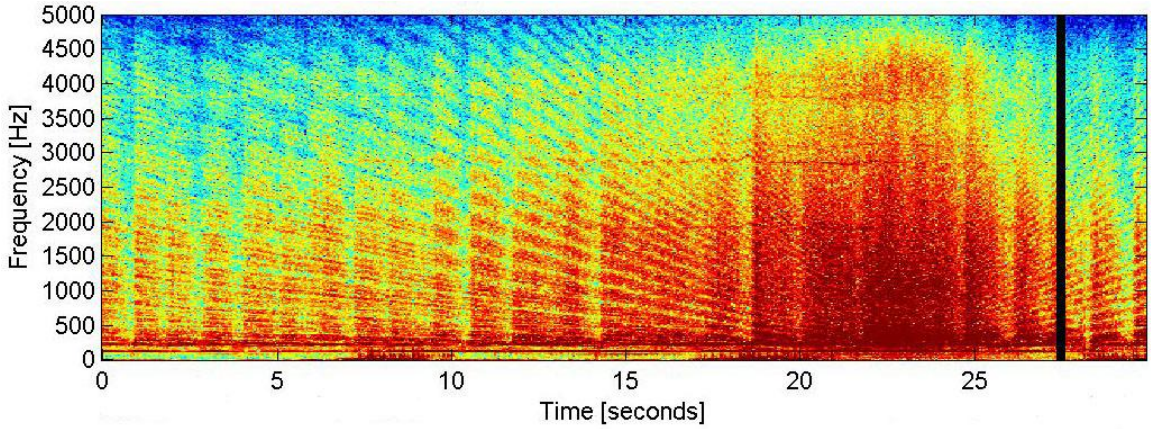

Figure 32. Broadband ship noise in the LTSA (above) and spectrogram (below).

Mid-Frequency Active Sonar

Many types of active sonar are used in the Jacksonville Range Complex. Their frequencies span 1 kHz to over 50 kHz and include short duration pings, frequency modulated (FM) sweeps and short and long duration continuous wave (CW) tones. One common type of sonar used in JAX is mid-frequency active (MFA) sonar. Sounds from MFA sonar vary in frequency and duration and can be used in a combination of FM sweeps and CW tones; however, many of these are between 2 and 5 kHz and are generically known as '3.5 kHz' sonar. We describe the process for identifying MFA sonar and how pings from these events were analyzed, including counts and distributions of sonar levels.

The first step in analyzing MFA sonar was conducted by an analyst scanning for periods of sonar activity. Start and end times of MFA sonar events from LTSAs were noted to provide target periods for automatic

detections. Full bandwidth (10Hz – 100kHz) data were used to calculate the spectra for the LTSAs with 100 Hz frequency bin-width and 5 s time bin width. These spectra were arranged sequentially to provide a long-term spectrogram so that hours of data can be easily displayed for analysis. Individual MFA sonar pings typically span 1 – 3 s, but are intense enough to show up as 'pulses' in LTSA plots (Figure **33**). LTSA display parameters used by the analyst were 1 or 2 hour window length, and 2 – 5 kHz bandwidth.

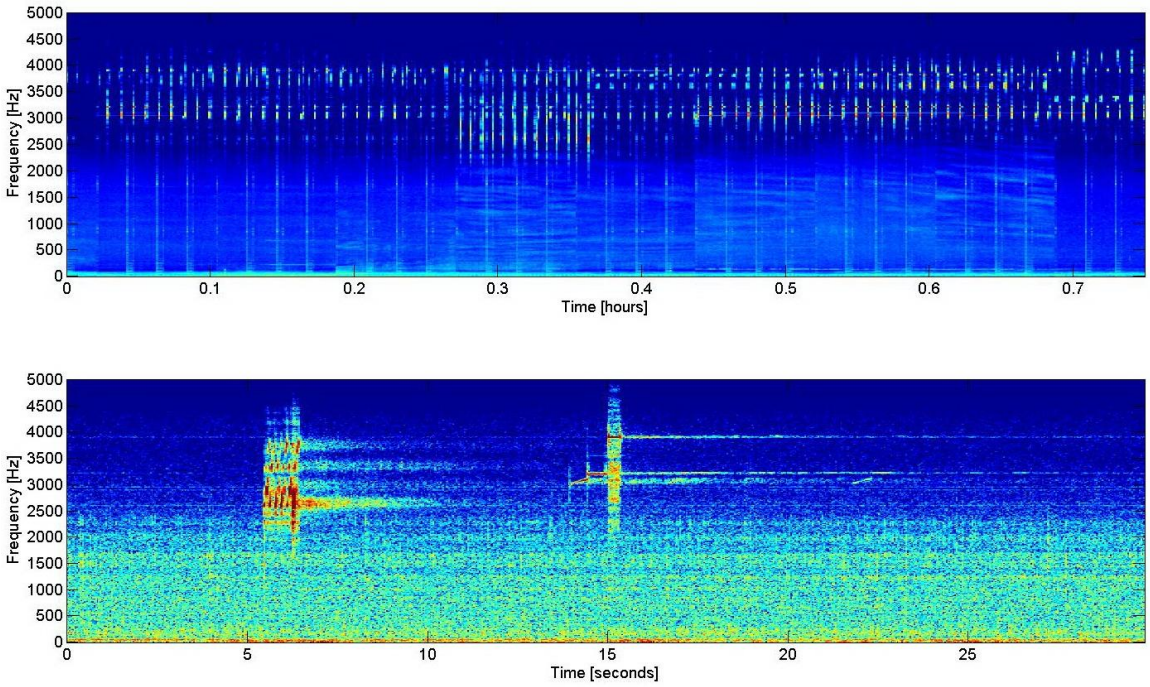

Figure 33. Mid-frequency active (MFA) sonar event. (Top) Long-Term Spectral Average of 45 minutes of data. (Bottom) Spectrogram of with multiple sonar pings.

A custom developed software routine was used to detect sonar pings and calculate peak-to-peak (PP) received sound pressure levels. For this detector, a sonar ping is defined as the presence of sonar within a 5 s window and may contain multiple individual pings (Figure 33. The detector calculates the average spectral level across the frequency band from 2.4 to 4.5 kHz for each 5 s window. This provides a long-term time series of the average received levels in that frequency band. Minimum values were noted for each 15 time bins, and used as a measure of background noise level over the sonar event period. Spectral bins that contained system noise (disk writing) were eliminated. Each of the remaining average spectral bins was compared to the background minimum levels. If levels were more than 3 dB above the background, then a detection time was noted. These detection times were used to index to the original time series to calculate PP levels. Received PP levels were calculated by differencing the maximum and minimum amplitude of the time series in the 5 s window. The raw time series amplitudes are in units of analog-to-digital converter (ADC) counts. These units were corrected to µPa by using the HARP calibrated transfer function for this frequency band. The HARP response is not flat over the 2.4 – 4.5 kHz band, and the value at 3.3 kHz was used to approximate the entire band. The transfer function value

for site 5A was 83.1 dB re $\mu Pa^2/counts^2$ while the transfer function value for site 6A was 82.3 dB re $\mu Pa^2/counts^2$. The transfer function value used for site 5B was 62.8 dB re $\mu Pa^2/counts^2$. There were no MFA ping events in site 6B. For sonar pings less than this 3.3 kHz, the levels are overestimated up to about 5 dB and for higher frequency sonar the levels are underestimated up to about 4 dB.

Echosounder

Echosounder pings were detected in a variety of frequencies (8-80 kHz); they are easily identified as lines in the LTSA (Figure **34**).

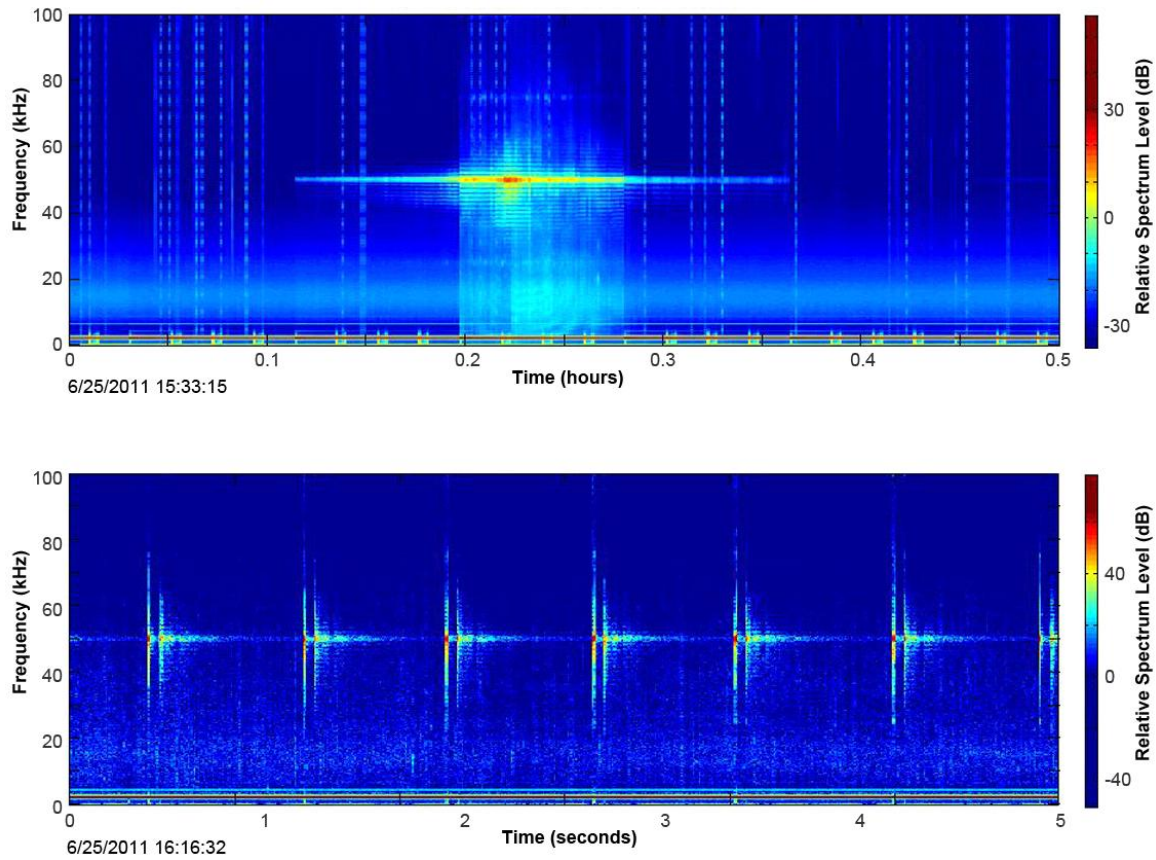

Figure 34. Echosounder in the LTSA (above) and spectrogram (below).

Explosions

Explosive sounds logged in the HARP data include military explosions, shots from sub-seafloor exploration, and seal bombs used by the fishing industry. An explosion appears as a vertical spike in the LTSA, and when expanded in the spectrogram has a sharp onset with a reverberant decay (Figure 35). These sounds have peak bandwidth as low as 10 Hz and often extend up to 2000 Hz or higher, lasting for several seconds including the reverberation.

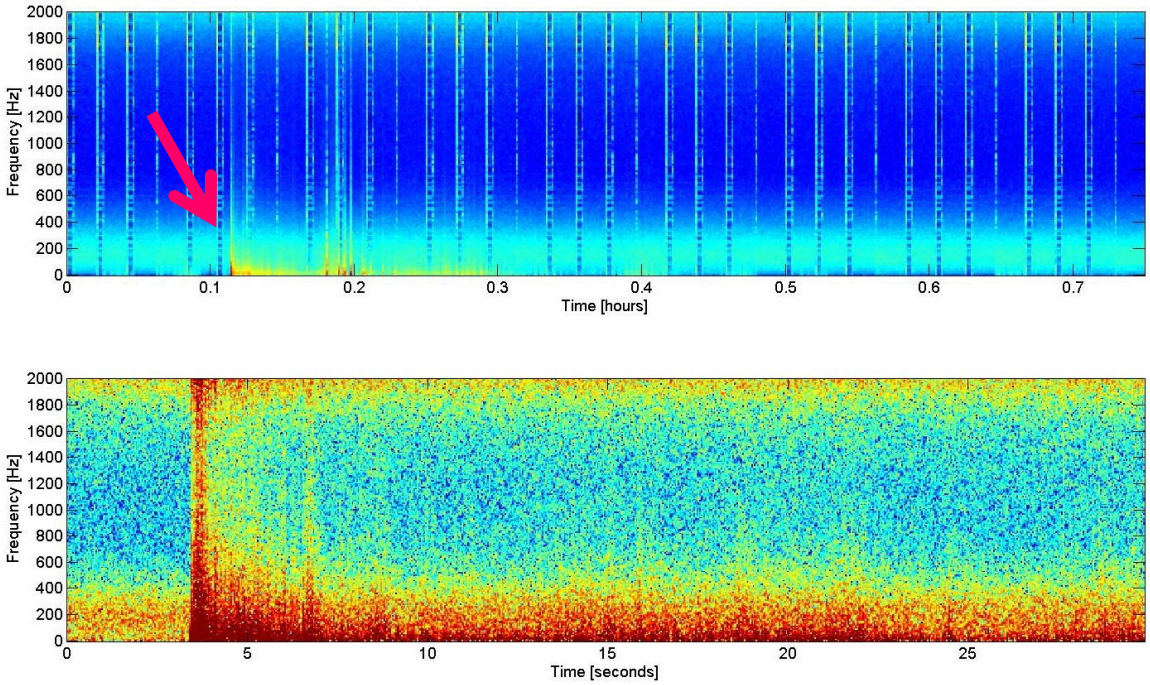

Figure 35. Five explosions are seen in the LTSA (arrow above) and one is expanded in the spectrogram (below). Site A on April 8, 2011.

Results

This report summarizes analysis of acoustic data collected from August 2010 - July 2011 at two sites in the Jacksonville Range Complex. We discuss ambient noise as well as the seasonal occurrence and relative abundance of marine mammal species and anthropogenic sounds.

Ambient Noise

Underwater ambient noise at sites A and B has spectral shapes with higher levels at low frequencies (Figure 36), owing to the presence of ship noise with secondary contributions from local wind and waves (Hildebrand 2009). An additional component of noise in the JAX data was due to mooring strum and fluid motion near the hydrophone sensor. These instrumental noise sources may have contributed to ambient noise levels at both sites that varied by as much as 20 dB at low frequency between monthly averages (Figure **36**). The months of February and March 2011 had very high noise levels at Site B.

Periods with high ambient noise at low frequency will result in lowered detection range for mysticetes calls. We attempted to quantify when high noise levels impacted the ability to detect low frequency calls (Appendix).

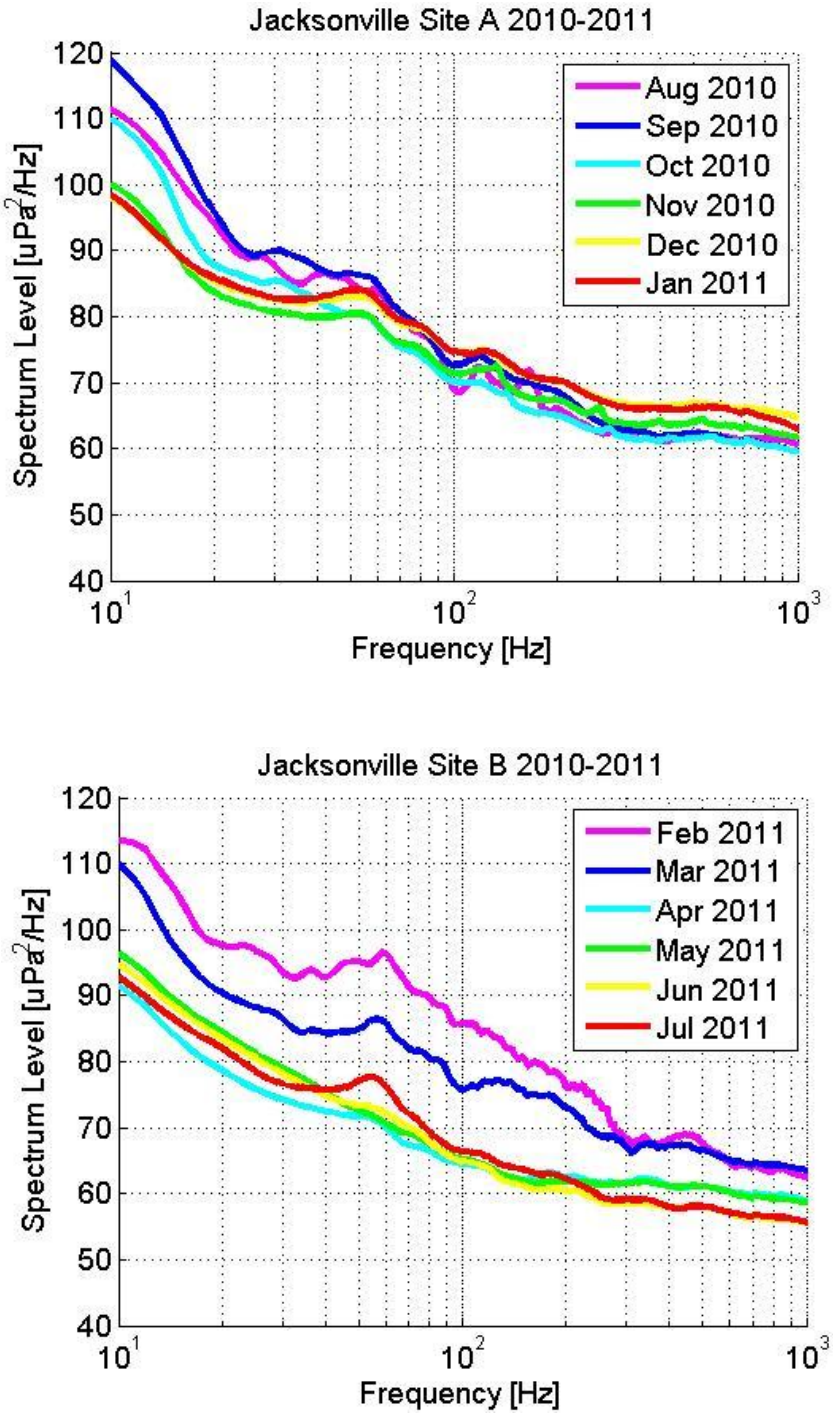

Figure 36. Monthly averages of ambient noise at site A (above) and site B (below) for the period August 2010 – July 2011. Legend gives color-coding by date.

Mysticetes

Four species of mysticete whales were recorded between August 2010 and July 2011 at sites A and B: fin, minke, sei, and humpback. In addition, the 5-pulse sound was detected, which we believe to be produced by a mysticete whale. No known blue or Bryde's whales sounds were detected at either site, nor were North Atlantic right whale upcalls or gunshot calls.

Site A was frequented by calling mysticete whales more often than site B. Fin, minke, and sei whale calls were all detected during more hours at site A, although this may be partially due to the higher ambient noise levels at site B during certain seasons, decreasing call detection ranges (Figure **36**).

Fin Whales

Fin whale 20 Hz calls were detected at site A in late January and early February (Figure **37**). Fin whale 40 Hz calls were not detected at either site, nor were there any 20 Hz calls at site B.

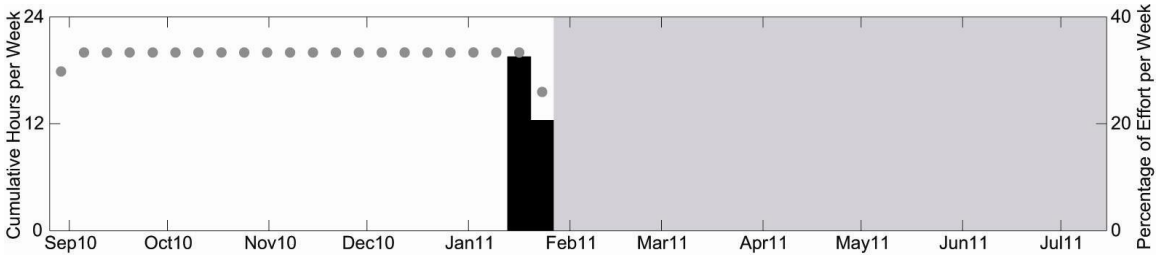

Figure 37. Weekly fin whale 20 Hz call presence at site A between August 2010 and February 2011. The area shaded in gray represents the section of data that were missing or corrupt. The light gray dots represent weekly recording effort.

Minke Whales

Two minke whale call types were recorded. 50 Hz pulses were recorded at site A, while no 50 Hz pulses were recorded at site B (Figure **38**). Minke whale pulse trains were recorded at both sites (Figure 39).

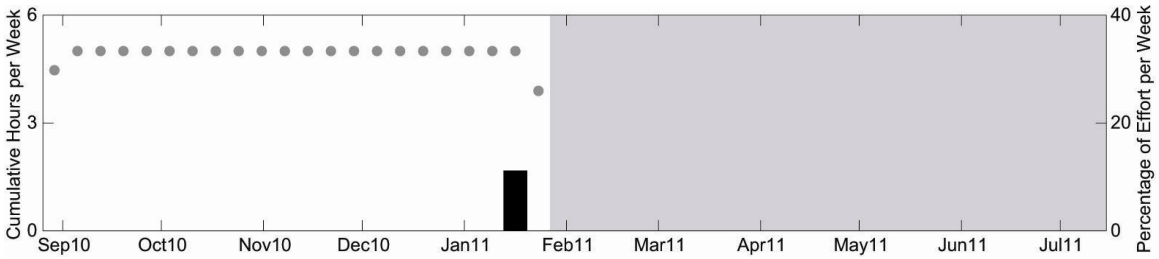

Figure 38. Occurrence of minke whale 50 Hz pulses at site A. Effort as described in Figure 37

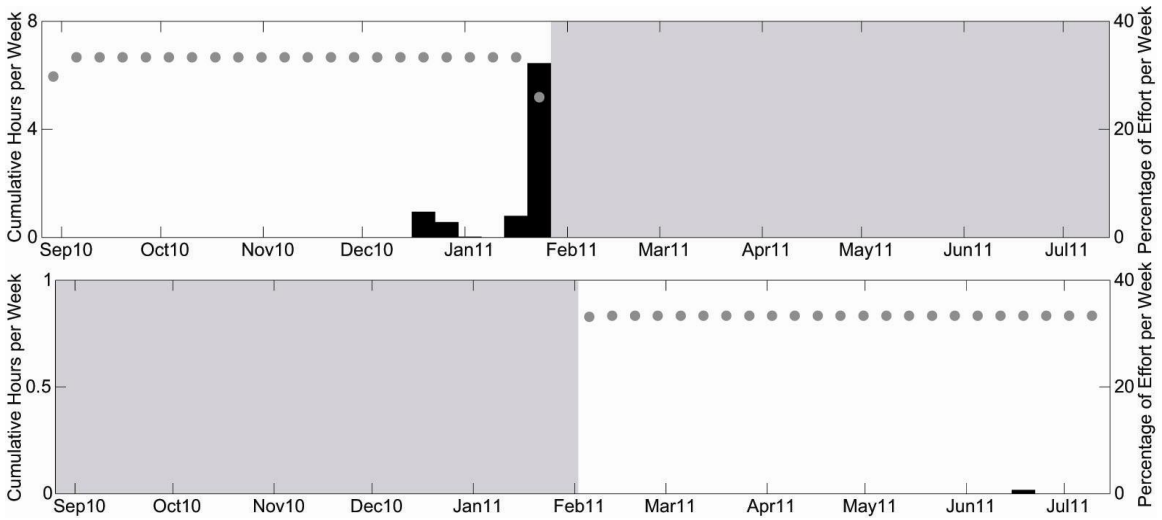

Figure 39. Weekly occurrence of minke speed-up/slow-down whale pulse trains at 150 Hz at site A (top) and site B (bottom). Effort as described in Figure 37

Sei Whales

Downsweep calls reported as being from sei whales were detected at site A, with detections occurring in November and December (Figure 40). No downsweep calls were detected at site B.

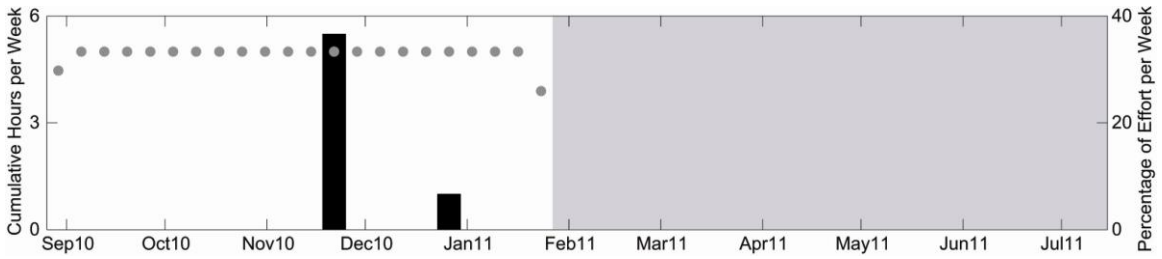

Figure 40. Weekly occurrence of downsweep calls in site A. Effort as described in Figure 37

5-Pulse Call

The 5-pulse call was detected late-October through early December in site A (Figure **41**). No 5-pulse calls were recorded at site B.

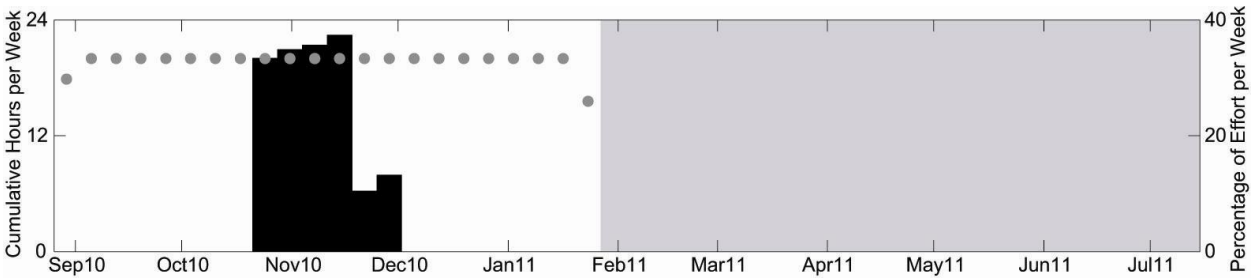

Figure 41. Weekly occurrence of 5-pulse calls at site A. Effort as described in Figure 37

Humpback Whales

Humpback whales were only detected on site B (Figure 42). The detections were few, likely owing to the fact that the migratory path of western North Atlantic humpbacks generally does not include the southeast US coastline as they migrate from their high-latitude feeding areas off the northeast coast of the US to the Barents Sea (Katona & Beard 1990, Smith *et al.* 1999) to a common breeding area in the West Indies to mate and calve (Katona & Beard 1990, Stevick *et al.* 1998).

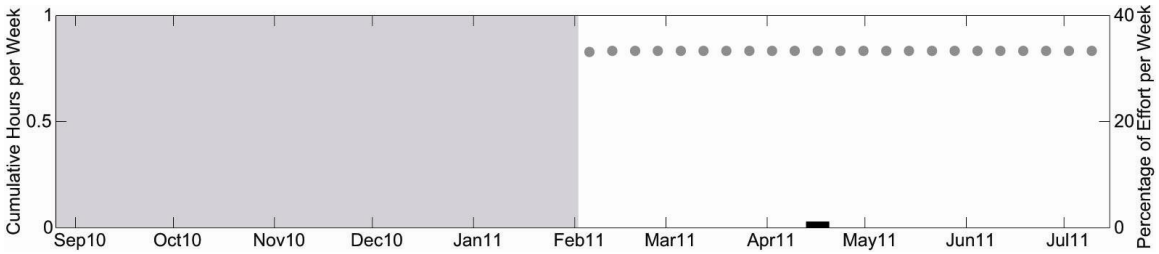

Figure 42. Weekly presence of all humpback whale calls (black bars) at site B between February and July 2011. No humpback calls were recorded at site A. Effort as described in Figure 37

Odontocetes

Clicks from Risso's dolphin and five click types that are not yet associated to a species were detected at sites A and B. Neither killer whale nor sperm whale sounds were detected at either site.

Unidentified Odontocete

The greatest number of odontocete click and whistle detections were attributed to the category unidentified odontocete (UO). Overall rates of UO detections were higher at site A than B (Figure 43). There was a distinct diel acoustic activity at site A, likely due to nighttime foraging. Nighttime clicking is more common at site B as well, but the diel pattern is not as distinct as at site A.

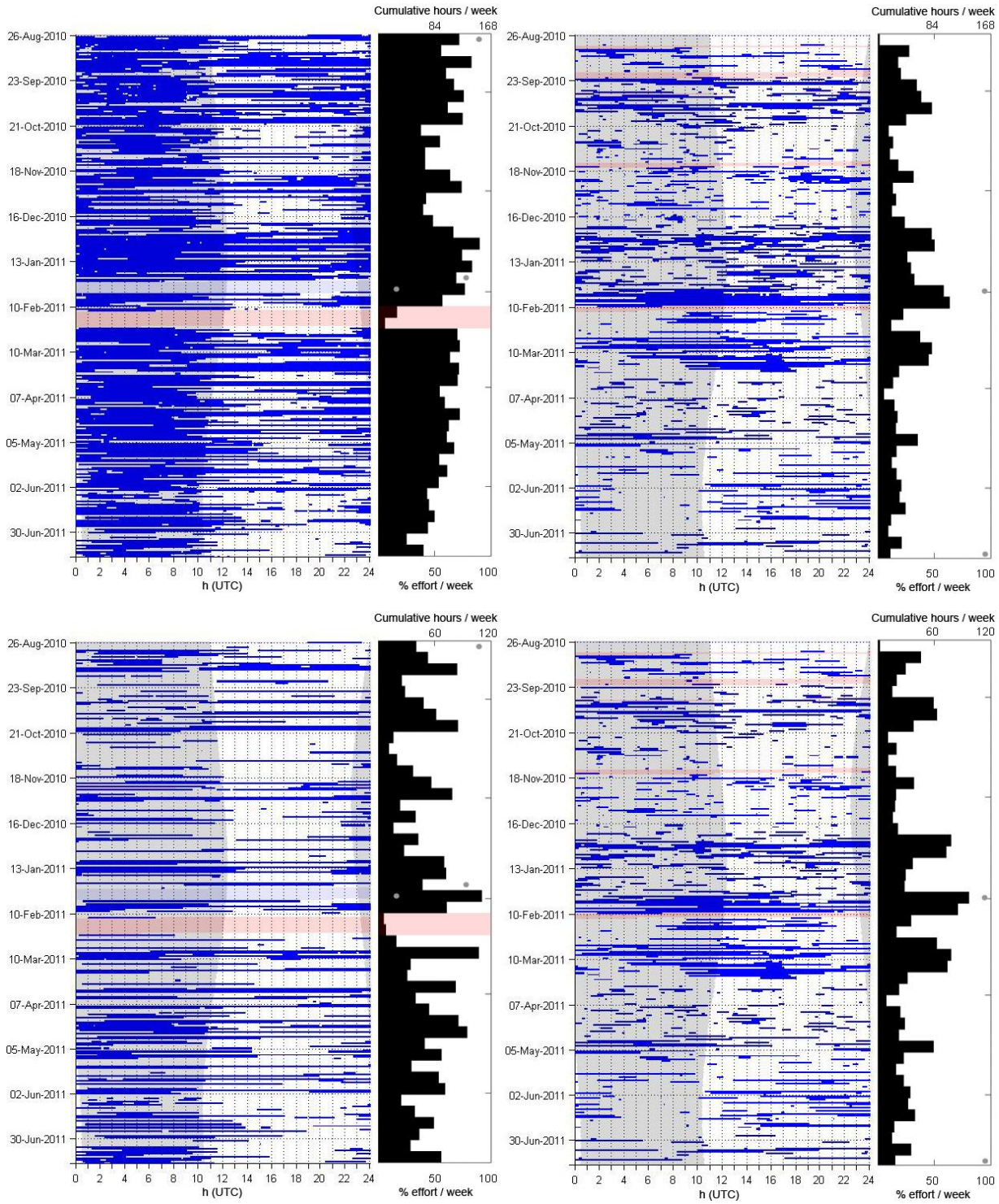

Figure 43. Odontocete echolocation clicks in one-minute bins (blue) and weekly presence (black) at site A (left) and site B (right) between August 2010 and July 2011. Top: all echolocation clicks of all species, Bottom: UO after all others were extracted. Red shading indicates data gaps. Gray shading is nighttime.

Risso's Dolphin

Risso's dolphin echolocation clicks were only detected at site A (Figure 44). Clicks were detected from the end of August until the end of November with two additional click segments: one in the middle of January and another at the beginning of March. A nighttime diel pattern is suggested.

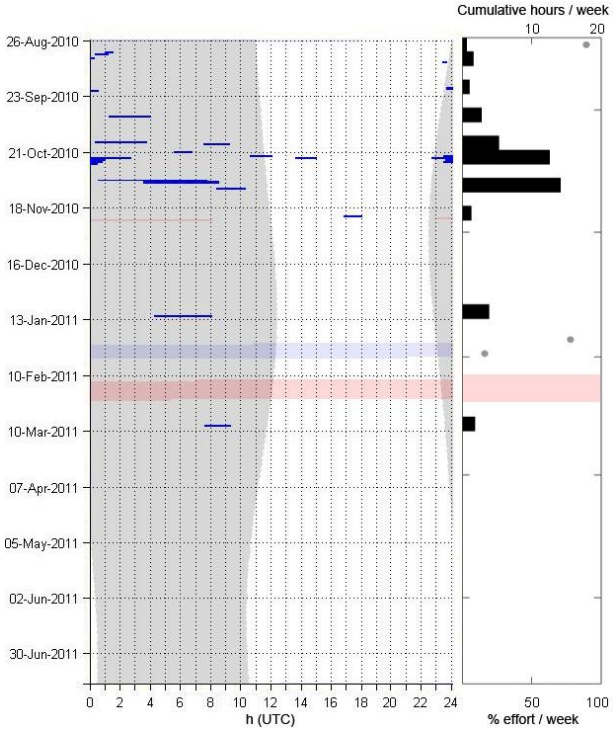

Figure 44. Risso's dolphin echolocation clicks in one-minute bins (blue) and weekly presence (black) at site A between August 2010 and July 2011. No Risso's dolphin were detected at site B. Red shading indicates data gaps. Gray shading is nighttime.

Click Type 25

Click Type 25 was detected intermittently between the end of August and the beginning of June with most of the clicks occurring at night (Figure 45). Out of the five specified click types, CT25 was the least prevalent click type.

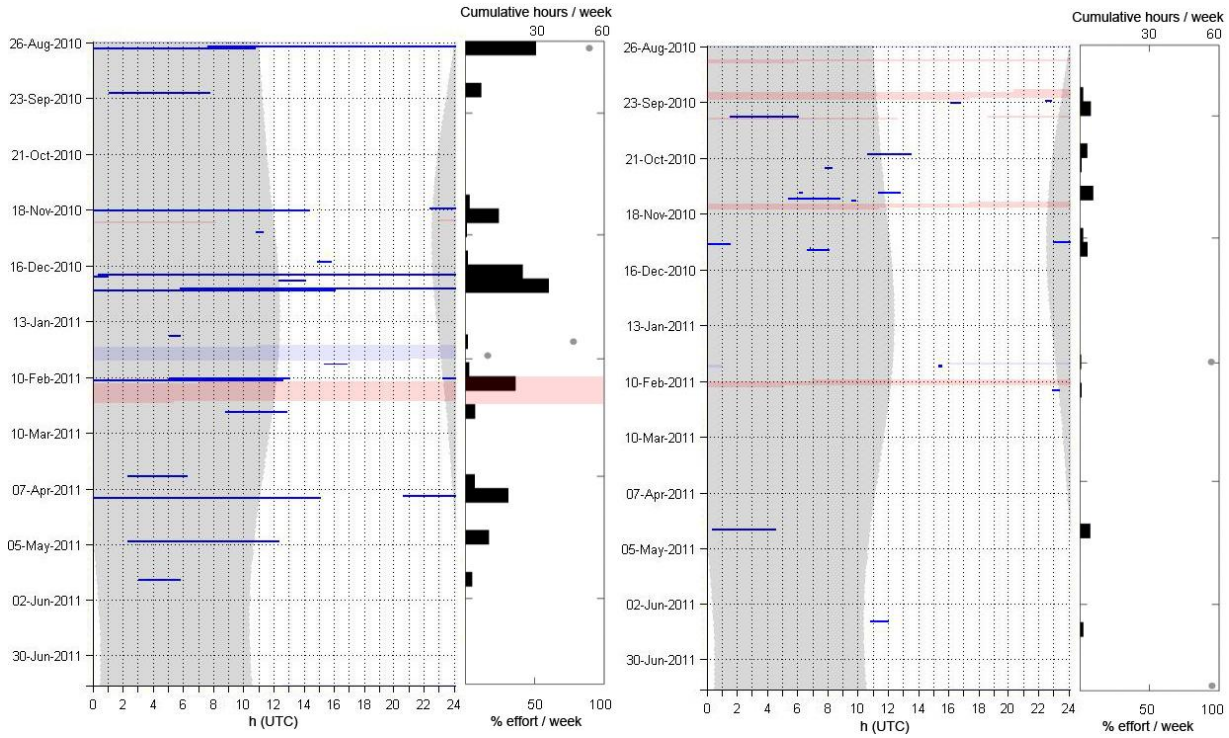

Figure 45. CT25 echolocation clicks in one-minute bins (blue) and weekly presence (black) at site A (left) and site B (right) between August 2010 and July 2011. Red shading indicates data gaps. Gray shading is nighttime.

Click Type 26

Click Type 26 was the most prevalent of the five click types detected in the JAX data set. This click type appeared throughout the duration for site A, but only occurred between the beginning of October and the middle of April at site B. A nighttime diel pattern is suggested at site A, but not at site B (Figure 46).

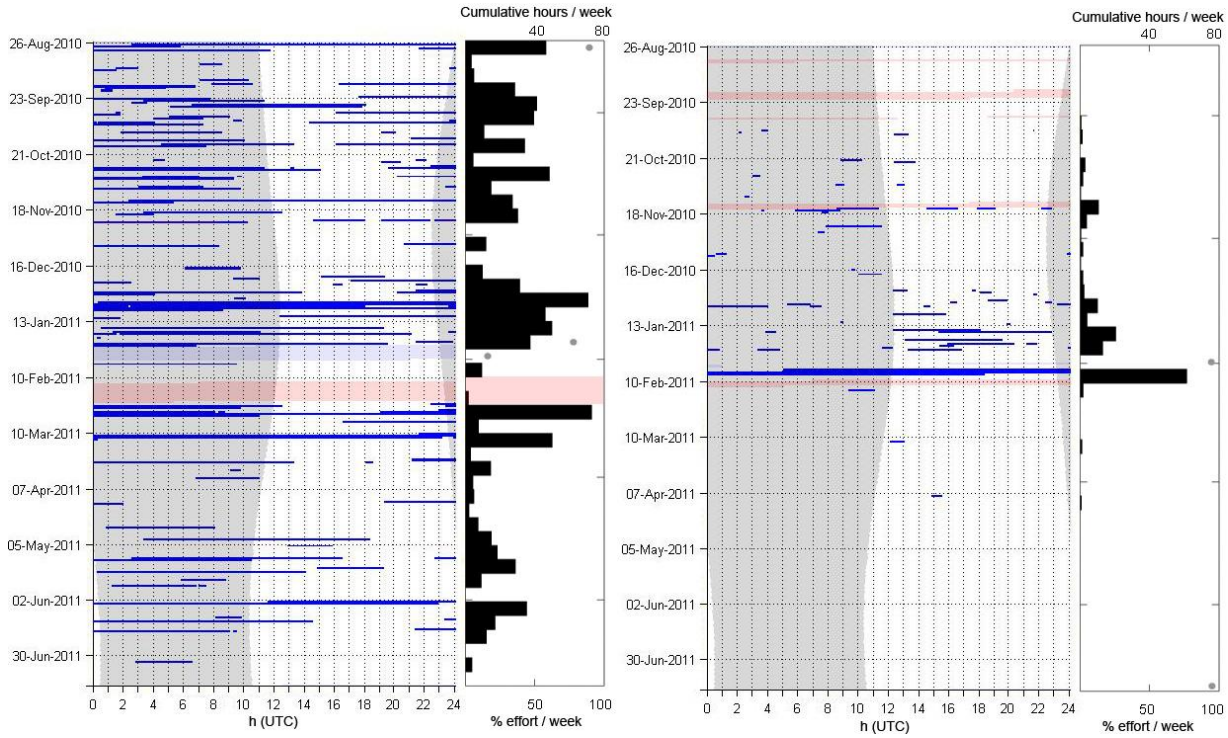

Figure 46. CT26 echolocation clicks in one-minute bins (blue) and weekly (black) at site A (left) and site B (right) between August 2010 and July 2011. Red shading indicates data gaps. Gray shading is nighttime.

Click Type 27

Click Type 27 encounters were detected throughout the entire time period at site A, but were only present at site B during the end of September and the end of November. More clicks appear to be present at night at site A (Figure 47).

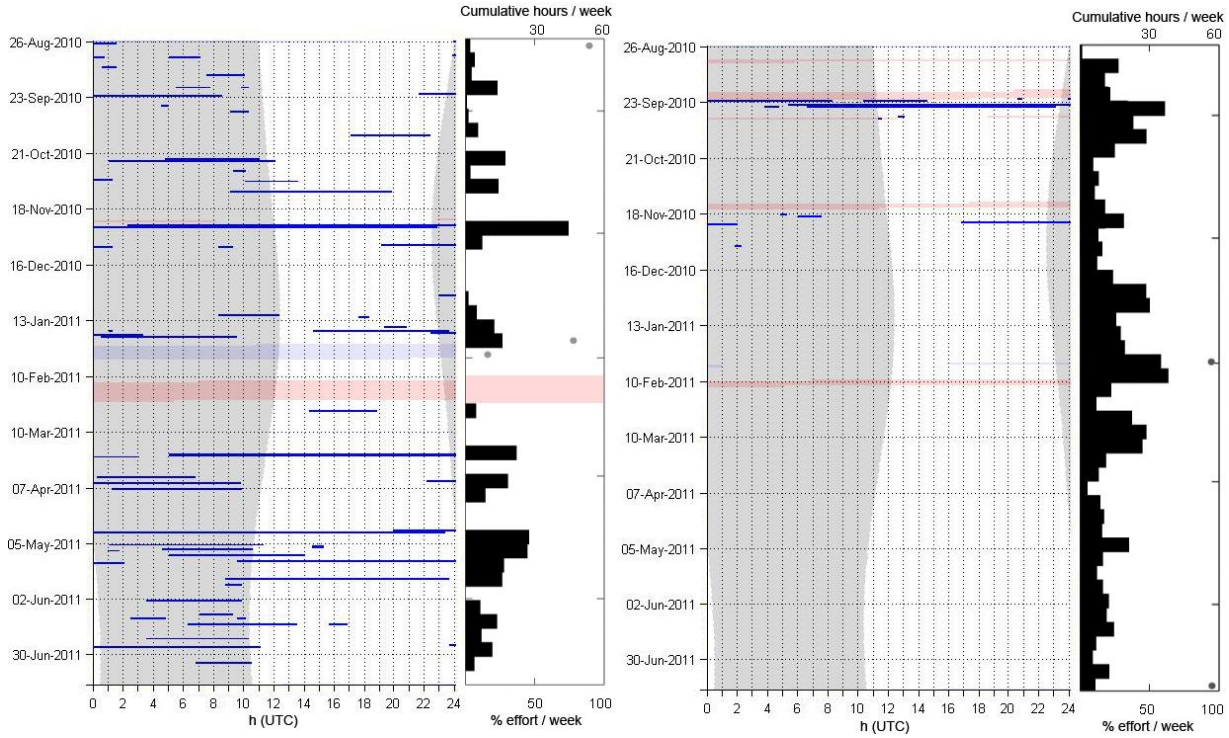

Figure 47. CT27 echolocation clicks in one-minute bins (blue) and weekly presence (black) at site A (left) and site B (right) between August 2010 and July 2011. Red shading indicates data gaps. Gray shading is nighttime.

Click Type 30

Click Type 30 was present during both day and night, but were more prevalent during the night. At site A, clicks occurred from late August to the end of December and then reoccurred at the beginning of March through the end of June (Figure 48). At site B, clicks were only present from the beginning of October to the beginning of February, with one occurrence in the middle of June. This pattern could be due to seasonal preference or based on excessive noise and the ability to identify a definitive click type.

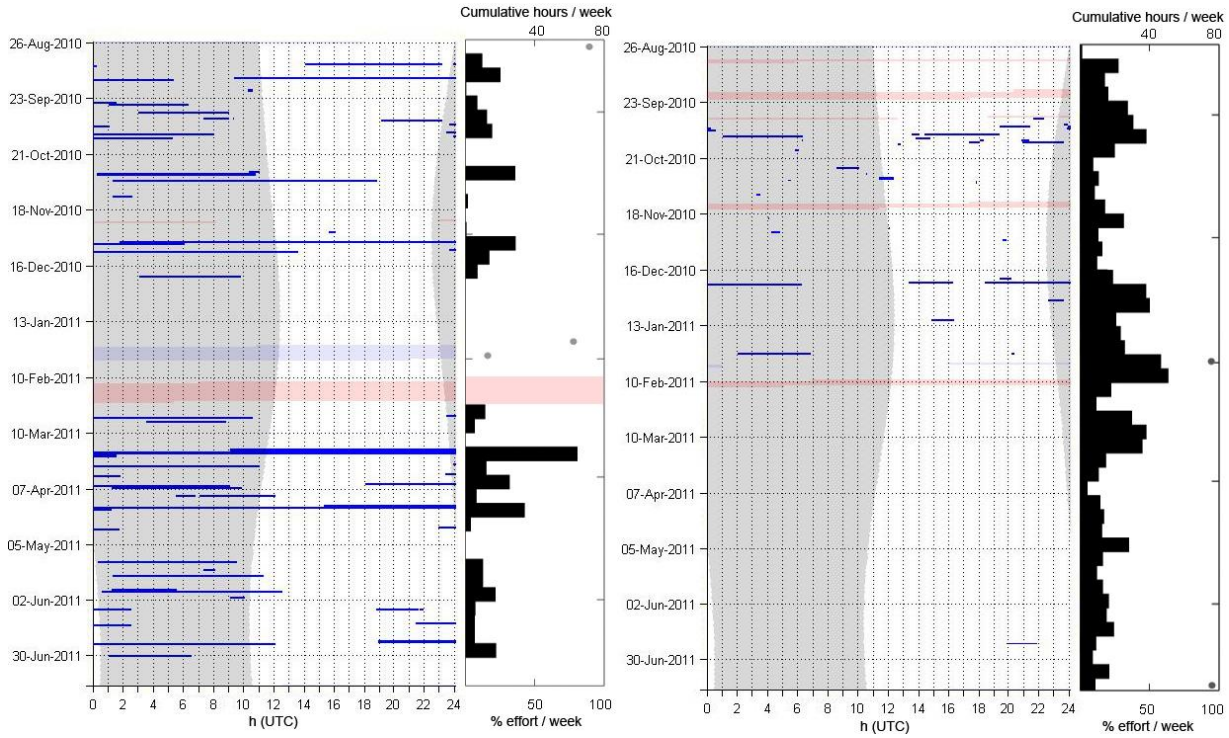

Figure 48. CT30 echolocation clicks in one-minute bins and weekly presence at site A (left) and site B (right) between August 2010 and July 2011. Red shading indicates data gaps. Gray shading is nighttime.

Click Type 32

Click Type 32 was detected from the end of August until the end of May. Site B had very few acoustic encounters. There was one encounter at the end of September, while the other encounters occurred from the end of November until the end of January. No specific diel pattern was seen (Figure 49).

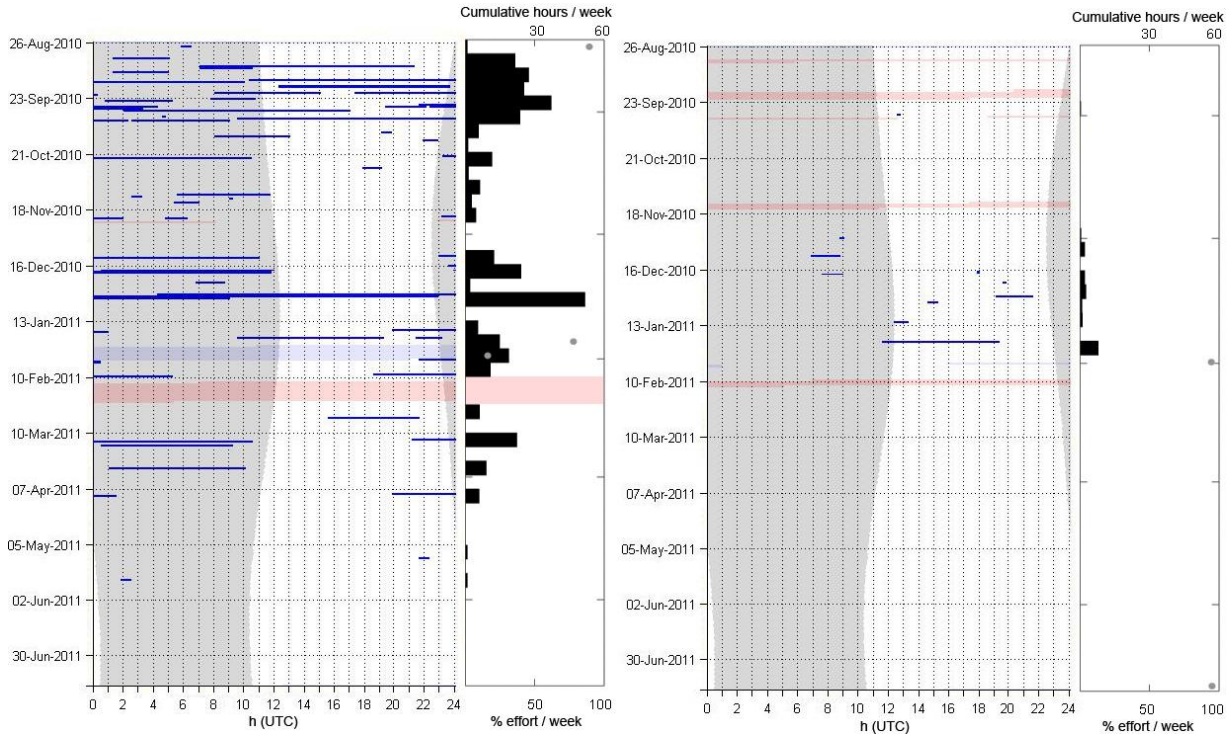

Figure 49. CT32 echolocation clicks in one-minute bins and weekly presence at site A (left) and site B (right) between August 2010 and July 2011. Red shading indicates data gaps. Gray shading is nighttime.

Anthropogenic Sounds

Broadband Ship Noise

Ship noise was common at sites A and B (Figure 50). Daily presence of ship noise had no temporal patterns (Appendix).

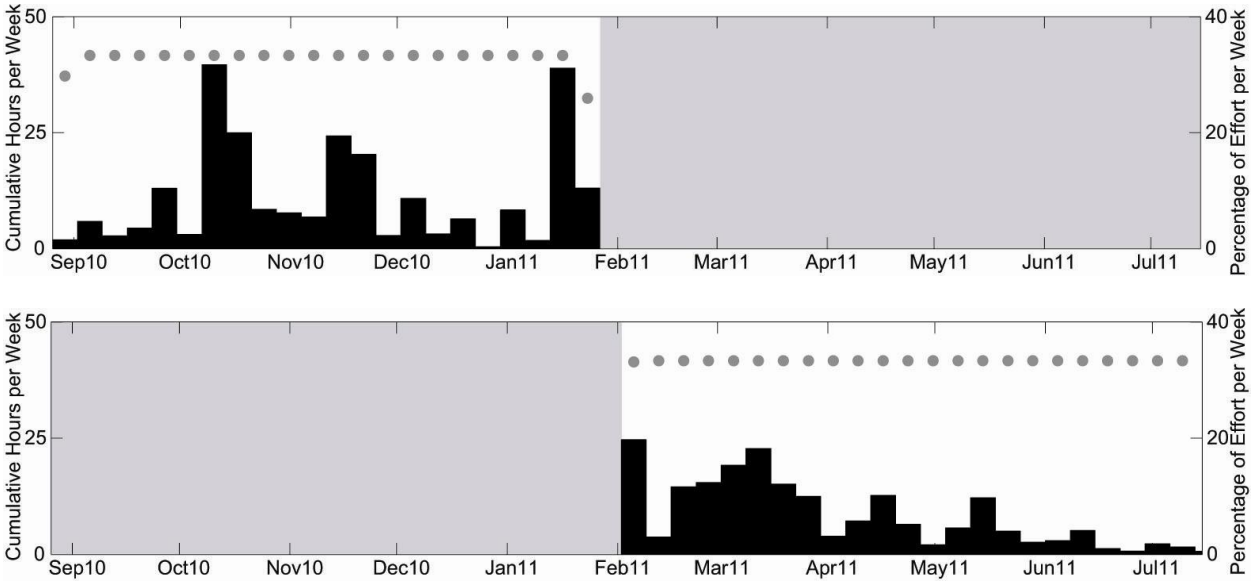

Figure 50. Broadband ship noise weekly hours at site A (top) and B (bottom) between August 2010 and July 2011. Effort markings are as described in Figure 35.

Mid-Frequency Active Sonar

Both sites A and B had MFA sonar events throughout the period August 2010 – July 2011 (Figure 51). At site A, a total of 2,437 MFA sonar pings were detected, ranging from 100 to 173 dB pp re 1 µPa; the maximum value is the clipping level of the HARP and the minimum value is a threshold limit based on the analysis methods used. 2,496 pings were detected at site B. Mid-October had the largest number of pings per week detected at both sites while some weeks did not have any sonar detections. Distribution of ping levels from site A shows a peak around 124 dB pp re 1 µPa and is long-tailed to higher levels while site B shows a peak around 134 dB pp re 1 µPa (Figure 52). Cumulative distribution of ping levels shows that half of the pings detected are above 125 dB pp re 1 µPa in both sites (Figure 53).

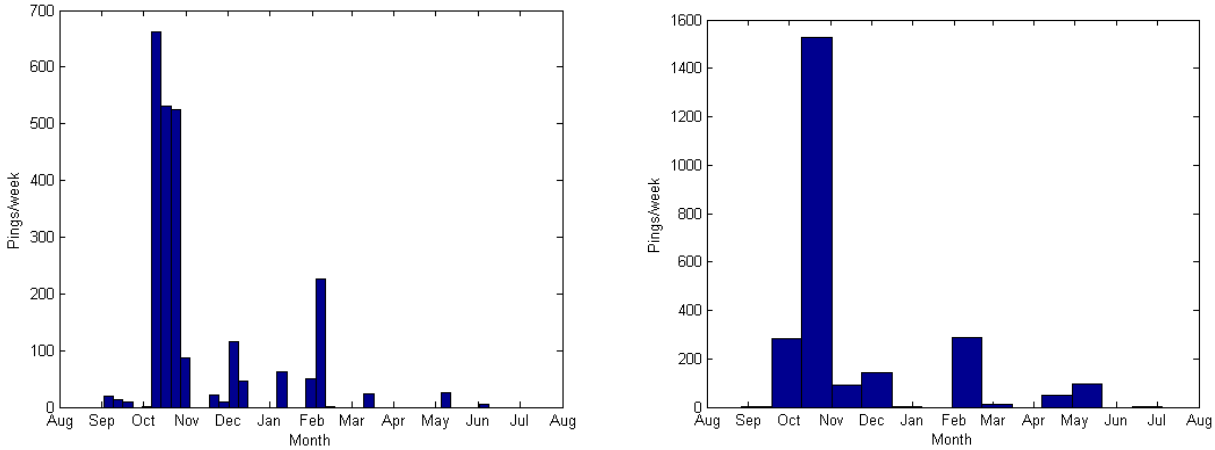

Figure 51. Mid-Frequency Active (MFA) sonar presence in weekly bins at site A (left panel) and site B (right panel) between August 2010 and July 2011.

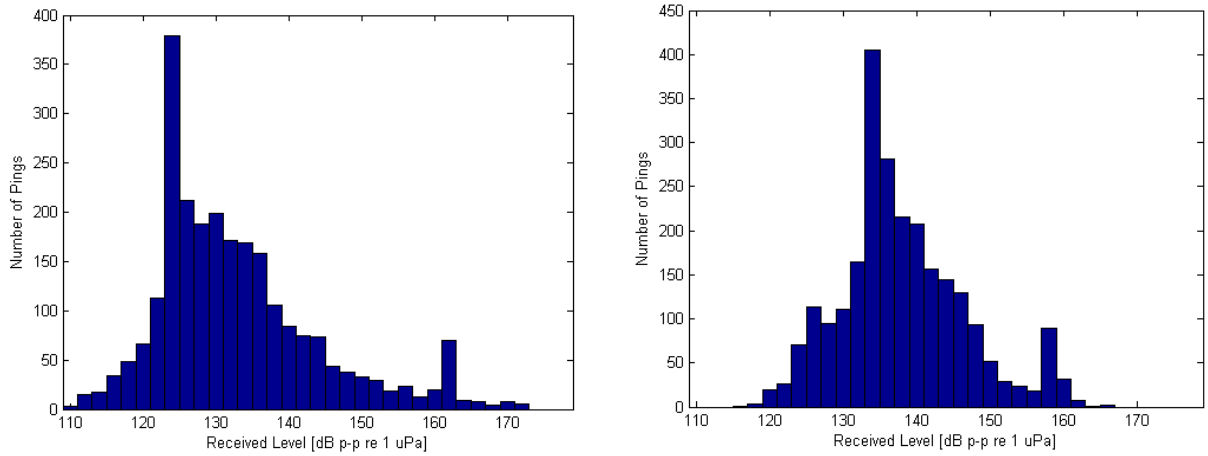

Figure 52. Distribution of MFA sonar pings by received level at site A (left) and site B (right) in 2 dB bins. Peak number of pings is 124 dB pp re 1 µPa for site A and 134 dB pp re 1 µPa for site B. Minimum level is 110 dB pp re 1 µPa and is related to the detection threshold. Maximum level is 173dB pp re 1 µPa for site A and 166 dB pp re 1 µPa for site B, set by the clipping level of the HARP.

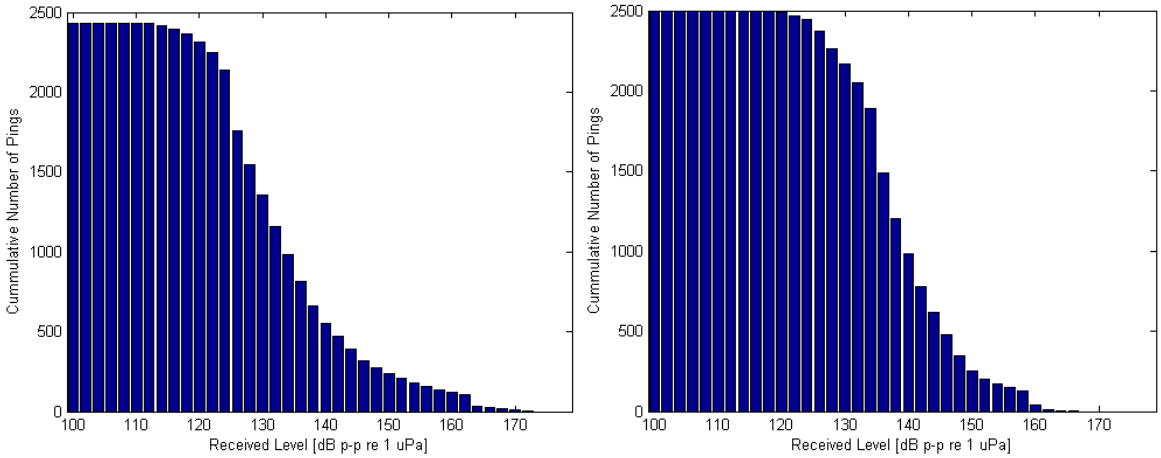

Figure 53. Cumulative distribution for the number of MFA sonar pings detected at a given received level or higher, at site A (left) and site B (right) in 2 dB bins.

Echosounders

Echosounder pings with a variety of primary frequencies (8 – 80 kHz) were found at both sites A and B (Figure 54). More echosounders were present at site A than site B, perhaps related to the greater depth at site A. Echosounder pings at both sites A and B occurred during similar times of the month. Pings were detected from the end of August to the middle of March and reoccurring at the beginning of April until the beginning of July. For site B, the pings occurred mostly at night while site A pings occurred more during the day.

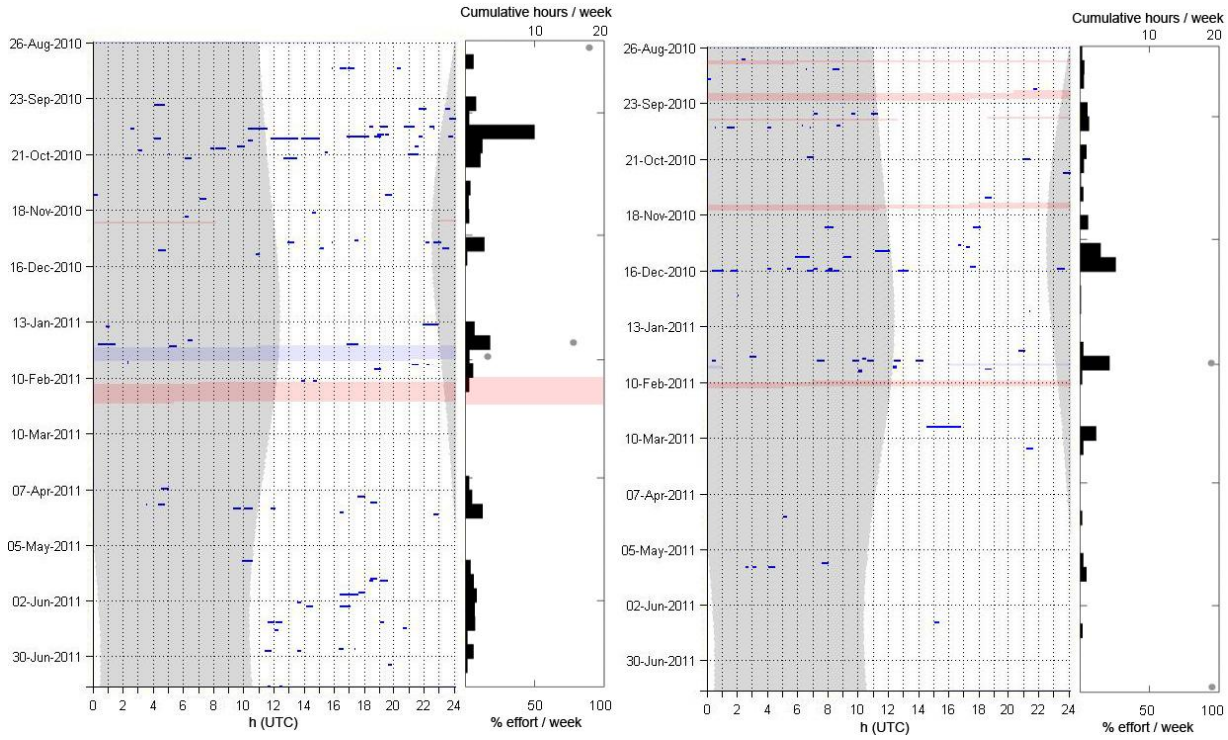

Figure 54. Echosounder pings in one-minute bins (blue) and weekly echosounder presence (black) at site A (left) and site B (right) between August 2010 and July 2011.

Explosions

Few explosions were recorded at either site (Figure 55). A peak in explosions was recorded in early July 2011 at site B.

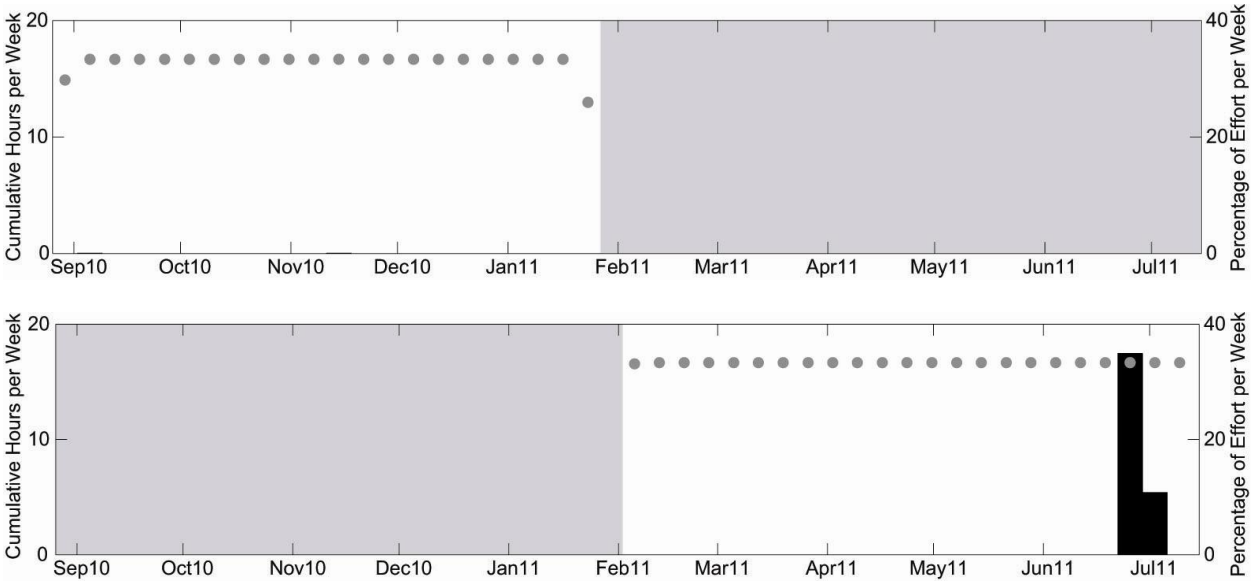

Figure 55. Weekly hours with explosions at sites A (top) and B (bottom) between August 2010 and July 2011. Effort markings are as described in Figure 37.

130-Hz Tone

The 130-Hz tone was detected at site A, with peaks in detections mid- to late November and mid-December (Figure 56). The tone was produced exclusively at night (Appendix). This tone was not detected at site B.

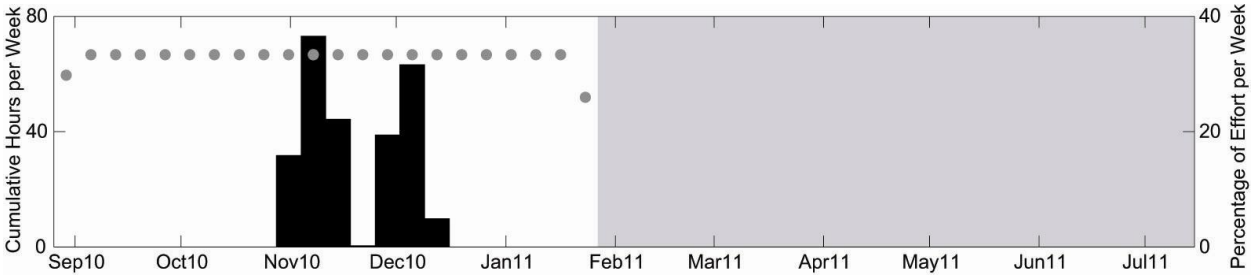

Figure 56. Weekly hours with 130-Hz tone detections at site A. Effort markings are as described in Figure 37.

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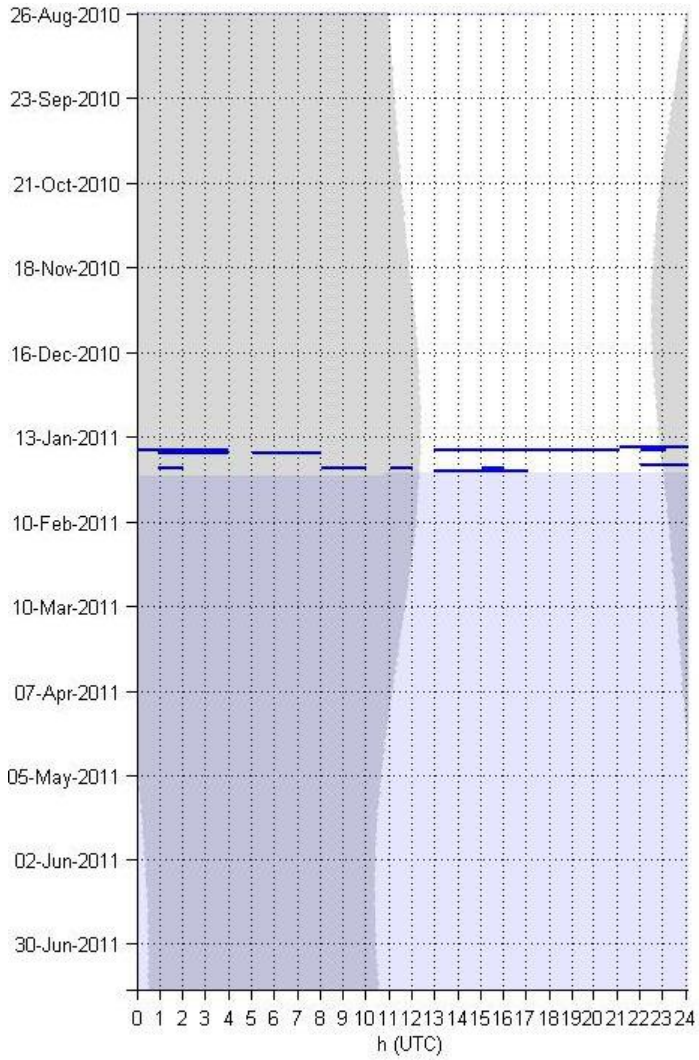
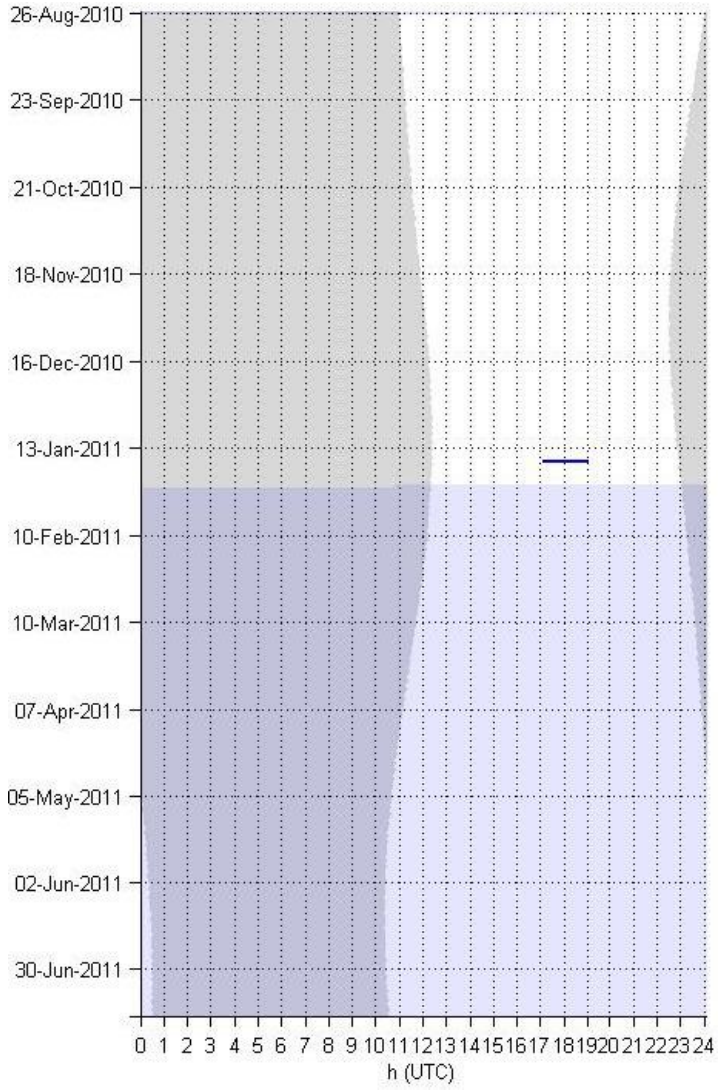
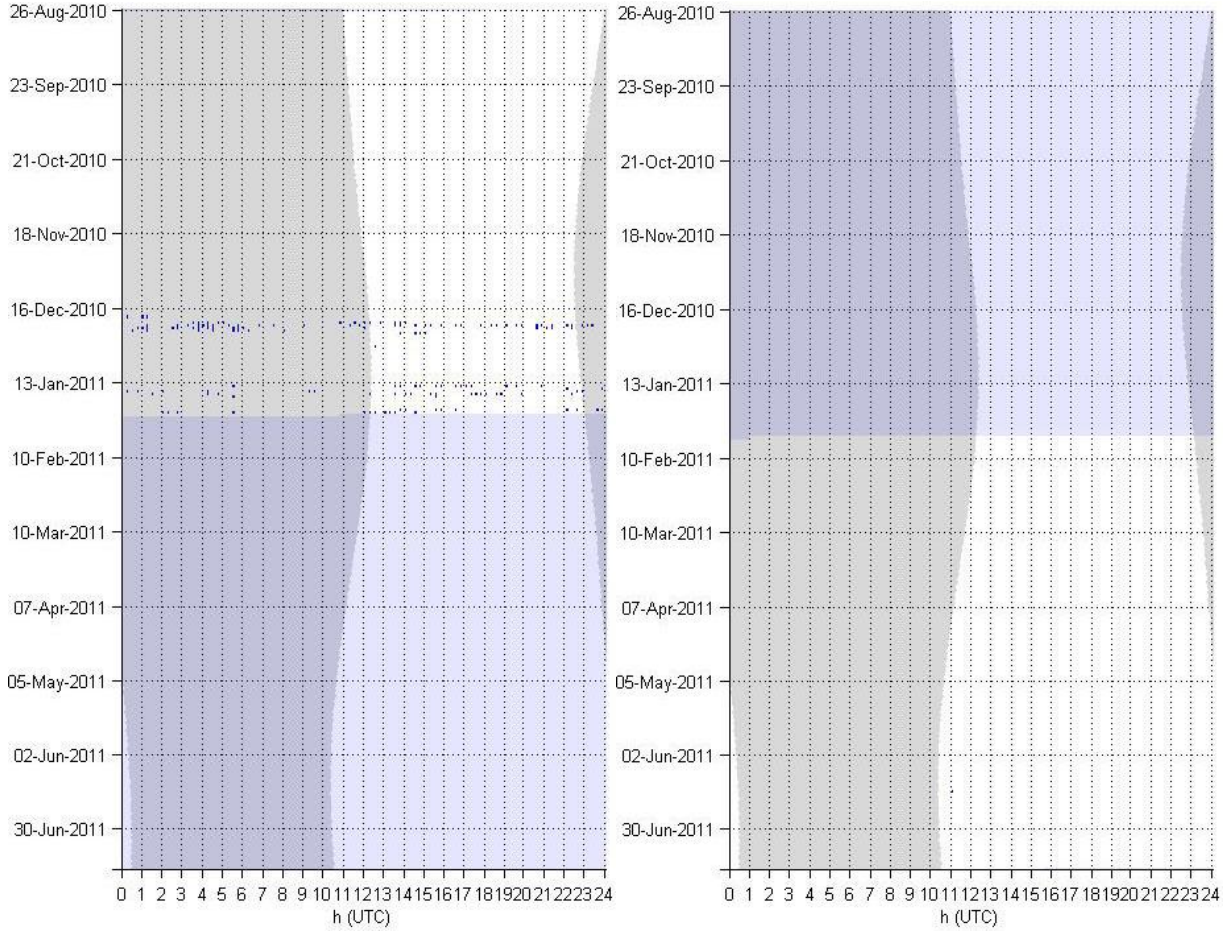
Appendix



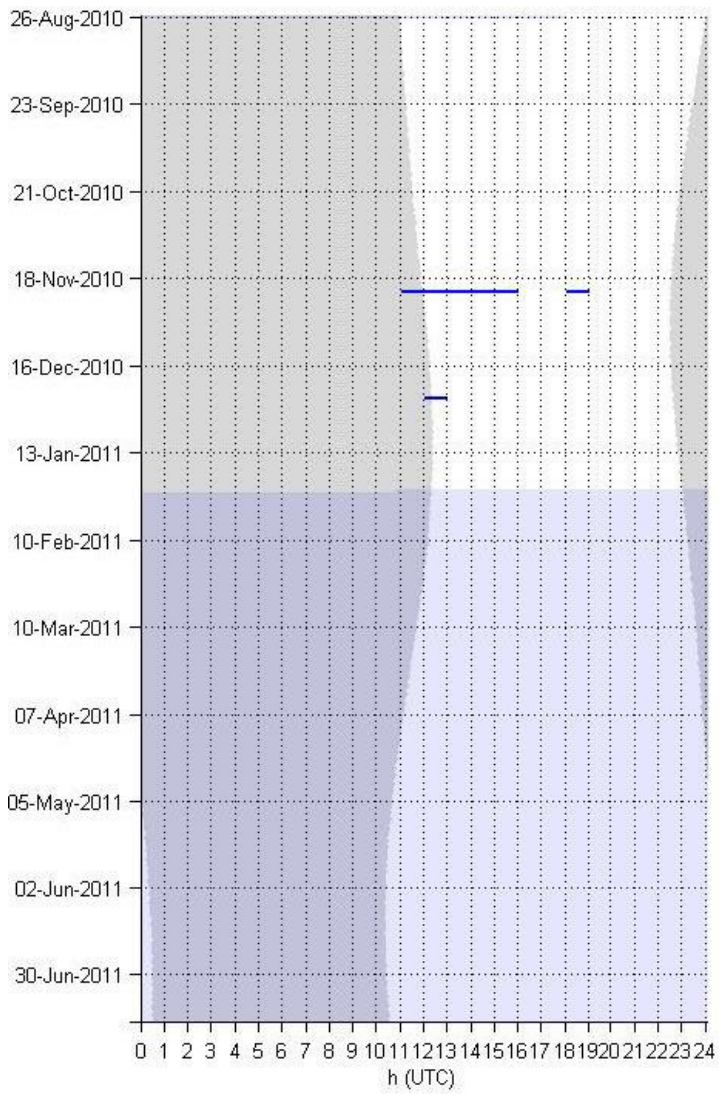
Fin whale – 20 Hz calls in hourly bins at site A. No calls were detected at site B.



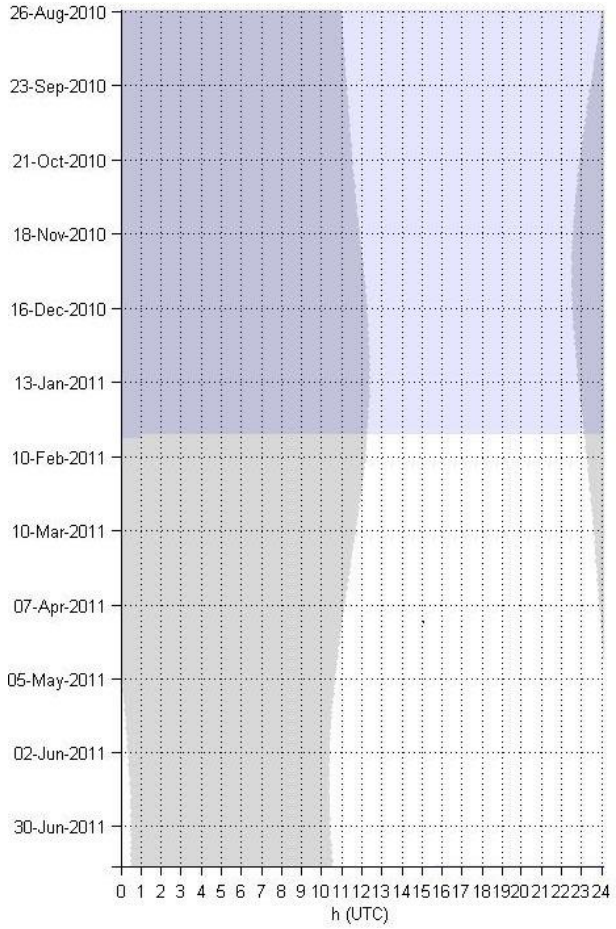
Minke whale – 50 Hz pulses in hourly bins at site A. No calls were detected at site B.



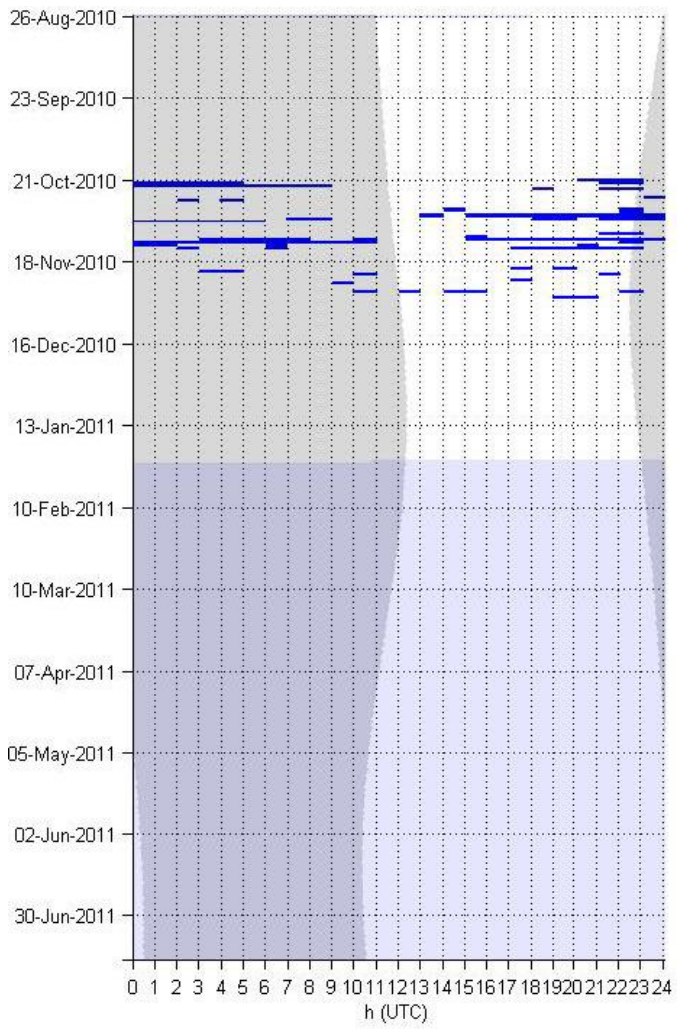
Minke whale – Speed-up/slow down pulse trains in hourly bins at sites A (left) and B (right).



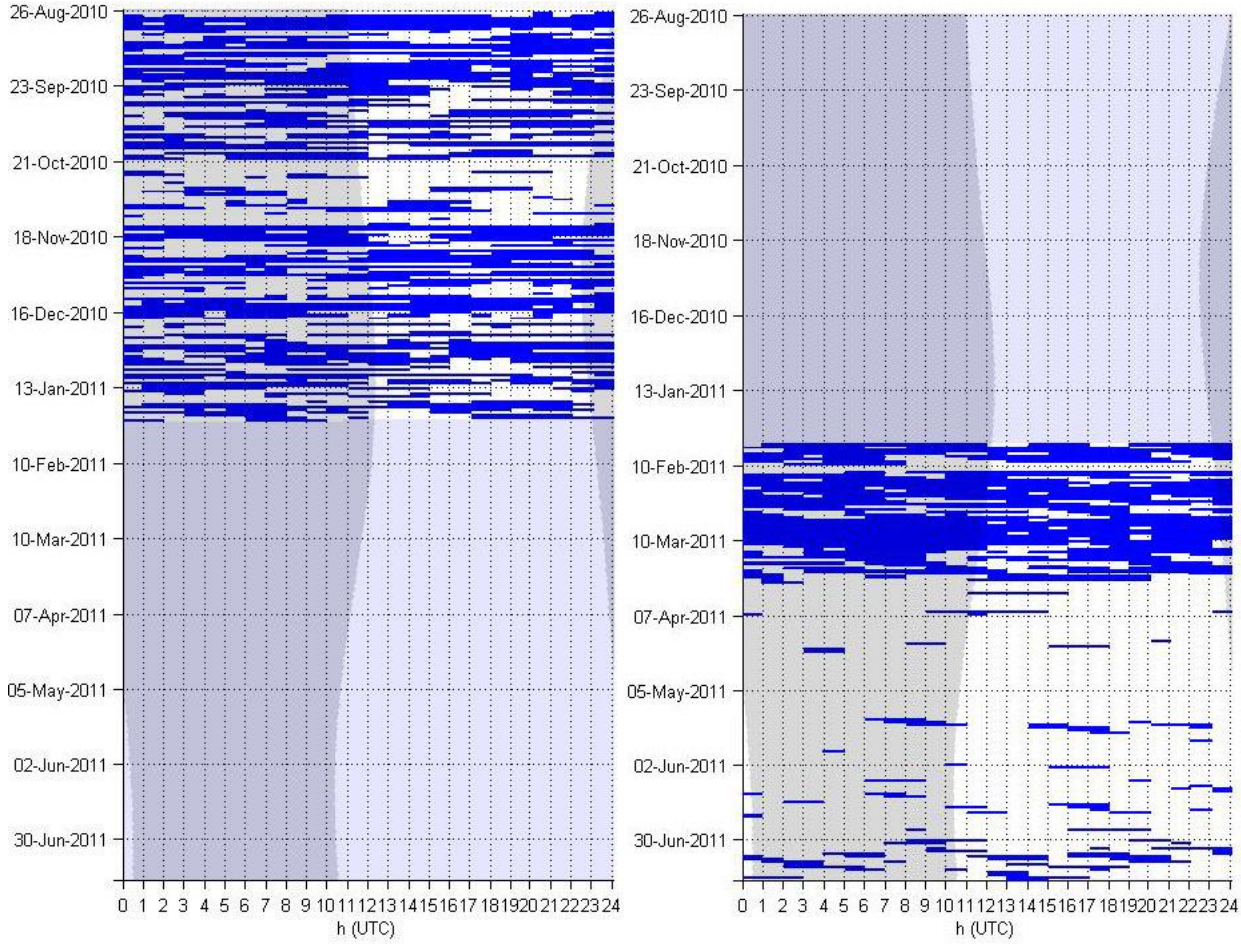
Sei whale – Downsweeps in hourly bins at site A. No calls were detected at site B.



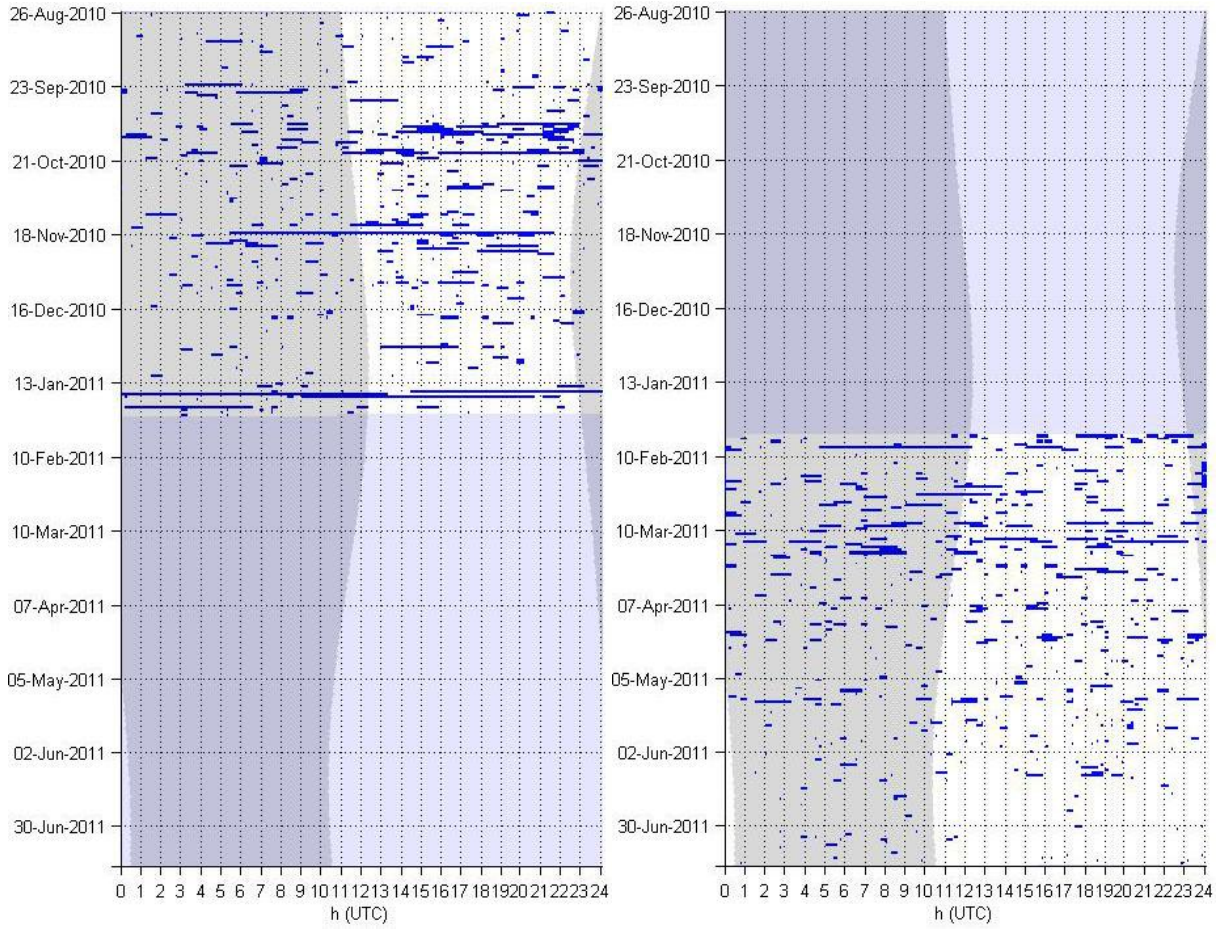
Humpback whale – Song and non-song calls detected in hourly bins at site B. No calls were detected at site A.



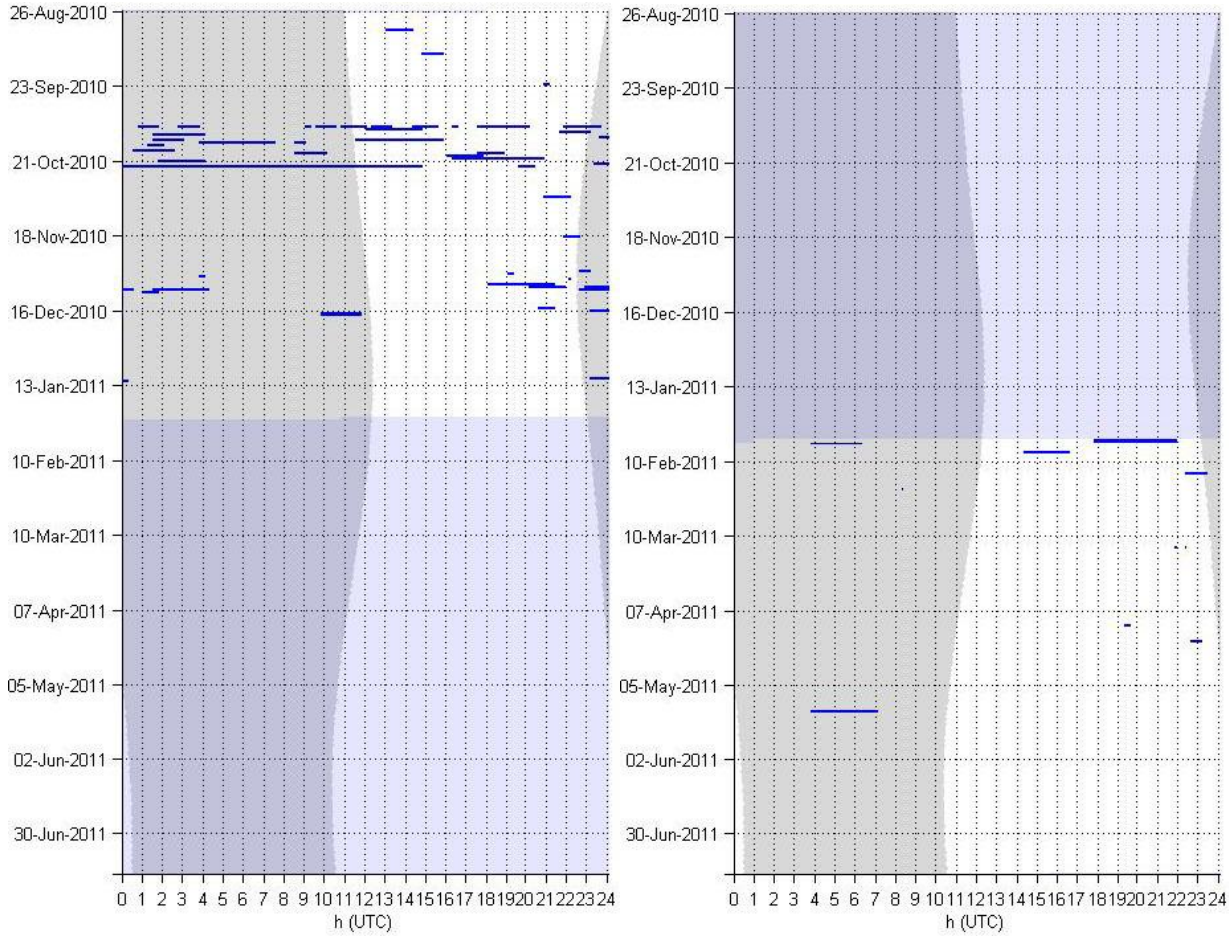
Unknown whale – 5-pulse calls in hourly bins at site A. No calls were detected at site B.



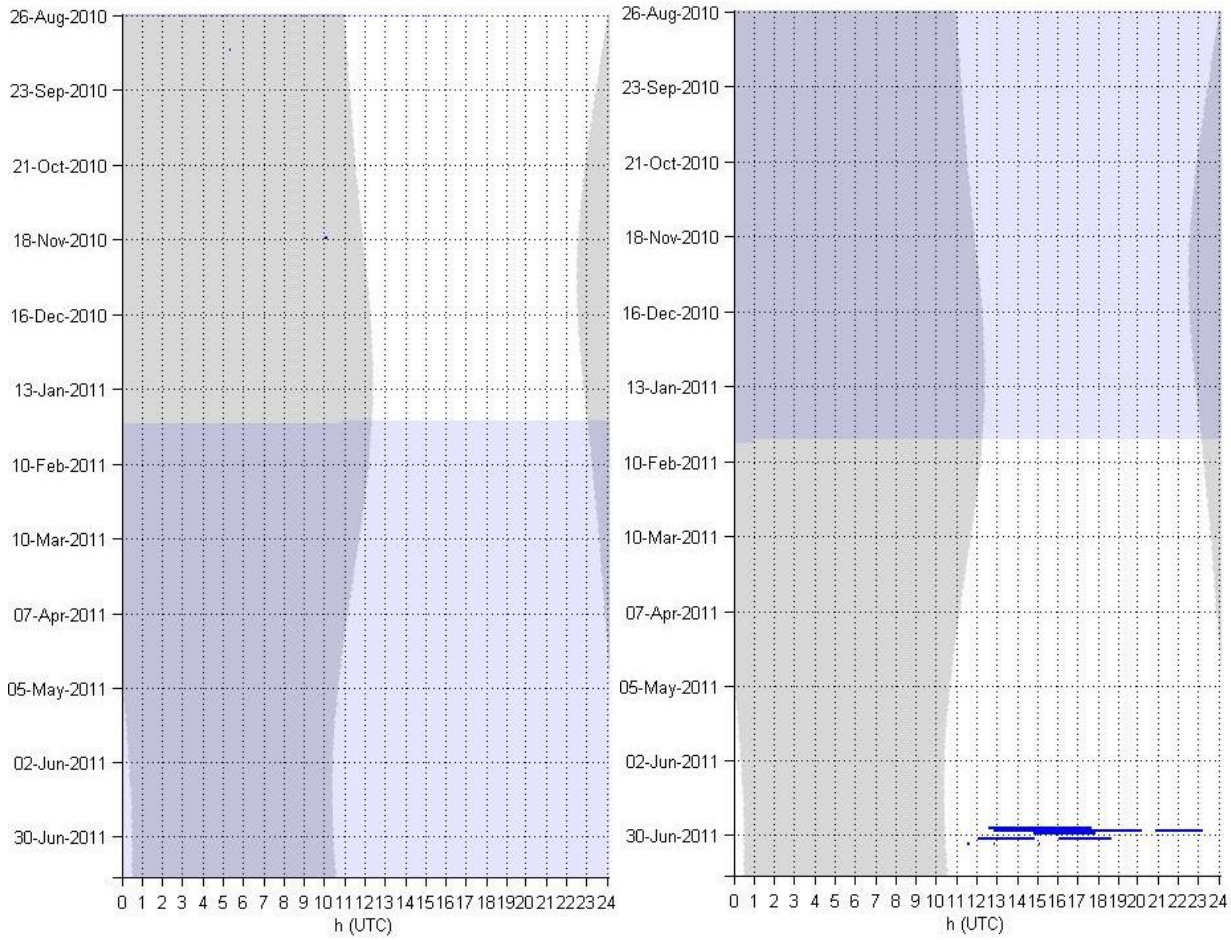
Low-frequency noise causing call masking – Occurrence in hourly bins at sites A (left) and B (right).



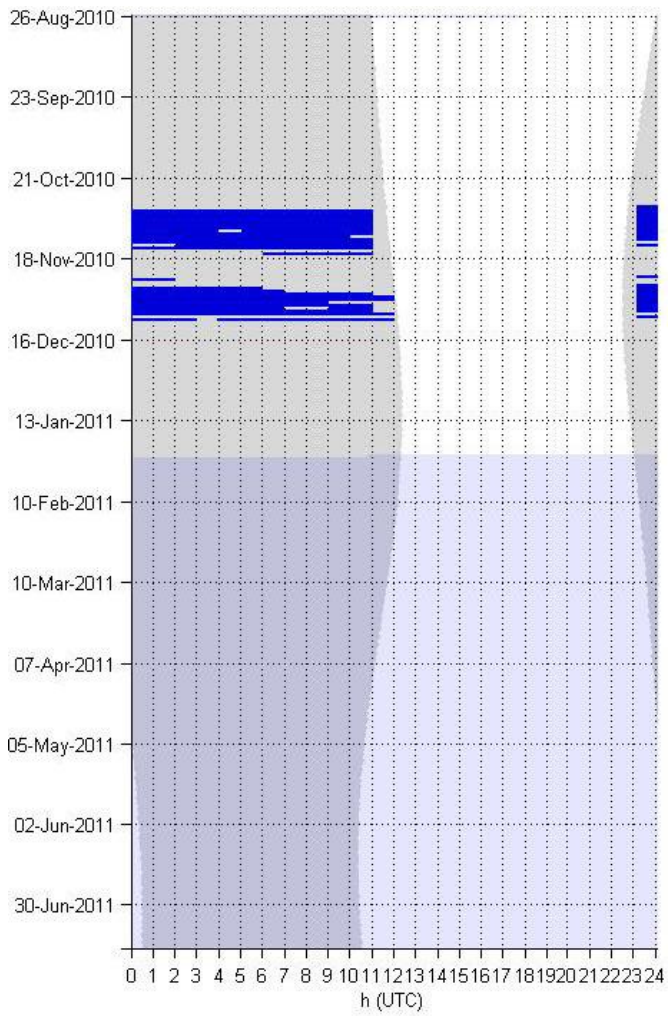
Broadband shipping – Occurrence in hourly bins at sites A (left panel) and B (right panel).



Mid-frequency active sonar – Occurrence in hourly bins at sites A (left panel) and B (right panel).



Explosions – Occurrence in hourly bins at sites A (left panel) and B (right panel).



130-Hz tone – Sounds recorded in hourly bins at site A.