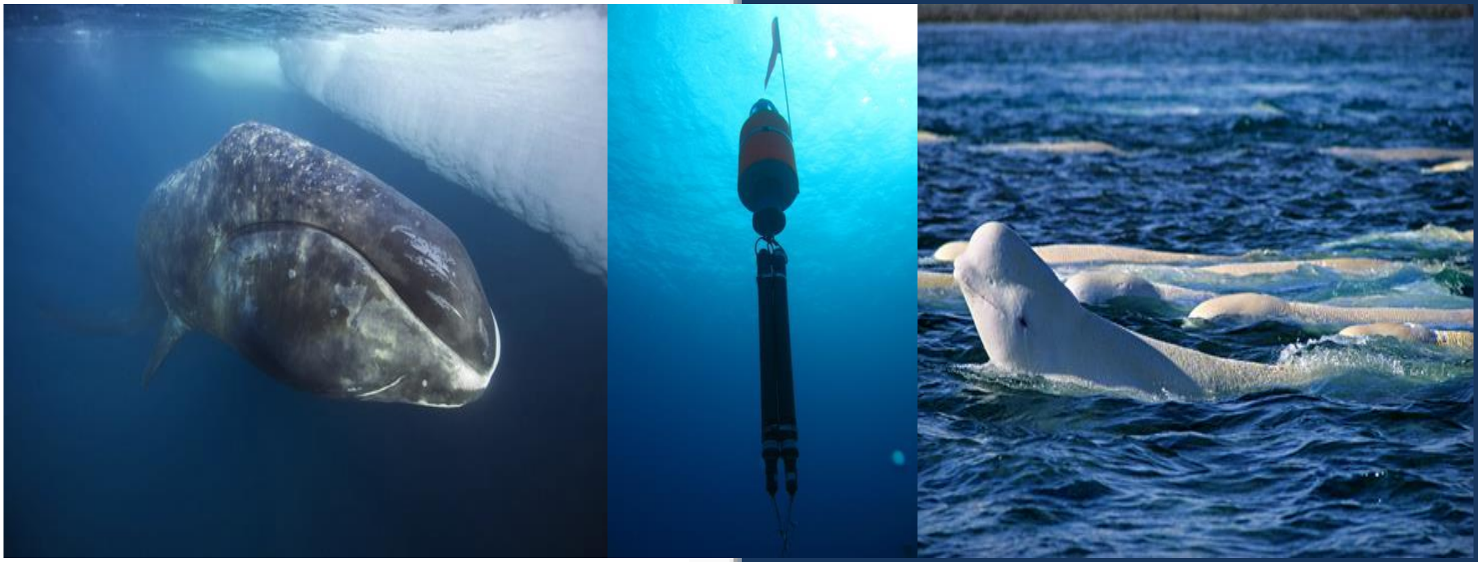
Acoustic Monitoring using Ecological Acoustic Recorders (EAR) in the Coleville River Delta, Beaufort Sea, Alaska during the SAE Seismic Survey, Fall 2014



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Photos:

Bowhead Whale: Holmes, M. [Photo of Bowhead Whale], Nature Picture Library. Retrieved from www.arkive.org.

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Executive Summary

In late August 2014 four second-generation Ecological Acoustic Recorders (EARs) were deployed in the Colville River Delta to measure ambient noise levels and monitor marine mammal calls relative to seismic surveys conducted by SAExploration (SAE). This monitoring was required under an incidental Harassment Authorization (IHA) issued to SAE by the National Marine Fisheries Service (NMFS). The EARs were deployed over 10 km north, northwest and west of the seismic survey. Each EAR was set to record on a 50 percent duty cycle (i.e., recording for 1-minute every 2-minutes), with a sample rate of 50 kHz. The original recording plan was to begin recording at least 24 hours before seismic survey operations commenced, and continue recording throughout the duration of the seismic survey, ending three days after operations ceased. Upon recovery of the EARs, it was determined that they did not record for the entire deployment period due to mechanical issues. However, almost 400 hours of acoustic data for the period August 29 through September 14, 2014 were successfully recorded and analyzed. Bioacousticians from OSI retrieved and downloaded the data, and created long-term spectral averages (LTSAs) for recordings from each EAR using the Matlab™ based software Triton (Wiggins 2007). LTSAs were created from both the original, full-bandwidth data, as well as from data down-sampled to 5 kHz for low frequency analysis.

OSI bioacousticians analyzed high frequency band (2.5 to 25 kHz) data recorded by the EARs to determine the presence of marine mammal species, fish and anthropogenic sound sources that produce higher frequency sounds. Bio-Waves, Inc. bioacousticians analyzed the down-sampled, low frequency band (0 to 2.5 kHz) data. For both the high and low frequency analysis, data were first examined in the LTSAs to locate and log any long periods of identifiable acoustic activity. Bioacousticians then examined each individual 1 minute .wav file in the dataset using Triton software, logging all sounds produced by marine mammal, fish or anthropogenic sources. Sounds from these three classification categories were logged as a single encounter when an interval of less than 30 minutes occurred between sounds and as separate encounters when more than 30 minutes of silence occurred between sounds. Graphs were compiled to show daily acoustic encounters and the percent total recording time containing acoustic encounters by EAR site. Probability of acoustic encounter occurrence relative to reported seismic activity was calculated for the three species or species groups with sufficient sample sizes: beluga whales, bowhead whales, and unidentified fish. Ambient noise levels at each EAR were calculated using a custom Matlab™ algorithm (developed by OSI). This algorithm calculated the averaged root-mean-square (RMS) sound pressure level (SPL) for each file. This calculation was performed for the full frequency band (0-25 kHz) and also the following five 1-octave frequency bands: 0-1.5625 kHz, 1.5625-3.125 kHz, 3.125-6.25 kHz, 6.25-12.5 kHz and 12.5-25 kHz.

Noise levels varied by site, with a full frequency band average noise level (RMS SPL) of 98.8 dB at EAR 59, 101.7 dB at EAR 60, and 105.4 dB at EAR 62. Daily average noise level was highest September 2 through September 3 based on EAR data spanning August 29-September 14. At EAR 60, which recorded for the longest duration (17 days), noise levels were also relatively high on September 7 and September 13-14. There was little variation in average noise level by hour of the day at any EAR, with only a slight peak in noise level at approximately 1700 at EAR 59. There were also relatively higher noise levels in the 0-1.5625 kHz octave band and in the full frequency band between 0700 and 1500 hours at EAR 62. Self-noise was present in recordings from all EARs, especially EAR 60 and 62, most likely due to their proximity to surface currents and the resulting movement of the moorings. No seismic acoustic activity was detected on any of the EAR recordings. We hypothesize this was most likely due to the extremely shallow water in the seismic survey and EAR deployment areas and the acoustically absorptive properties of the seafloor, which limited sound propagation. Additionally, during the recording period, seismic surveying occurred only in the eastern portion of the study area, estimated to be approximately 10 km or more from the nearest recording EAR.

Beluga whale, bowhead whale, bearded seal and ringed seal sounds were identified in the EAR datasets. Beluga whale sounds were the most commonly recorded marine mammal sound, comprising the largest percentage of the total number of encounters at all EAR locations. This result was not surprising given the known distribution of beluga whales in the Beaufort Sea nearshore environment during late August and September (Richard et al. 2001, Allen and Angliss 2014). The probability of a beluga whale acoustic encounter was significantly higher (Probability [P] = 0.35; P = 0.11, respectively) during reported seismic activity versus when there was no reported seismic activity (P = 0.19; P = 0.04, respectively) at EARs 59 and 62 (2-sample z-test, p = 0.00; p = 0.003, respectively), and not significantly different for the two conditions at EAR 62 (2-sample z-test, p = 0.139), which only recorded for six days. The reasons for this difference are not clear given the differences in recording durations and locations of each EAR. There were 12 acoustic encounters of bowhead whales at EAR 60. The probability of the occurrence of a bowhead whale acoustic encounter during reported seismic activity (P= 0.02) was not significantly different (2-tailed z-test, p = 0.072) than the probability of the occurrence of a bowhead whale acoustic encounter when there was no reported seismic activity (P = 0.01).

Ringed and bearded seal calls were only detected during small percentages of the overall recording time and only at EAR 60. This suggests that these two species of pinnipeds were either uncommon in the study area during the recording period, or that they were present but were not vocalizing frequently in the vicinity of the EARs.

There were several biological sounds that bioacousticians were not able to identify to species. These were identified to the lowest taxonomic classification possible (e.g., unidentified cetacean, unidentified pinniped, unidentified marine mammal, unidentified fish, or unidentified biological). Unidentified fish occurred regularly at EAR 59 and more sporadically at EARs 60 and 62. The probability of an unidentified fish acoustic encounter relative to seismic status differed by EAR location. At EAR 59, it was significantly higher (2-sample z-test, p = 0.005) during reported seismic activity (P = 0.70) versus when there was no reported seismic activity (P = 0.58). In contrast, at EAR 60, this detection probability was significantly lower (2-sample z-test, p = 0.003) during reported seismic activity (P = 0.01) versus when there was no reported seismic activity (P = 0.03) at EAR 60. Probability analysis was not conducted for unidentified fish encounters at EAR 62 due to insufficient sample.

Anthropogenic sounds detected included ship noise, active sonar, and other unknown anthropogenic sounds. One such sound was a broadband signal identified in the frequency band from approximately 2 to 8 kHz. There were 13 acoustic encounters of this unknown anthropogenic sound at all three EAR sites during three consecutive days (August 31 – September 2) for a total of 16.5 hours. At times, this signal occurred regularly every 16 seconds, but at other times its occurrence pattern was haphazard. This sound appeared to be correlated with seismic activity during those days and therefore might be related to seismic survey activities.

This report describes marine mammal call occurrence and distribution in the Colville River Delta study area, provides valuable insights about marine mammal presence that could not be obtained by visual observations alone, and offers recommendations for future work that would allow for improved understanding of the relationship between marine mammal occurrence and vocal behavior relative to seismic activities.

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Acronyms and Abbreviations

BCB	Bering-Chukchi-Beaufort (Bowhead whale stock)
dB	Decibels
EAR	Ecological Acoustic Recorder
EARII	Ecological Acoustic Recorder (Second Generation)
Hz	Hertz
IHA	Incidental Harassment Authorization
kHz	Kilohertz
kgs	Kilograms
km	Kilometers
LTSA	Long-term spectral averages
m	Meters
NMFS	National Marine Fisheries Service
OSI	Oceanwide Science Institute
PAM	Passive Acoustic Monitoring
QA/QC	Quality Assessment/Quality Control
RMS	Root mean square
SAE	SAExploration
SES	Smultea Environmental Sciences
SNR	Signal-to-Noise Ratio
SPL	Sound pressure level
SSD	Solid state drive
UNID	Unidentified

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1. INTRODUCTION

1.1 Background

Passive acoustic monitoring (PAM) using autonomous recorders is an effective method for monitoring the presence of marine mammals in diverse habitats and geographic locations (Clark et al. 2002, Clark and Clapham 2004, Baumgartner et al. 2008, Mellinger et al. 2007). Autonomous recorders have been used to investigate the acoustic behavior of several different marine mammal species in the presence of anthropogenic noise (Nieukirk et al. 2004, Di Iorio and Clark 2010, Castellote et al. 2012, Melcón et al. 2012, Risch et al. 2012) and have been proven effective for long-term monitoring of marine mammals and ambient noise in Arctic waters (Moore et al. 2006, Blackwell and Greene 2006, Blackwell et al. 2007, Stafford et al. 2007, Moore et al. 2010).

In August and September 2014, Oceanwide Science Institute (OSI) deployed four autonomous recorders in the Colville River Delta. These deployments were intended to coincide temporally and geographically with seismic surveys that were being conducted in the general area by SAExploration (SAE). These Ecological Acoustic Recorders (EARs) were deployed to the north, northwest and west of the seismic survey area. All EARs were pre-configured to start recording for at least 24 hours before operations and continue to record throughout the entire duration of the project, which was expected to end between late September and early October. All recorders were collected three days after seismic survey operations ceased. After recovery, it was found that the EARs did not record for the entire period of deployment, however acoustic data was successfully recorded and analyzed for the period between August 29 and September 14, 2014.

The project was conducted in shallow (<10 m), nearshore waters off the Colville River Delta. Based on previous studies in the Beaufort Sea, several marine mammal species were expected to occur in the region, including spotted seals (*Phoca largha*), ringed seals (*Pusa hispida*), bearded seals (*Erignathus barbatus*), beluga whales (*Delphinapterus leucas*), and possibly bowhead whales (*Balaena mysticetus*) (Blood 1977, Alaska Department of Fish and Game 2006, Moore et al. 2006, Cobb et al. 2008, Boveng et al. 2009, Charif et al. 2013). All of these species were expected to occur in the study area during the deployment period.

Other species have been documented in the Bering and Chukchi Seas, but were considered unlikely to be encountered, either because of seasonal migration patterns or because their expected ranges occur outside the study area. These species include gray whales (*Eschrichtius robustus*), killer whales (*Orcinus orca*), walrus (*Odobenus rosmarus*), and ribbon seals (*Histriophoca fasciata)* (Dyke et al. 1999, the Carmack and Macdonald 2002, Alaska Department of Fish and Game 2006, Cobb et al. 2008).

In this report we provide a summary of the occurrence of marine mammal species based on acoustic encounters in the EAR recordings. We also document sources of anthropogenic noise and measure noise levels at each EAR location. The goals of this study were:

1. To determine ***if*** marine mammal species were present in the study area during the deployment period.
2. To determine which species, if any, were present in the recordings.

3. To determine what temporal patterns of occurrence, if any, the detected species exhibited at each deployment location.
4. To determine how ambient noise levels, including noise from seismic surveys, varied over the deployment period and among the recording locations.

Below are descriptions of general distribution and vocal characteristics for species expected to occur in the Colville River Delta study area.

1.1.1 Bowhead whale

Bowhead whales in U.S. Arctic waters are part of the Western Arctic stock, also known as the Bering-Chukchi-Beaufort (BCB) stock (Rugh et al. 2003, Allen and Angliss 2014). These whales are migratory, and spend the summer months (June to September) feeding in the Canadian and Eastern Alaskan Beaufort Sea, before migrating through the Beaufort and Chukchi Seas into the Bering Sea for the winter months (Braham et al. 1980, Moore and Reeves 1993). The BCB stock of Bowhead whales were expected to occur near the study area during the deployment period, however they would most likely occur in deeper waters outside of the study area.

Bowhead whales produce several types of low-frequency vocalizations, including 'moans' (ranging between 25 and 900 Hz), songs (ranging from 20 Hz to 5 kHz), and pulsed calls (ranging up to 3.5 kHz; **Figure 1**; Clark and Johnson 1984, Cummings and Holliday 1987, Stafford et al. 2008, Tervo 2011, Thode et al. 2012, Charif et al. 2013, Hannay et al. 2013). Based on the known occurrence of bowhead whales in the Beaufort Sea, it was expected that sounds produced by bowhead whales would be detected in the low frequency acoustic data.

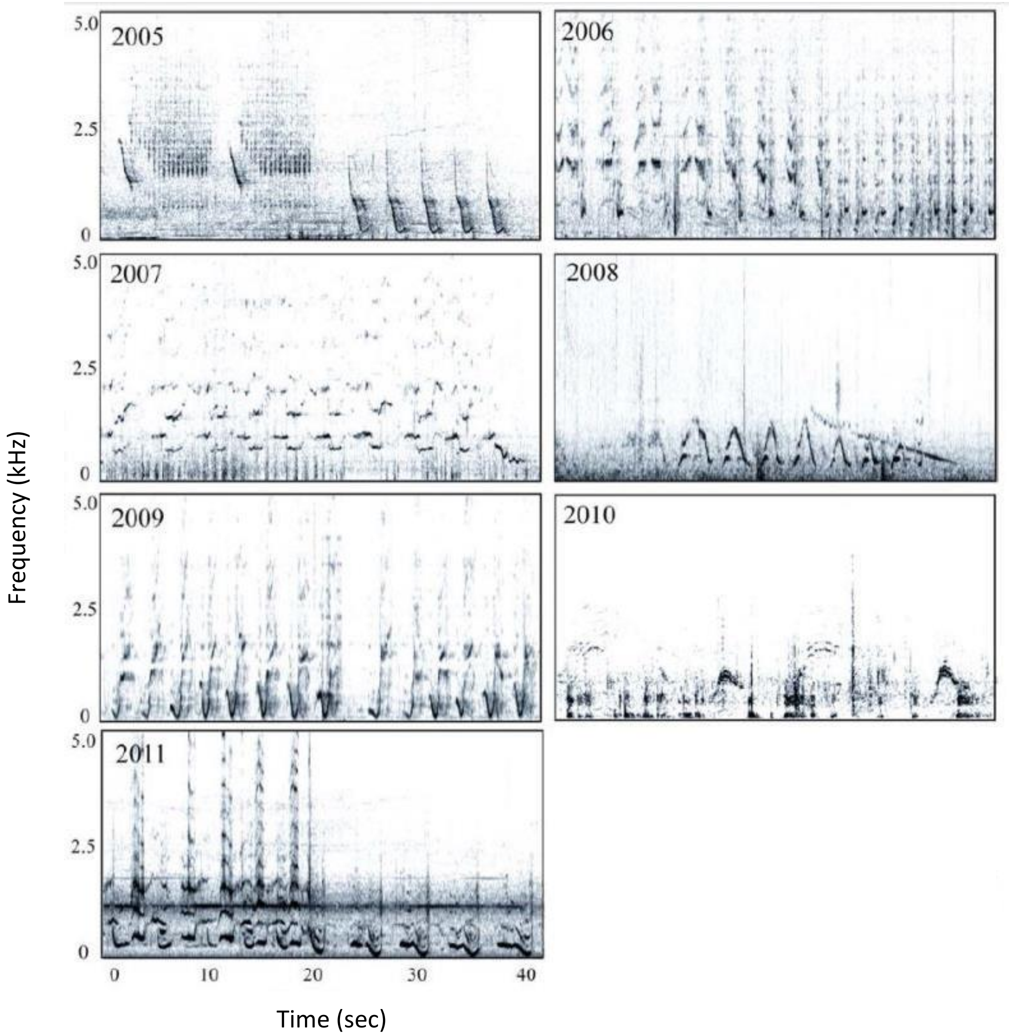

Figure 1. Examples of bowhead whale songs recorded in Disko Bay, Western Greenland, in 2005-2011. Figure adapted from "Acoustic behavior of bowhead whales, *Balaena Mysticetus*, in Disko Bay, Western Greenland" by O. Tervo, 2011, Doctoral dissertation, Museum of Denmark, The PhD School of Science, Faculty of Science, University of Copenhagen, Denmark.

1.1.2 Beluga whale

Beluga whales that occur within the study area are likely part of the Beaufort Sea stock, and would be most likely distributed in nearshore coastal waters, as well as offshore. Belugas are known to summer in the Eastern Beaufort Sea, but migrate west through Alaskan waters in the early fall to the Chukchi Sea, and move further offshore to where the pack-ice is (Richard et al. 2001, Allen and Angliss 2014). Therefore, it was expected that sounds produced by beluga whales would be detected in the acoustic data recorded by the EARs.

Belugas produce whistles with energy that is generally below 12 kHz (**Figure 2**), as well as echolocation clicks and burst pulses with higher frequency energy (Sjare and Smith 1986, Chmelnitsky and Ferguson 2012, Lammers et al. 2013, Hannay et al. 2013). Belgua whale echolocation clicks have peak frequencies between 40 and 120 kHz, but also contain energy down to approximately 20 kHz (Au et al. 1985, Lammers et al. 2013).

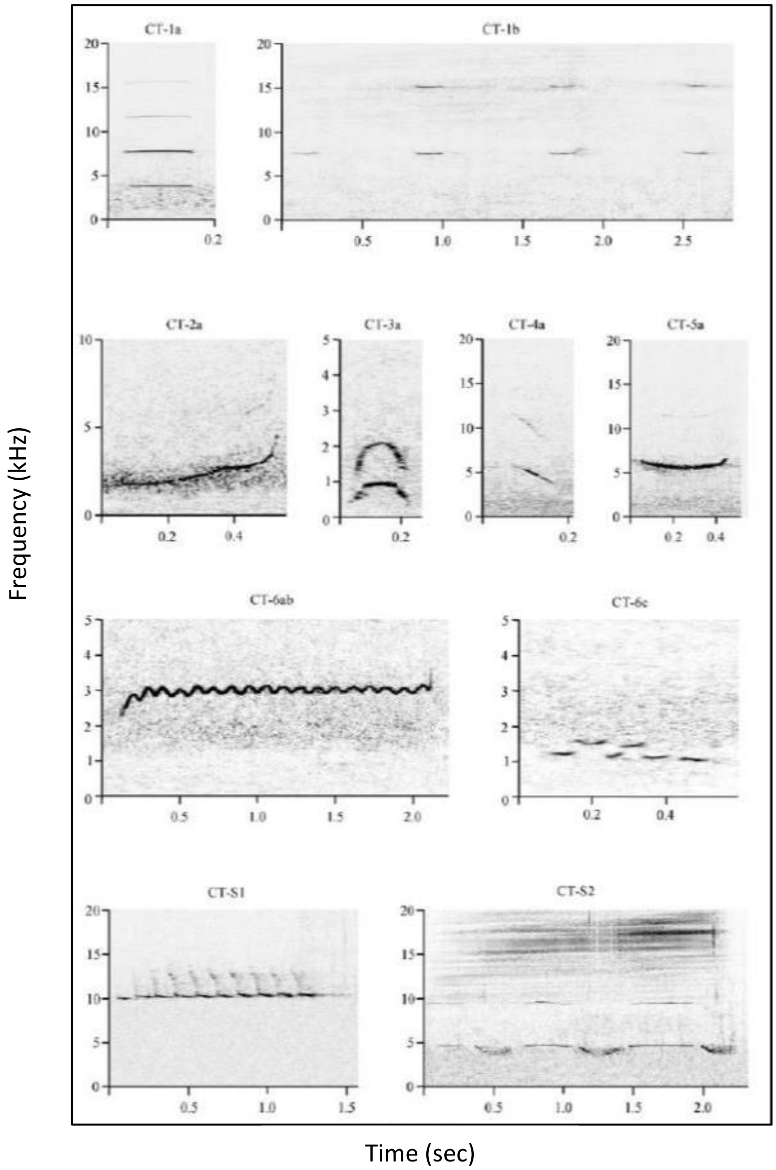

Figure 2. Examples of beluga whale whistle types recorded in Van Keulenfjorden, Svalbard. Figure adapted from "Summer vocalisations of adult male white whales (*Delphinapterus leucas*) in Svalbard, Norway" by J.D. Karlsen et al., 2002, *Polar Biology* 25: 808-817.

1.1.3 Bearded Seal

Bearded seals have a circumpolar distribution, and are known to occur throughout the Beaufort, Bering and Chukchi Seas. As this species feeds mainly on benthic organisms, they are predominantly found in coastal waters less than 200 m deep, and prefer areas with 70 to 90 percent sea-ice coverage (Bengtson et al. 2005, Simpkins et al. 2003, Allen and Angliss 2014). Although bearded seals exhibit a limited southern migration in the winter months, their vocalizations have been recorded year-round in the Beaufort Sea, usually associated with the presence of sea ice (MacIntyre et al. 2013, Allen and Angliss 2014, Jones et al. 2014).

Bearded seal vocalizations can be identified by their characteristic trills, moans, sweeps and flat tones (**Figure 3**; Van Parijs et al. 2001, Risch et al. 2007, Jones et al. 2014). The trill is a relatively long-duration (15 - 45 seconds), frequency-modulated, cascading vocalization that starts around 4 kHz and descends to approximately 0.3 kHz (**Figure 3a-d**). The sweep is similar to the trill, but shorter in duration (4 - 6 seconds), with a swift descent in the middle of the call. The moan is a descending tone with two or more harmonics, lasting 1.5 – 14 seconds with a frequency range between 0.3 and 21.7 kHz (**Figure 3f**). One additional vocalization described (but not depicted in Figure 3) is the 'flat tone' which is composed of a single, short (0.7- 4 seconds) vocalization between 0.2 and 1.3 kHz (Van Parijs et al. 2001). As bearded seals are known to occur in the Beaufort Sea year-round, it was expected that their vocalizations would be present in the low-frequency acoustic data recorded by the EARs.

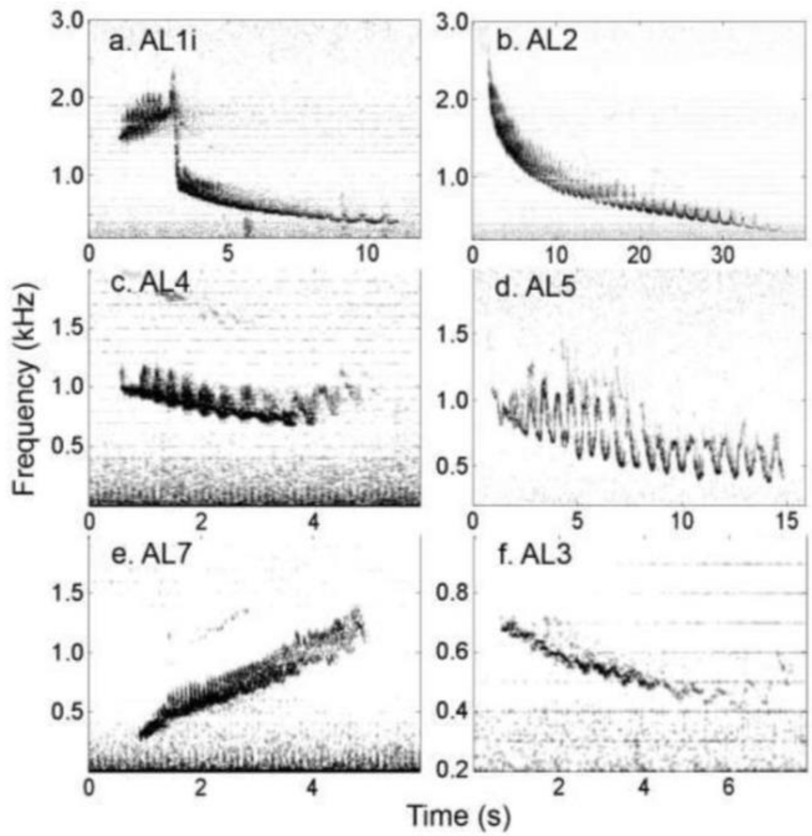

Figure 3. Examples of bearded seal call types recorded in the Chukchi Sea during 2008-2009. Panels a through d are examples of trills, panel e is an example of an ascent, and panel f is an example of a moan. Figure adapted from "Ringed, Bearded, and Ribbon Seal Vocalizations North of Barrow, Alaska: Seasonal Presence and Relationship with Sea Ice" by J.M. Jones et al, 2014, *Arctic* 67(2): 203-222.

1.1.4 Spotted Seal

Spotted seals are distributed along the continental shelf throughout the Bering, Chukchi and Beaufort Seas (Allen and Angliss 2014). During late fall through early spring months, spotted seals are associated with sea ice and use broken ice flows as haul out areas for breeding and whelping. As the ice moves further offshore, the seals follow in order to remain near areas of open water for foraging purposes (Burns 2002, Boveng et al. 2009). During the spring and summer months, when the sea-ice breaks up, spotted seals migrate from the Bering Sea to the north into the Chukchi and Beaufort Seas (Burns 1970, Burns 1973, Lowry et al. 1998). During migration they remain close to the coastline, in areas with accessible food resources and haul-out sites (Burns 2002, Boveng et al. 2009). Because of their nearshore distribution throughout the Beaufort Sea, this species was expected to occur within the study area.

Little is known about the vocalizations of spotted seals, as there are only a few confirmed recordings of spotted seals in the wild. A study conducted by Beier and Wartzok (1979) describes vocalizations from a captive mating pair of spotted seals. The authors described five different underwater call types: 1) growls (short sound bursts with peak frequency between 500 Hz and 2 kHz), 2) drums (short pulses with short inter-pulse intervals, and peak frequencies between 500 Hz and 3.5 kHz), 3) chirps (short, 1.1 kHz pure tones), 4) barks (short calls with a fundamental frequency of approximately 1.3 kHz, and at least two harmonics) and, 5) creaky doors (short, pure tone segments between 2.1 and 2.8 kHz).

1.1.5 Ringed seal

Ringed seals have a circumpolar distribution, and can be found throughout the Bering, Chukchi and Beaufort Seas, commonly associated with sea ice (Kelly 1988, Allen and Angliss 2014). Little is known of the migratory movements of ringed seals. Limited information suggests that they generally move north from the Bering Sea during the spring and summer months to the pack-ice in the northern Chukchi and Beaufort Seas, and migrate back towards the Bering Sea in the fall and winter, with some animals remaining in the Beaufort Sea year-round (Crawford et al. 2012, Allen and Angliss 2014). Ringed seals were expected to be detected in the acoustic data recorded by the EARs.

Ringed seals are known to produce several different call-types described as yelps, barks, growls and woofs, with low, medium and high-pitched subtypes of these calls (**Figure 4**; Stirling 1973, Smith and Stirling 1978, Stirling et al. 1983, Calvert and Stirling 1985, Jones et al. 2014). Calls are short in duration (<0.5 seconds), vary in frequency (generally between 100 – 950 Hz), and are commonly grouped into vocalization sequences that include alternating barks and yelps (Jones et al. 2014).

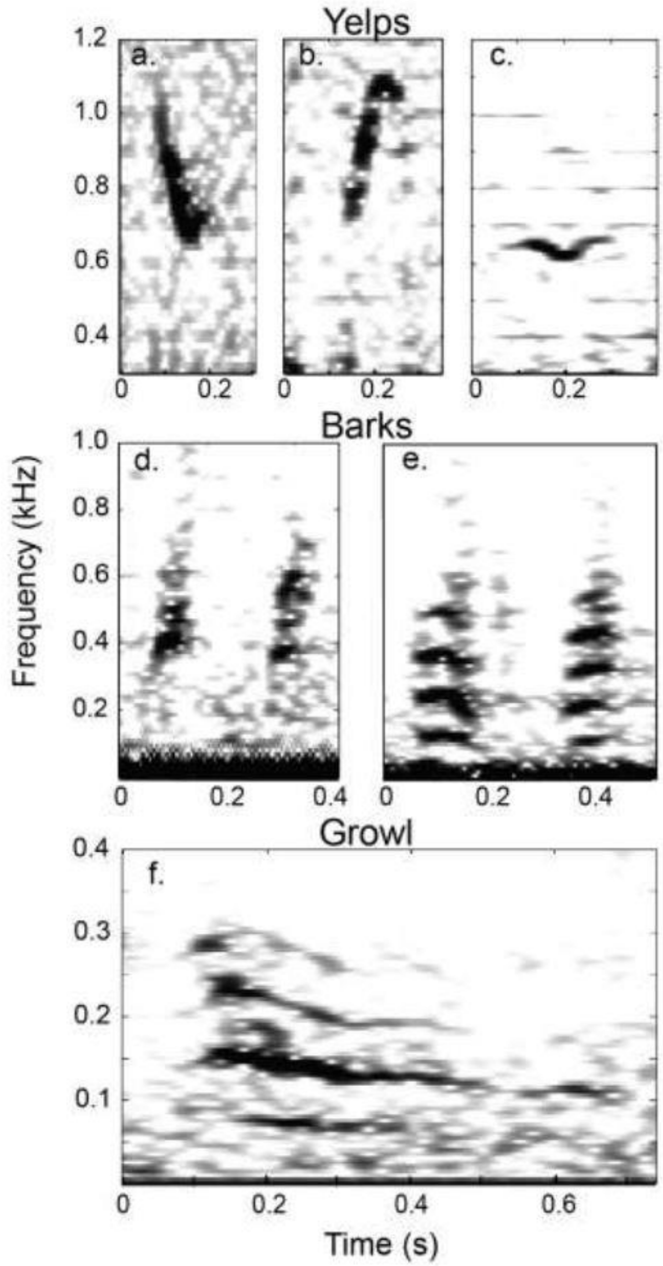

Figure 4. Examples of ringed seal yelp, bark and growl call types recorded in the Chukchi Sea in 2008-2009. Figure adapted from "Ringed, Bearded, and Ribbon Seal Vocalizations North of Barrow, Alaska: Seasonal Presence and Relationship with Sea Ice" by J.M. Jones et al, 2014, *Arctic* 67(2): 203-222.

2. METHODS

2.1 Data Collection

2.1.1. EAR Deployment

On August 29, 2014, OSI staff deployed four second-generation EARs in support of SAE's Incidental Harassment Authorization (IHA) requirements for passive acoustic monitoring of marine mammals during seismic explorations in the Colville River Delta. Each EAR was deployed as part of a mooring composed of an EAR, a syntactic foam float, an acoustic release device, and a sand bag (approximately 68 kgs) used as a mooring anchor (**Figure 5**).

The EARs were programmed to record for 60 seconds every 120 seconds (a 50 percent duty cycle) at a sampling rate of 50 kHz, providing an effective recording bandwidth of approximately 25 kHz.

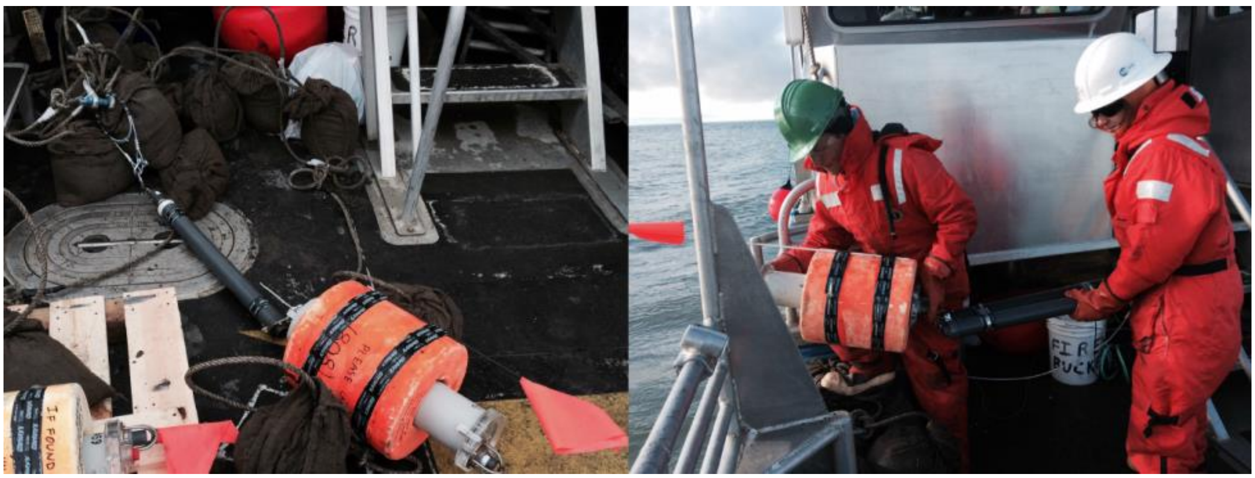

Figure 5. EAR mooring on deck of vessel prior to deployment and while being deployed.

Based on consultation with SAE, the EAR moorings were deployed at the following Locations (**Table 1, Figure 6**):

Table 1. Locations and water depths of deployed EARs.

EAR	Location	Coordinates	Water Depth (m)
55	Northeast	N 70' 34.610, W 149' 47.015	7.92
59	West	N 70' 31.300, W 150' 10.526	3.96
60	Far northwest	N 70' 34.410, W 150' 11.210	7.62
62	Northwest	N 70' 34.146, W 150' 03.505	7.92

An attempt was made to deploy EAR #60 at a site to the southeast of the Spy Island region (**Figure 6**), but that location was only 2.44 m deep, which was too shallow for the mooring. The full mooring requires a minimum water depth of 3.05 m for deployment due to the length of the EAR, the acoustic release device and the cable connecting the mooring to the sand bags. In the future, a shallower deployment configuration is feasible, but would require advanced planning.

OSI staff members returned to the study site to recover the instruments on September 28, 2014. All four EAR units were successfully recovered, including EAR 59 which was considered to be the most problematic mooring because of the extremely shallow water depth (3.96m). This EAR was located only 0.9 – 1.2 m from the surface, which exposed the mooring to additional physical stress from surface-breaking waves.

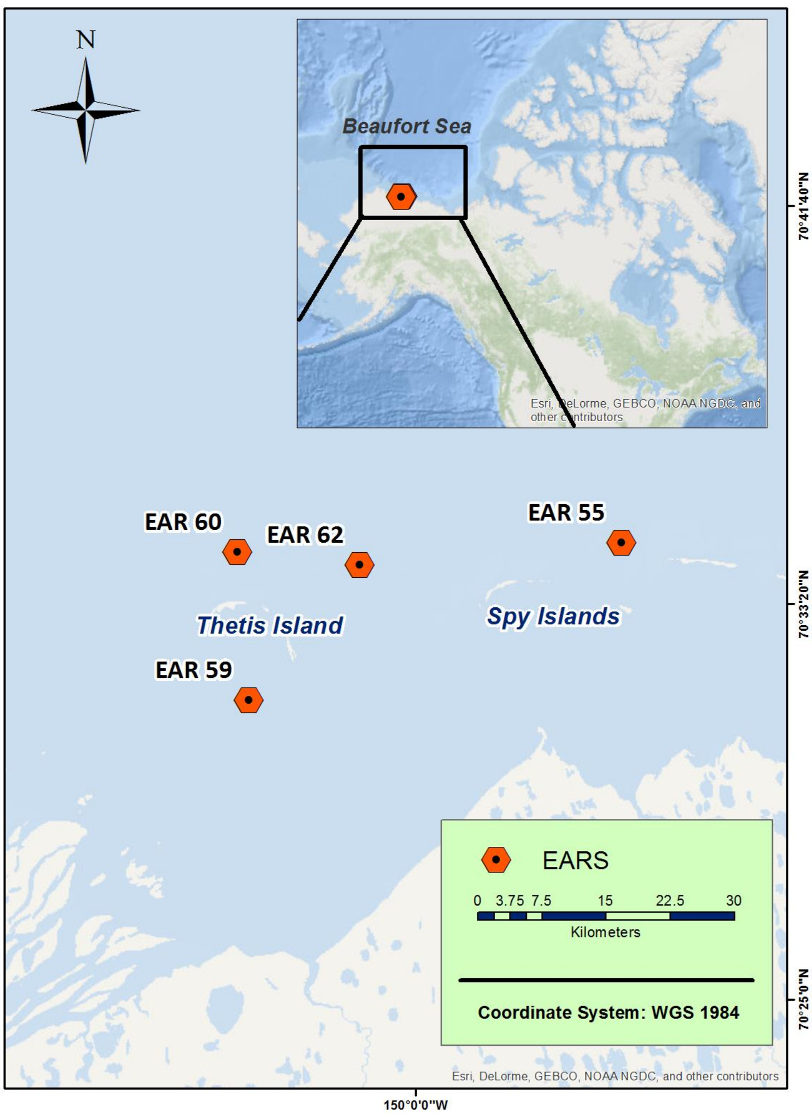

Figure 6. EAR deployment locations in the Colville River Delta

2.2 Data Logging and Analysis

2.2.1 High Frequency Logging Methods

Bioacousticians from OSI analyzed high frequency (2.5 to 25 kHz) data recorded by the EARs to determine the presence of marine mammal species and anthropogenic sources that produce higher frequency sounds. In order to initially review the presence of sounds from marine mammal species and anthropogenic sources, a long-term spectral average (LTSA) was created for each deployment using Triton, a Matlab™ based program (Update 4-9, Wiggins 2007). Because masking caused by broadband noise from surface-breaking waves and mooring self-noise made it difficult to identify calls within the LTSA for these data (**Figure 7**), the analysis was conducted by examining each 1 minute .wav file individually in Triton's spectrogram mode, using a plot length of 20 seconds.

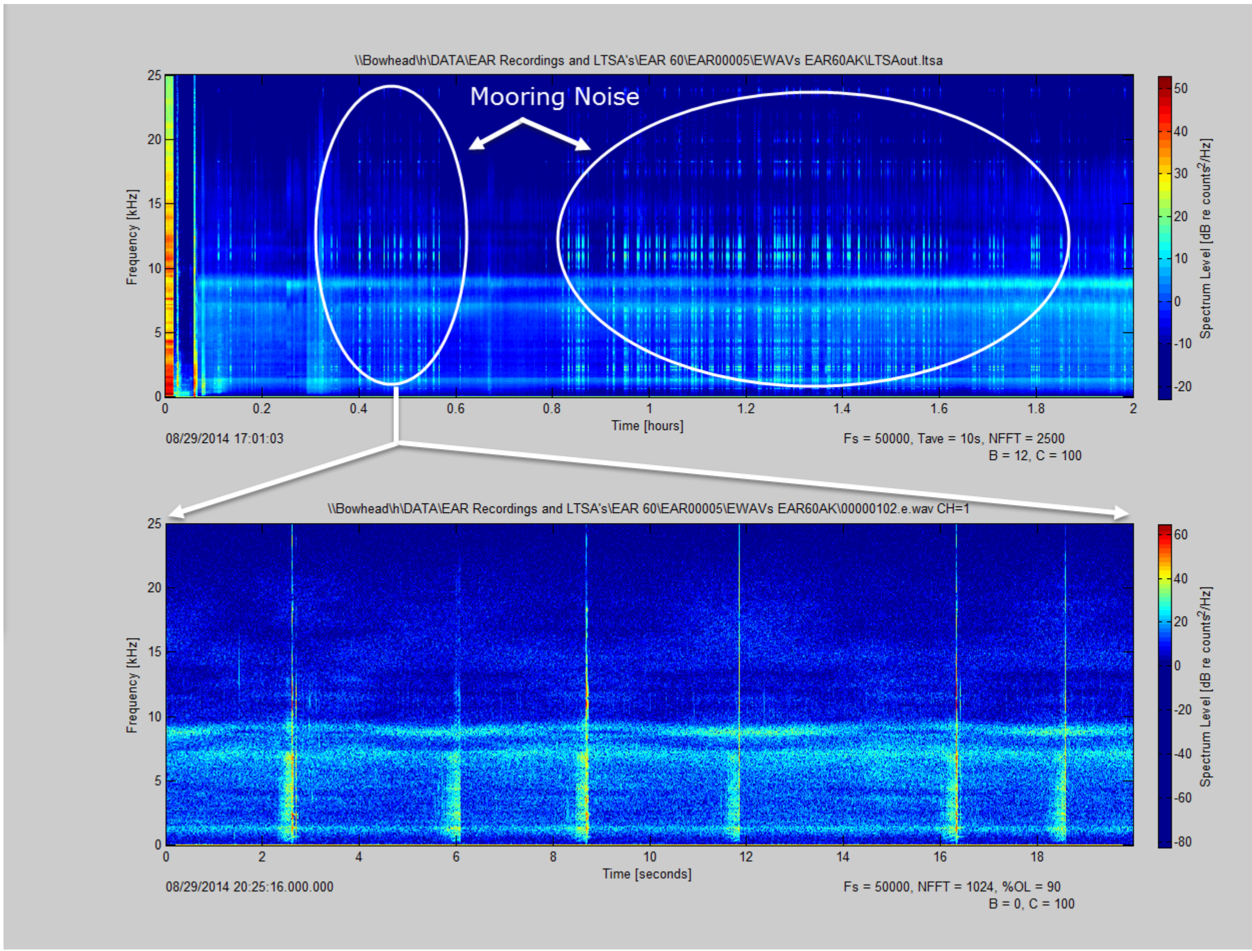

Figure 7. Example of an LTSA (top panel) and a spectrogram (bottom panel) from EAR 60. Broadband mooring noise was present throughout the LTSA, which made it difficult to detect biological signals. Mooring noise is apparent in both the full LTSA and in the spectrogram which shows a 20 second section of the LTSA. Frequency range 0 – 16 kHz.

When biological¸ anthropogenic or unknown biological/anthropogenic sounds were detected, they were reviewed by an experienced bioacoustician who examined the files aurally (using a headset) and visually (spectrographic display) to verify, classify, and log the start and end times of the encounter. An acoustic encounter was defined to include any sounds from the same classification category with an interval of less than 30 minutes between sounds. If an encounter spanned more than one day, each subsequent day was split into separate events. For example, if belugas started calling at 23:00 on September 1st and continued calling until 03:00 September 2nd, this encounter would be split at 00:00 on September 2nd into two separate encounters. If two seemingly unrelated sounds (i.e. belonging to different classification categories) occurred at the same time, they were logged as separate encounters. Anthropogenic noise was identified as accurately and completely as possible given the shallow water noise conditions. All biological signals were identified to the lowest taxonomic level possible. Any unknown sounds were sent to outside experts to confirm group or species identification. Descriptive codes for each sound type, including unknown sounds, were created to allow efficient logging of all sounds detected (**Table 2**).

Table 2. Descriptive codes used for logging high frequency sounds.

Source	Call Type
Beluga	Burst Pulse
	Buzz
	Clicks
	Pulsed Call
	Whistles
Pinniped	NA
Unidentified Biological	Chirp
	Clicks
	Unknown
Unidentified Cetacean	Clicks
	Unknown
Anthropogenic	Possible Engine
	Possible Sonar
	Unknown
Seismic Event	NA
Unknown	NA

Once logging had been completed, all logged acoustic encounters were submitted to Quality Assessment/Quality Control (QA/QC) protocols. First, each log was reviewed by a bioacoustician for accuracy and consistency, to confirm that: 1) start and end times of events were accurate, 2) all acoustic encounters of the same type that occurred within a 30-minute period were logged as one encounter, and 3) all acoustic encounters that had been labeled "unknown" were identified to the lowest taxonomic level possible. Once the QA/QC process had been completed, the logs were compiled into a single database for analysis.

2.2.2 Low Frequency Logging Methods

Bioacousticians at Bio-Waves, Inc. analyzed low frequency (0 to 2.5 kHz) data recorded by the EARs to determine the presence of marine mammal species and anthropogenic sources that produce lower frequency sounds. Specifically, all low frequency sounds produced by baleen whales, pinnipeds, fish, seismic activity and ships were logged. Recordings were down-sampled to 5 kHz by OSI, and LTSAs were generated using Triton software (Update 4-9, Wiggins 2007). Bio-Waves bioacousticians examined the LTSAs to locate and log any long periods of identifiable acoustic activity from the LTSA. Bioacousticians then proceeded to examine each individual one minute .wav file in the dataset using Triton software, and logged any marine mammal, fish or anthropogenic sounds present in the low frequency band. Acoustic encounters were defined and unknowns were handled in the same way as in the high-frequency analysis. Descriptive codes for each sound type, including unknown sounds, were created to allow efficient logging of all sounds detected (**Table 3**).

Once logging was completed, all logged acoustic events underwent the same QA/QC protocols described in section 2.2.1. High and low frequency logs were then compiled into a single database for analysis.

Table 3. Descriptive codes used for logging low frequency sounds.

Group	Species	Call Type
Mysticetes	Bowhead Whale	Moan Song
Odontocetes	Beluga Whale	Whistles
Pinniped	Bearded Seal	Trill
Pinniped	Ringed Seal	Bark Yelp Growl
Pinniped	Spotted Seal	Other
Fish	Unidentified Fish	Other
Unidentified Cetacean	Other	Other
Pinniped	Unidentified Pinniped	Other
Unidentified Marine Mammal	Unidentified Marine Mammal	Other
Unidentified Biological	Other	Other
Anthropogenic	Anthropogenic	Ship/Broadband Ship/Narrowband Sonar Other

2.2.3 Noise Analysis

The IHA issued to SAE required that PAM data be used to measure the ambient soundscape throughout the study area and to record received levels of sounds from industry and other activities. To quantify ambient noise, the data obtained by each EAR were processed using a custom Matlab™ algorithm (developed by OSI) that calculated the averaged root-mean-square (RMS) sound pressure level (SPL) for each file using the equation:

$$RMS\ SPL = 20 \log \sqrt{\frac{1}{T}\int_0^T p^2\,(t)dt}$$

Where:

T is the duration of each file, and

p(t) is the acoustic pressure waveform where:

t is the time in the waveform series, and

p is the instantaneous sound pressure (re: 1 uPa)

This calculation was performed for the full frequency band (0-25 kHz) and also the following five 1-octave bands: 0-1.5625 kHz, 1.5625-3.125 kHz, 3.125-6.25 kHz, 6.25-12.5 kHz and 12.5-25 kHz. These provided a measure of the overall ambient sound level and also the variation in acoustic energy over different frequency bands. The results were averaged by hour of the 24-hour day (e.g., 8 AM, 9 AM, etc.) over the course of each deployment.

2.2.4 Data Analysis

Acoustic encounter logs (Microsoft Excel files) were created for each day, at every EAR deployment site for both the low and high frequency band data using the Triton logging methods described above. A custom Matlab™ script (written by Bio-Waves) was used to combine all acoustic encounter logs into a single Excel database. From the Excel database, the number and duration of acoustic encounters was summarized by classification category and EAR. Acoustic encounter durations were divided by the total length of the deployment to obtain event durations as percentages of recording duration at each site to standardize duration measurements among sites.

In addition, encounters within each classification category were combined across all three recorders to determine the total number of encounters. Graphs of daily occurrence were made for each species and classification category that had sufficient data to plot. The percentage of days during which each encounter type was detected with respect to total recording days were also plotted by site, as was the percentage of total encounters by site.

2.2.5 Probability analysis

Custom-written Matlab™ scripts were used to calculate the probability of a biological acoustic encounter occurring in the presence and in the absence of reported seismic activity. These methods were based on the methods used in Melcón et al. (2012). The Matlab™ scripts stepped through the acoustic logs for each day and each EAR in 10 minute increments. Matrices were then created of the presence or absence of biological sounds (by species or species group) and reported seismic activity for each 10 minute interval. The probabilities of biological sounds in the presence and absence of reported seismic activity were calculated based on these matrices. The probability of the presence of biological sound in the presence of reported seismic activity was calculated as:

$$\frac{\#\ bins\ with\ biological\ and\ seismic}{(\#bins\ with\ biological\ and\ seismic) + (\#\ bins\ with\ only\ seismic)}$$

The probability of a biological acoustic encounter in the absence of reported seismic activity was calculated as:

$$\frac{\#\ bins\ with\ only\ biological}{(\#bins\ with\ only\ biological) + (\#\ of\ \ bins\ with\ no\ biological\ or\ seismic)}$$

These probabilities were calculated individually for each EAR and for each species or species group that had a large enough sample size. Two-tailed z-tests were conducted to examine whether the probability of biological acoustic encounters was significantly different with versus without seismic activity.

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3. RESULTS

3.1 Data Collection

All four EARs began recording as scheduled at 1700 on August 29, 2014. However, upon examination of the data obtained, it was found that the EARs did not record throughout the entire deployment period. Rather, each EAR stopped recording prematurely on different days. The start/end times, number of files and duration of recordings for each EAR is listed in **Table 4**.

Table 4. Duration of recordings collected by each EAR. Duty cycle recording duration represents the cumulative duration of data recorded given the 50% duty cycling, while real time recording duration represents elapsed time of recordings in real time.

EAR	Start Date/Time	End Date/Time	Number of Files	Duty Cycled Recording Duration	Elapsed Recording Period	Days of Recording
59	08/29/2014 17:01:03	09/07/2014 05:38:01	6124	102:04:00	204:38:58	10
60	08/29/2014 17:01:03	09/14/2014 04:49:01	11155	185:55:00	371:48:57	17
62	08/29/2014 17:01:03	09/03/2014 15:38:02	3544	59:04:00	118:38:58	6

*Note: EAR #55 not included in analysis due to insufficient data.

In spite of the fact that all the EARs stopped recording prematurely, a total of almost 400 hours of acoustic data were obtained and analyzed. EAR #55 was not included in this analysis, because this EAR recorded for only half a day and did not provide enough data for analysis. An explanation of the likely reason for the premature termination of recordings is given in the discussion.

3.2 Noise Analysis

3.2.1 Summary of Noise Analysis

Noise levels varied by site, with an overall full frequency band average noise level (RMS SPL) of 98.8 dB at EAR 59, 101.7 dB at EAR 60, and 105.4 dB at EAR 62. Daily average noise levels were highest on all EARs on September 2 to September 3 (**Figures 8 -10**). At EAR 60, which recorded for the longest duration, noise levels were also higher on September 7 and September 13 to September 14 (**Figure 9**). There was little variation in average noise levels by hour of the day at any EAR, with only a slight peak in noise levels at 1700 at EAR 59 and higher noise levels in the 0-1.5625 kHz octave band and in the full frequency band between 0700 and 1500 hours at EAR 62 (**Figures 11 – 13**). It should be noted that self-noise from parts of the EAR mooring (e.g. the shackle) was prominent at EAR 60 and 62 and thereby contributed to the noise levels at these sites.

3.2.2 Average Hourly Noise Levels

On recordings made by EAR 59, the average root mean square (RMS) sound pressure level (SPL) was highest in all bands from September 2 through September 4 (**Figure 8**). The lowest frequency, 0-1.5625 kHz octave band contributed the most to the noise level, with an average

RMS SPL between 96 and 100 dB over all days. The three bands between 1.5625 and 12.5 kHz were approximately equivalent in energy and also contributed significantly to the noise, but were more variable, with an average RMS SPL between 77 and 94 dB over all days. The band between 12.5 and 25 kHz generally contributed the least amount of total acoustic energy, despite spanning the widest frequency range.

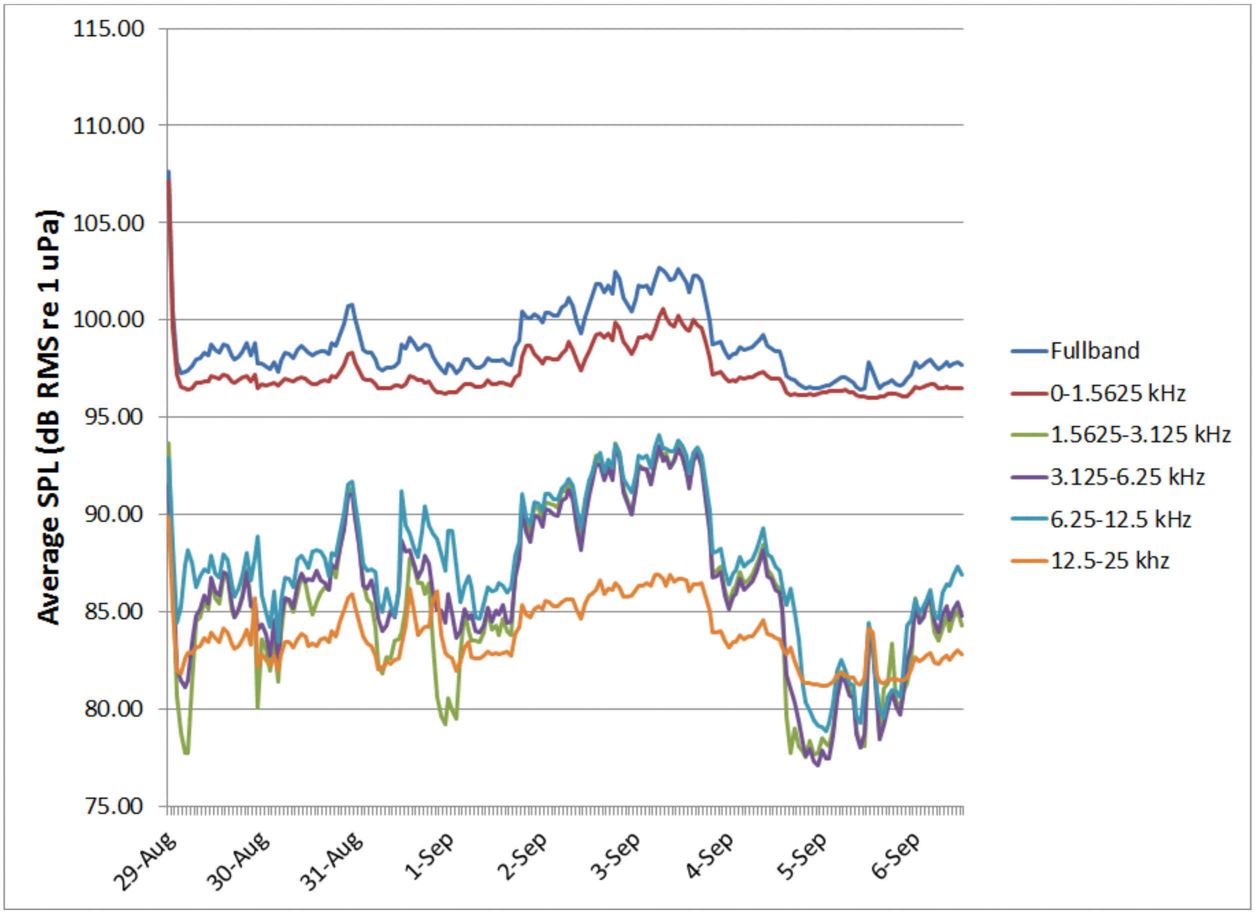

Figure 8. Average Hourly RMS sound pressure level at EAR 59.

On recordings made by EAR 60, the average RMS–SPL level was highest in all bands during three distinct temporal periods; August 29 through August 30, September 2 through September 4, and September 13 (**Figure 9**). The lowest frequency, 0-1.5625 kHz octave band contributed most to the noise level, with an average RMS SPL between 96 and 103 dB over all days. The 6.25 to 12.5 kHz band also contributed significantly to the noise level, with a more variable average RMS SPL ranging between 82 and 104 dB over all days. The octave bands between 1.5625 and 6.25 kHz were similarly variable, but had lower maxima. The band between 12.5 and 25 kHz had relatively low variability and generally contributed the least amount of total acoustic energy, despite spanning the widest frequency range.

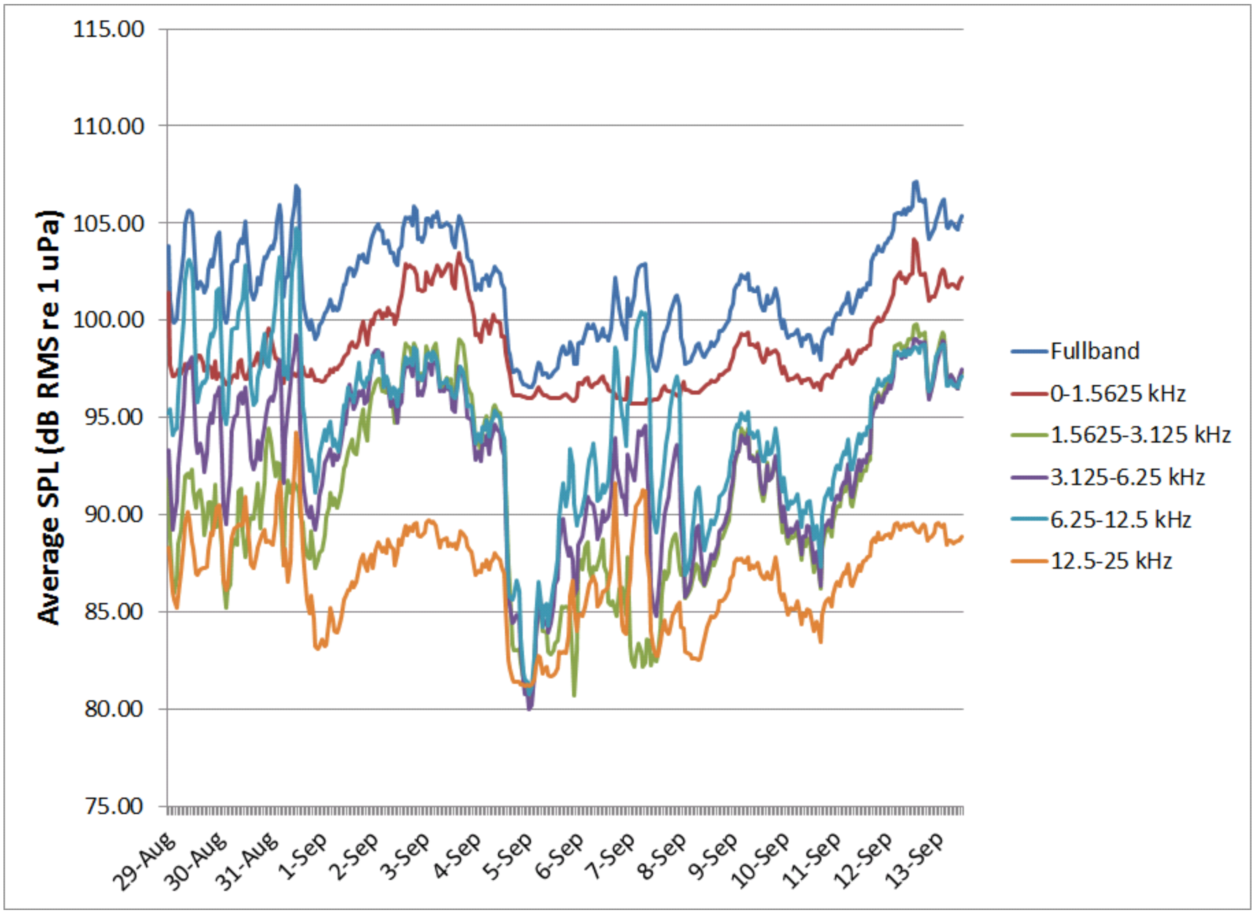

Figure 9. Average hourly RMS sound pressure level at EAR 60.

EAR 62 had the highest average RMS SPL of all three EARs. The highest RMS SPL noise levels in all bands occurred on September 2 (**Figure 10**). The 0-1.5625 kHz octave band contributed most to the noise level with an average RMS SPL between 104 and 113 dB over all days. The two octave bands between 3.125 and 12.5 kHz also contributed significantly to the noise level, with an average RMS SPL between 87 and 97 dB over all days. The 1.5625 to 3.125 kHz band was the most variable of the five octave bands, with averaged hourly RMS SPL ranging between 82 and 99 dB. The band between 12.5 and 25 kHz had relatively low variability and generally contributed the least amount of total acoustic energy, despite spanning the widest frequency range.

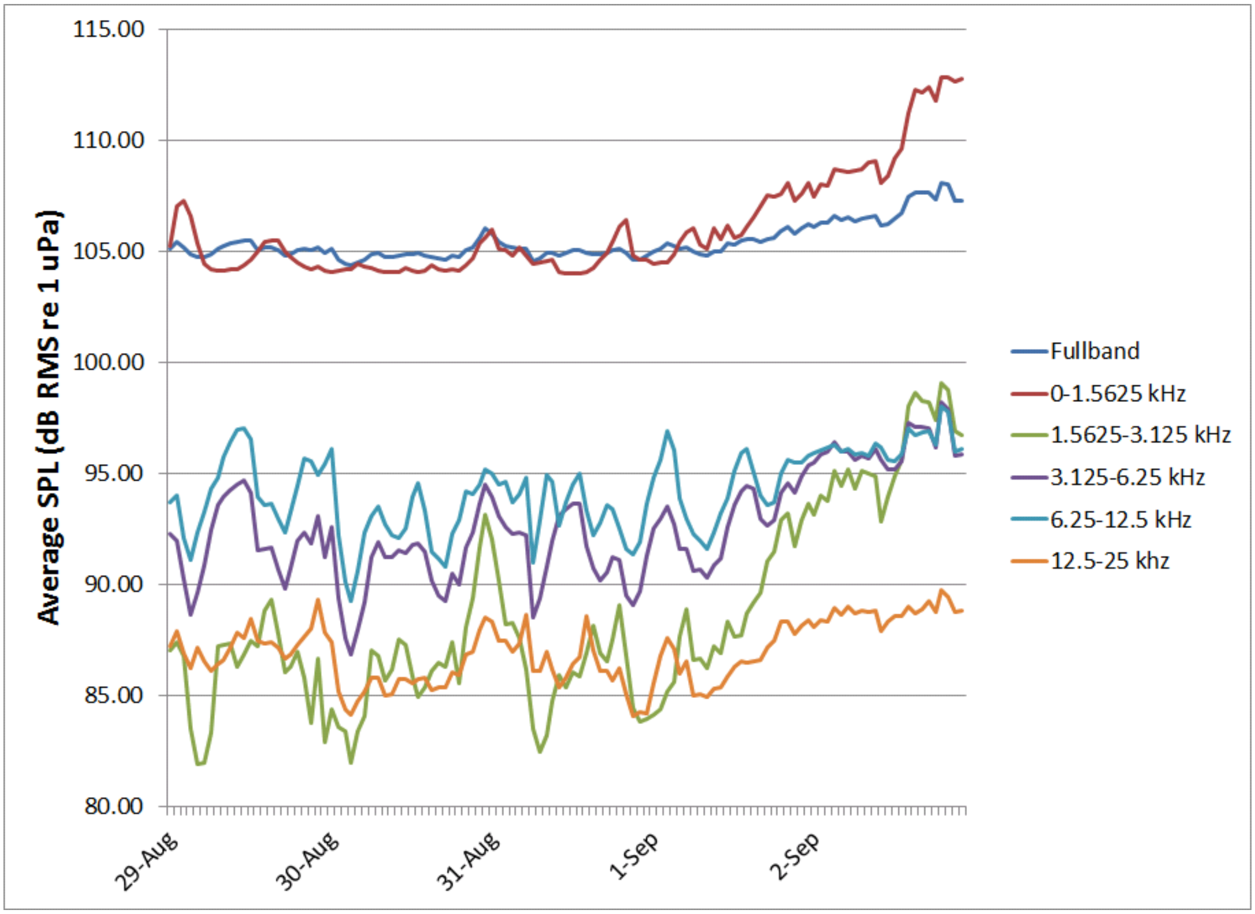

Figure 10. Average hourly RMS sound pressure level averaged at EAR 62.

3.2.3 Average Noise Per Hour

Recordings made by EAR 59 had the highest average RMS SPL in all bands at 1700 hours (**Figure 11**). However, this was likely due to the recorder being turned on prior to deployment and recording noise from the transiting vessel and the deployment process itself. The 0-1.5625 kHz octave band contributed most to the noise level over all hours with an average RMS SPL between 97 and 99 dB. The 6.25 to 12.5 kHz band also contributed to the noise level significantly with a more variable average RMS SPL between 87 and 89 dB over all hours.

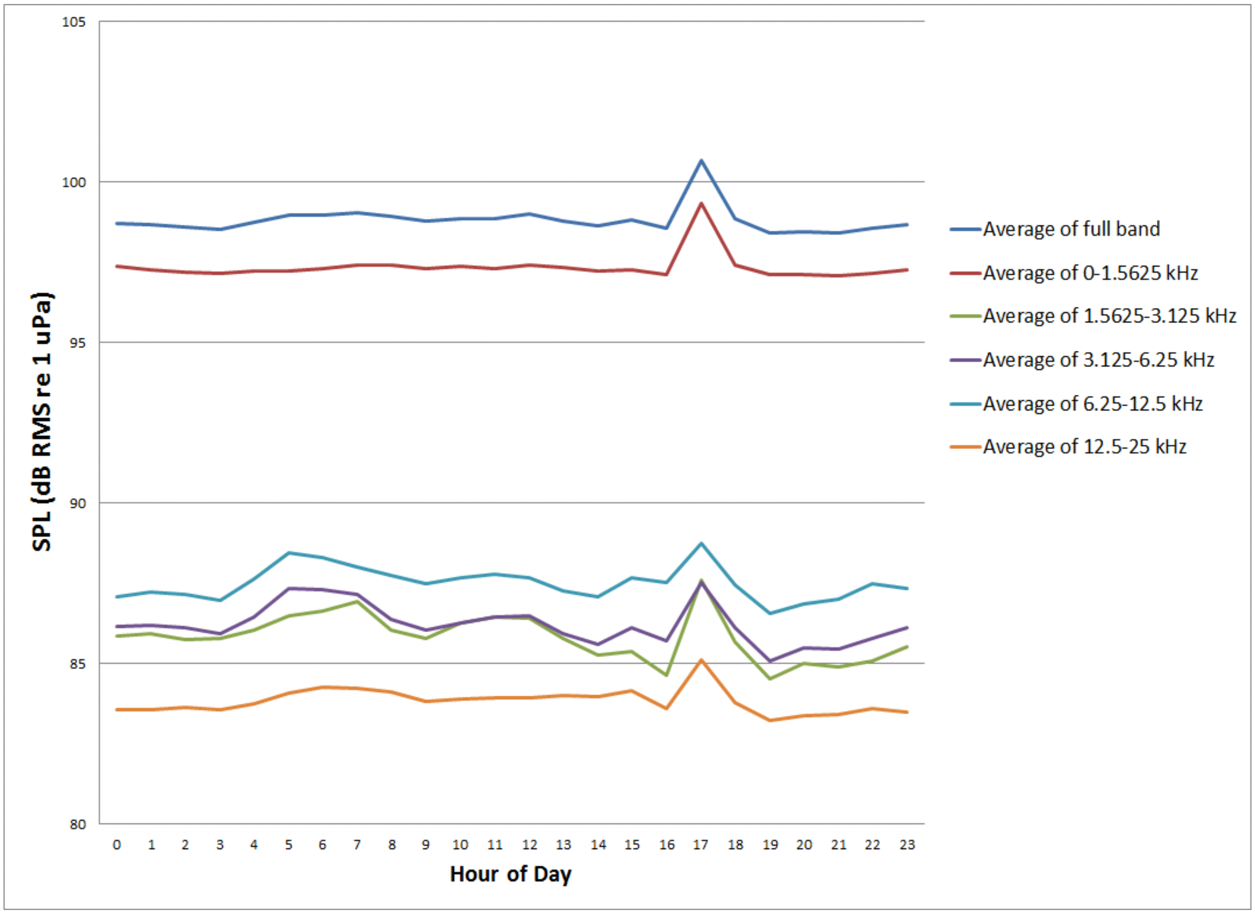

Figure 11. RMS sound pressure level averaged by hour at EAR 59.

Recordings made by EAR 60 had the highest average RMS SPL in all bands between 0100 and 0500 hours (**Figure 12**). The 0-1.5625 kHz octave band contributed most to the noise level over all hours with an average RMS SPL relatively constant at approximately 99 dB. The 6.25 to 12.5 kHz band also contributed to the noise level significantly with an average RMS SPL between 94 and 95 dB over all hours.

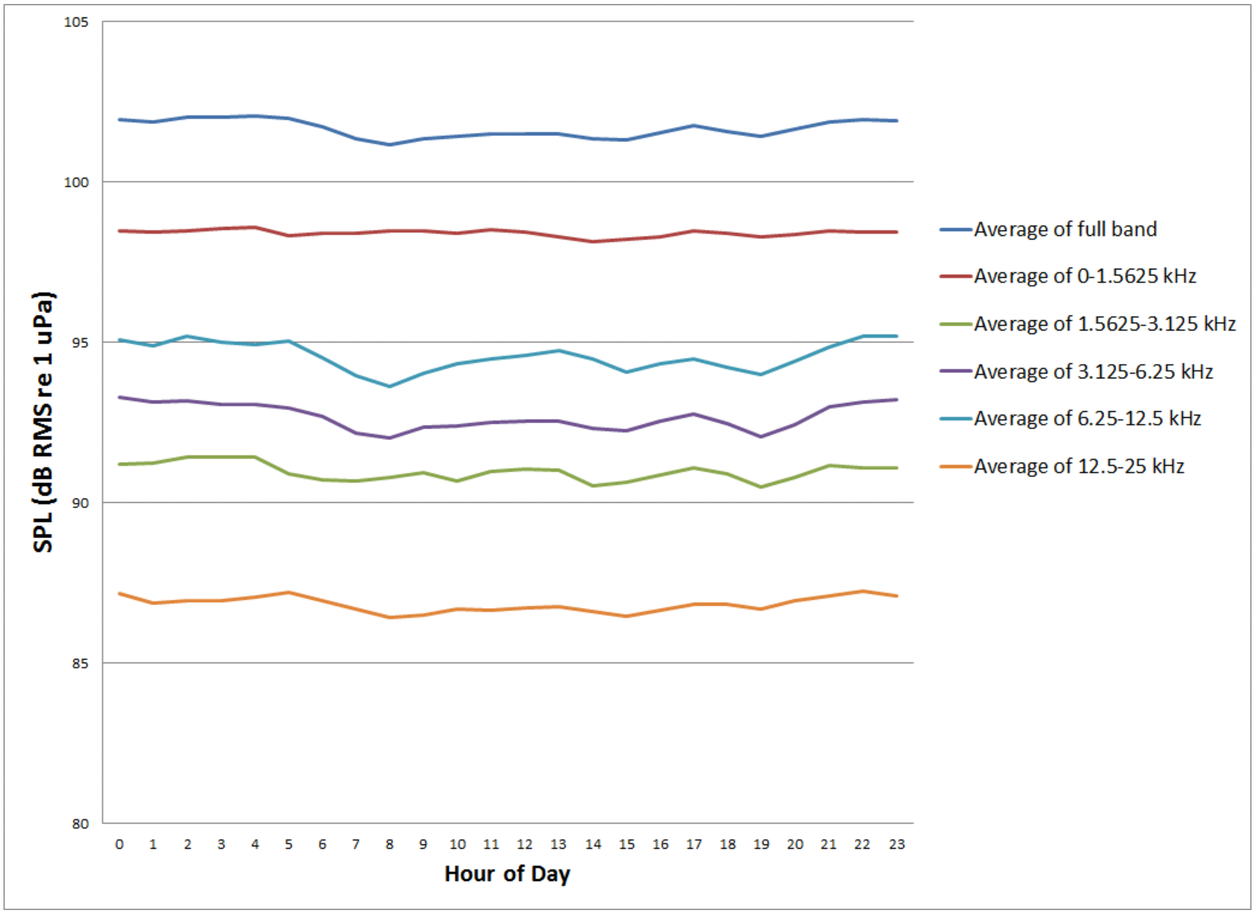

Figure 12. RMS sound pressure level averaged by hour at EAR 60.

Recordings made by EAR 62 had a more temporally variable average RMS SPL among octave bands (**Figure 13**). The 0-1.5625 kHz octave band contributed most to the noise level over all hours with an average RMS SPL relatively constant at approximately 105 dB, with a slight increase to approximately 107 dB between 0700 and 1400 hours. The 6.25 to 12.5 kHz band also contributed to the noise level significantly with an average RMS SPL between 94 and 95 dB over all hours, with peaks in noise occurring from 0500 to 0600 hours, 1200 to 1300 hours and 1600 to 1700 hours. It is worth noting that there was an energy peak in the 1.5625 to 3.125 kHz octave band between 0700 and 1500 hours.

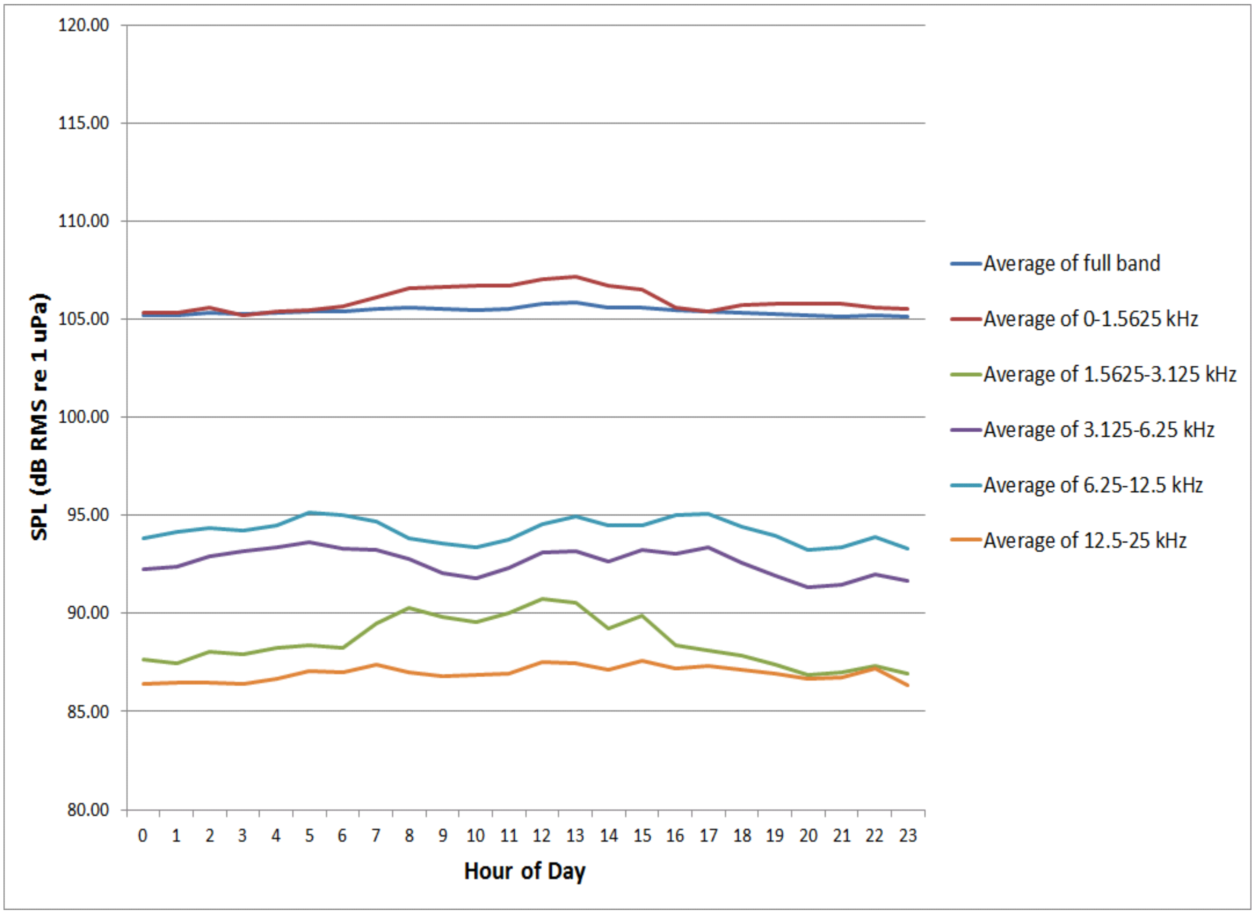

Figure 13. RMS sound pressure level averaged by hour at EAR 62.

3.3 Acoustic Encounter Analysis

3.3.1 Logging Summary

There were 14 categories of acoustic encounters identified during high and low frequency band logging. Four of these categories consisted of different types of anthropogenic noise, and the remaining ten categories consisted of different types of biological sounds. Four of the biological classification categories were identified to the species level, and the remaining six consisted of unidentified categories (**Table 5**). There were a total of 331 acoustic encounters detected within the entire dataset (**Table 5**). Of these, the majority were identified as beluga whales (38 percent), followed by unidentified fish (17 percent) and unidentified marine mammal (6 percent) (**Table 5, Appendix A: Table A1**). The number, type and duration of encounter types detected at each EAR varied (**Table 3, Appendix A: Table A1, Figures 14-16**). EAR 60 had the greatest variety of encounter types with 86 percent of encounter categories represented. At EAR 59 unidentified fish and beluga whales were the two most common acoustic encounter types, occurring during 100 percent and 90 percent of recording days, for a total of approximately 138 hours and 48.5 hours, respectively (**Appendix A: Table A1, Figures 14 - 16**). At EAR 60, beluga whales were the most common encounter type, occurring during 88 percent of recording days for approximately 19.5 hours. Unidentified fish occurred on 53 percent of recording days for approximately 7.25 hours at this EAR (**Appendix A: Table A1, Figures 14 - 16**). At EAR

62 beluga whales occurred during 67 percent of recording days for approximately 4 hours and unidentified fish occurred during 50 percent of recording days, but the encounters were a very short duration, only totaling 6 seconds (**Appendix A: Table A1, Figures 14 - 16**).

Table 5. Total number of acoustic encounters per EAR recording site by classification category.

Encounter Type	EAR 59	EAR 60	EAR 62	Total Number of Encounters
Anthropogenic - 0-50 kHz Noise	-	3	-	3
Anthropogenic - Ship	6	3	6	15
Anthropogenic - Sonar	-	-	1	1
Anthropogenic - Unknown	6	3	4	13
Bearded Seal	-	7	-	7
Beluga Whale	52	74	22	148
Bowhead Whale	-	12	-	12
Ringed Seal	-	3	-	3
Unidentified Biological - HF	8	-	-	8
Unidentified Biological - LF	-	11	1	12
Unidentified Cetacean	2	2	-	4
Unidentified Fish	34	27	5	66
Unidentified Marine Mammal	18	4	-	22
Unidentified Pinniped	-	14	3	17
Total Encounters per EAR	**126**	**163**	**42**	**331**

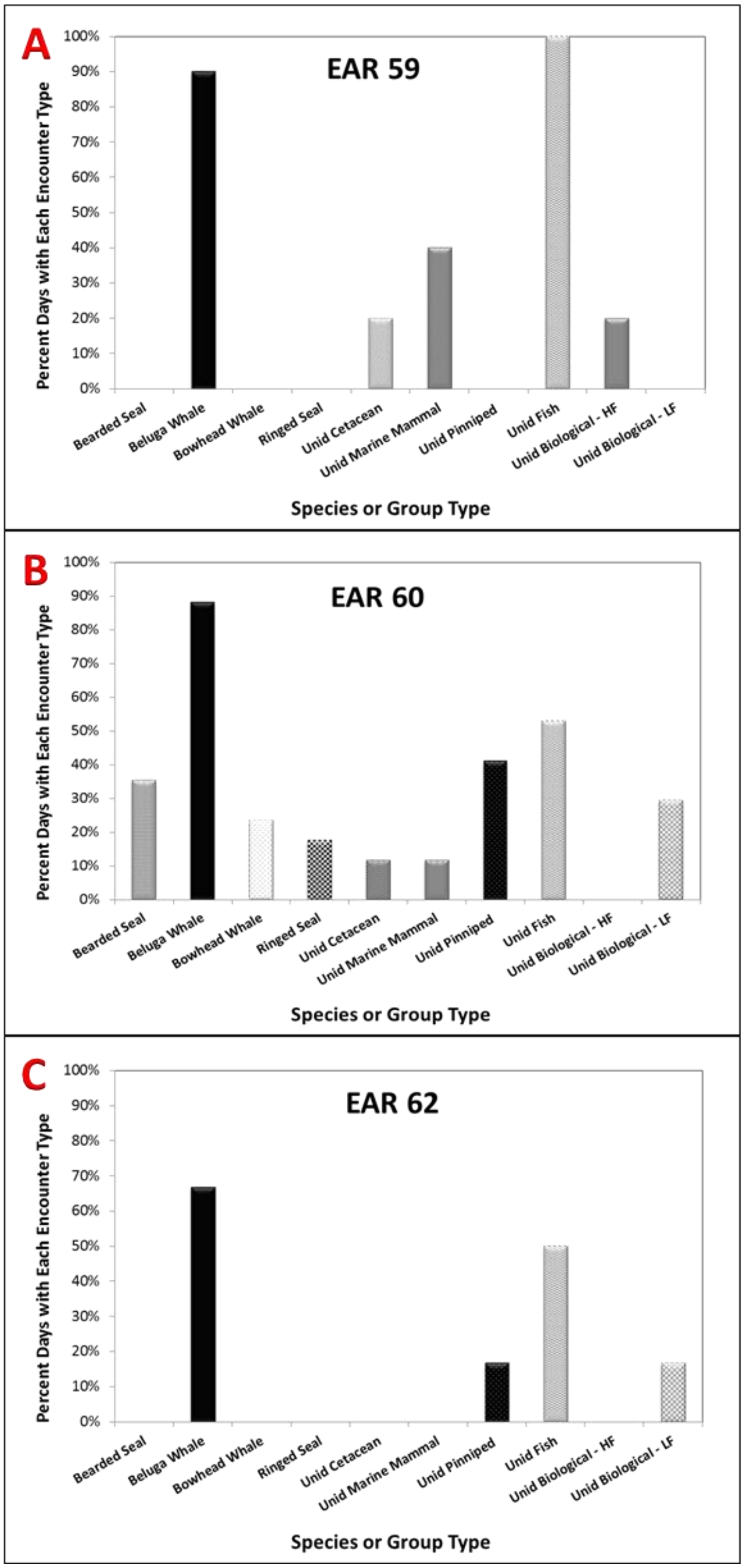

Figure 14. Biological acoustic encounters at each EAR recording location. The y-axis shows the percentage of days during which each encounter type occurred.

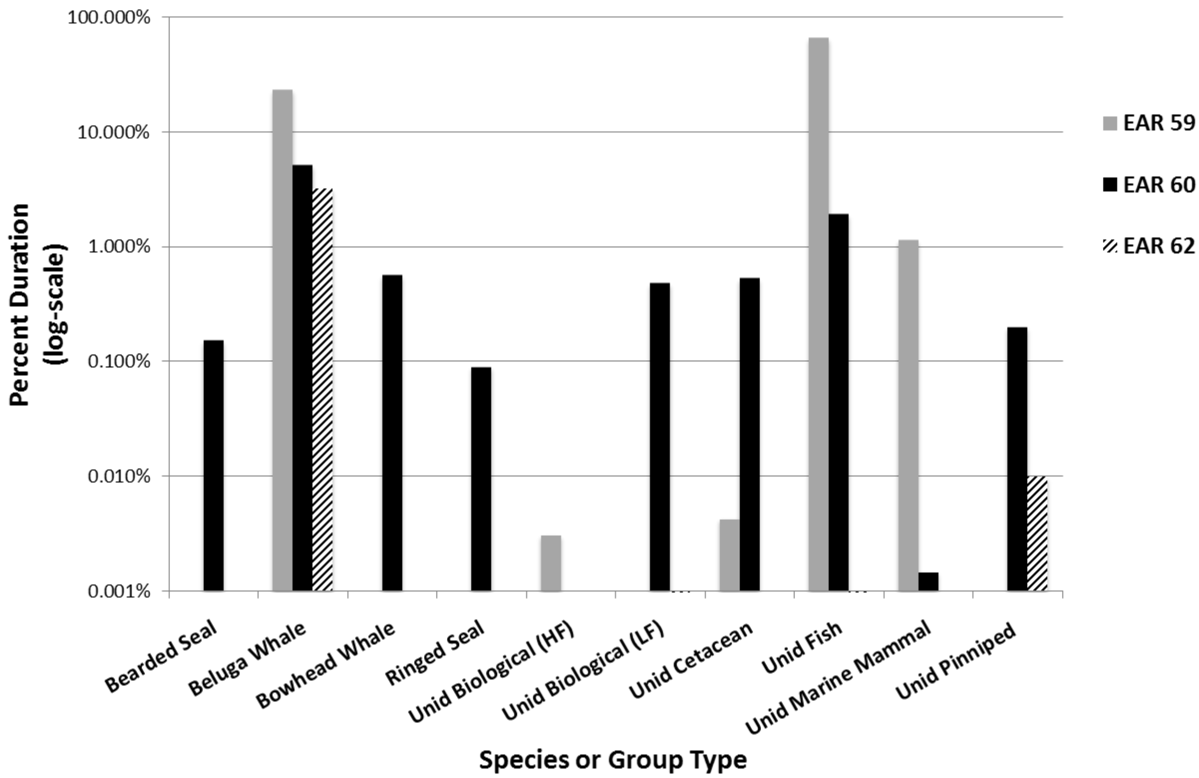

Figure 15. Percent of the total recording duration comprised of biological acoustic encounters by species or group for each EAR deployment. Species is shown on the x-axis, and the logarithmic y-axis indicates the percentage of time each species was encountered during the deployment. Unid biological (HF) and Unid biological (LF) are biological sounds that could not be identified to species or species-groups in the high-frequency and low-frequency analyses, respectively.

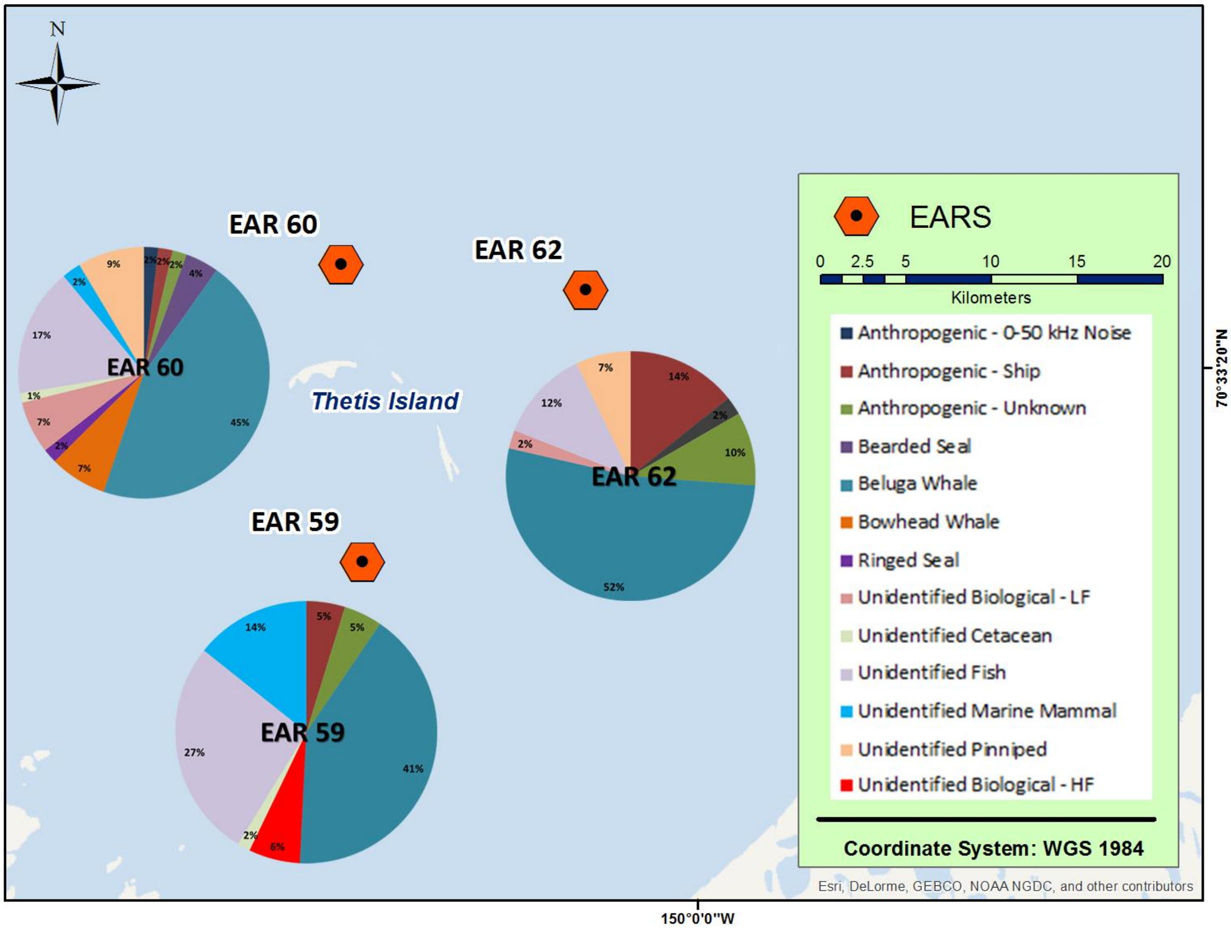

Figure 16. Percent of the total number of acoustic encounters for each encounter type and EAR.

3.3.2 Seismic Activity

Documentation of seismic survey activity was provided by Smultea Environmental Sciences (SES). During the EAR recording period, seismic activity occurred between August 31 and September 2, and between September 6 and September 12 (**Figure 17**). Seismic activity began at the eastern edge of the study area and moved west. The seismic activity was estimated to occur at ranges between approximately 10 and 19 km from the EARs during the time of the recordings. There was no audible seismic activity detected (either visually or aurally) on any of the EARs recordings. Seismic activities continued until September 25, however no EARs recorded any acoustic data after September 14.

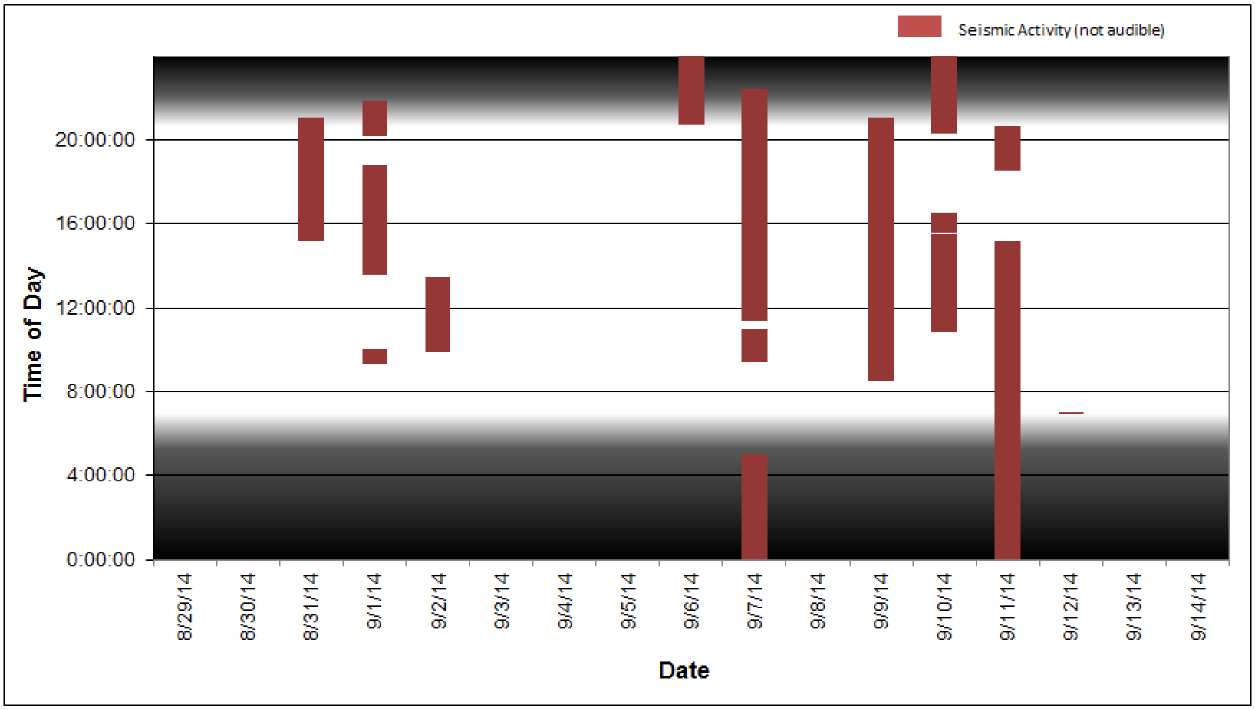

Figure 17. Client Reported occurrence of seismic activity from August 29 to September 14, 2014.

3.3.3 High Frequency Logging

3.3.3.1 Beluga Whale

Beluga whale acoustic encounters were recorded on all three EARs. Acoustic encounters were comprised of burst pulses, whistles, and clicks (**Figures 18 - 20**). The vocal repertoire of acoustic encounters varied by site (**Figure 21**). Encounters recorded at EAR 59 and 60 were primarily mixed sound-types, including whistles, burst pulses and echolocation clicks, followed by burst pulse encounters at EAR 59 and whistle encounters at EAR 60, whereas, encounters recorded at EAR 62 were comprised almost solely of whistles (68 percent of encounters). Beluga whale acoustic encounters occurred during 15 of the 17 days of the deployment (**Figures 22 - 25**). There was no apparent temporal or diurnal pattern in the acoustic presence of beluga whales. Beluga whale acoustic encounters were detected throughout the recording period on all EARS during both day and night. The probability of a beluga whale acoustic encounter was significantly higher (P = 0.35; P = 0.11, respectively) during reported seismic activity versus when there was no reported seismic activity (P = 0.19; P = 0.04, respectively) at EARs 59 and 62 (2-sample z-test, $p < 0.001$; p = 0.003, respectively), and not significantly different for the two conditions at EAR 62 (2-sample z-test, $p = 0.139$) (**Table 6)**.

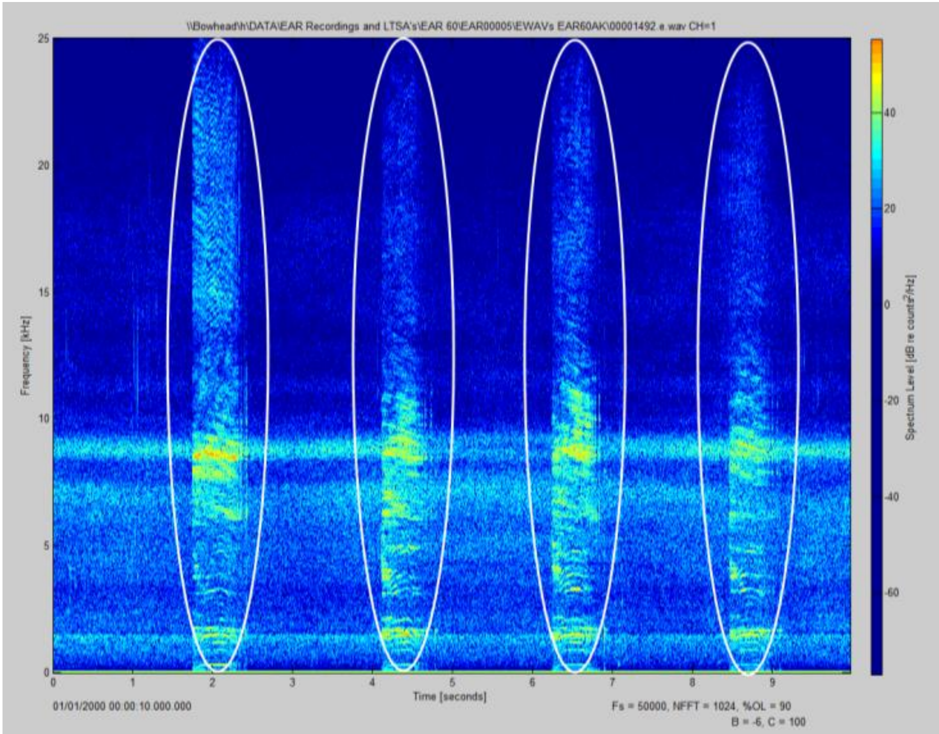

Figure 18. Spectrogram of beluga whale burst pulses recorded by EAR 60. Spectrogram was produced using a 10s plot length, 512 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz.

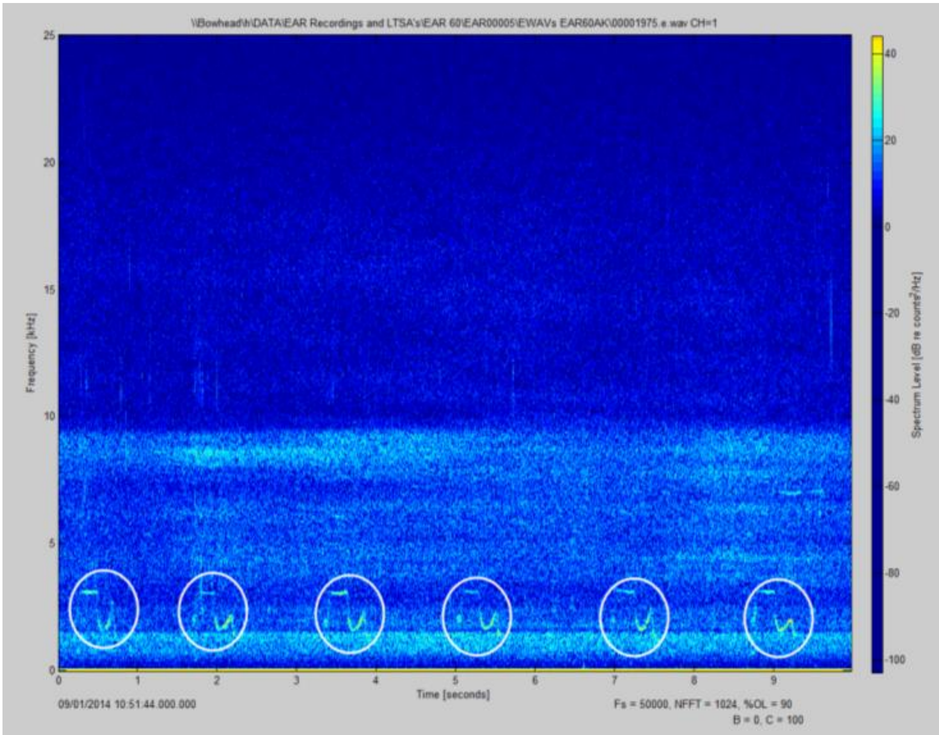

Figure 19. Spectrogram of beluga whale whistles recorded by EAR 60. Spectrogram was produced using a 10s plot length, 1024 point FFT with 90% overlap, and a frequency range of 0-25 kHz.

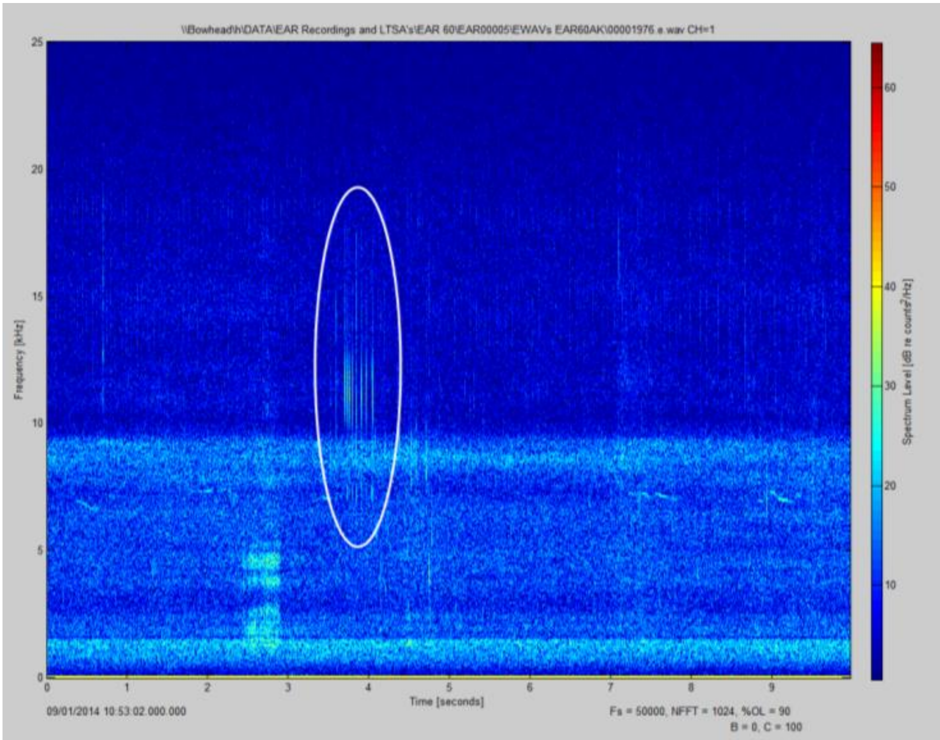

Figure 20. Spectrogram of beluga whale clicks recorded by EAR 60. Spectrogram was produced using a 10s plot length, 1024 point FFT with 90% overlap, and a frequency range of 0-25 kHz.

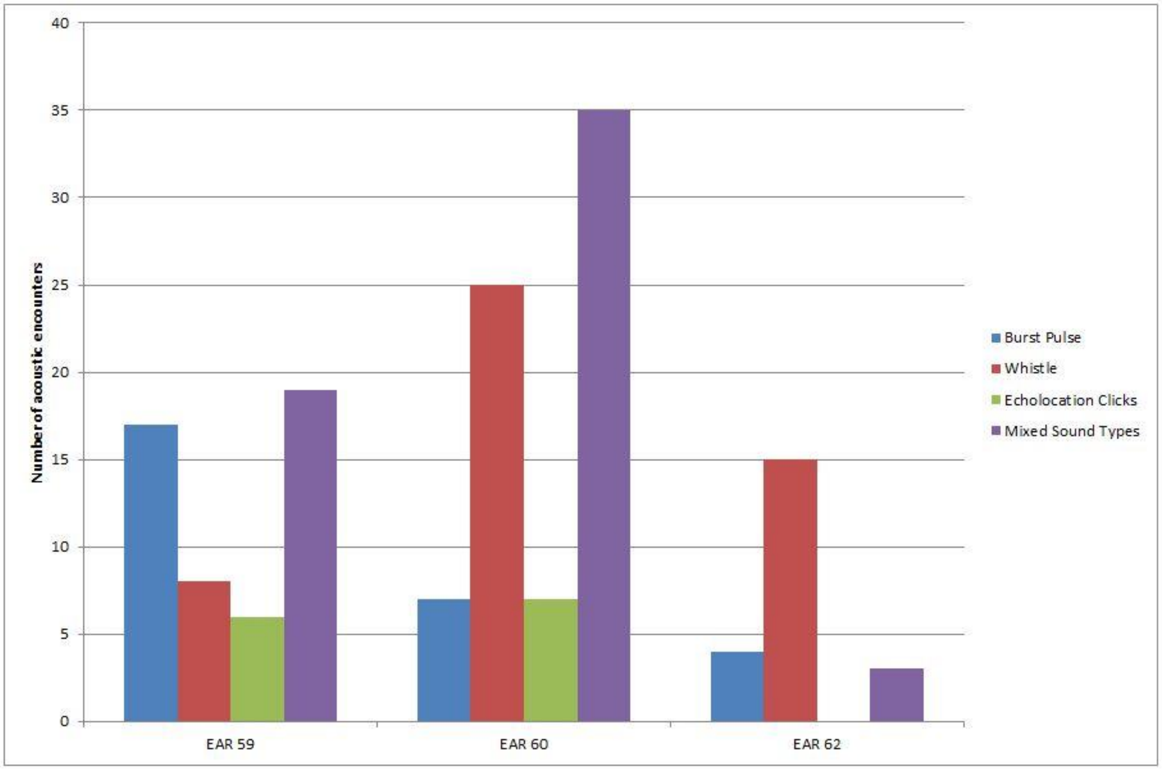

Figure 21. Number of beluga whale acoustic encounters for each vocalization category by EAR.

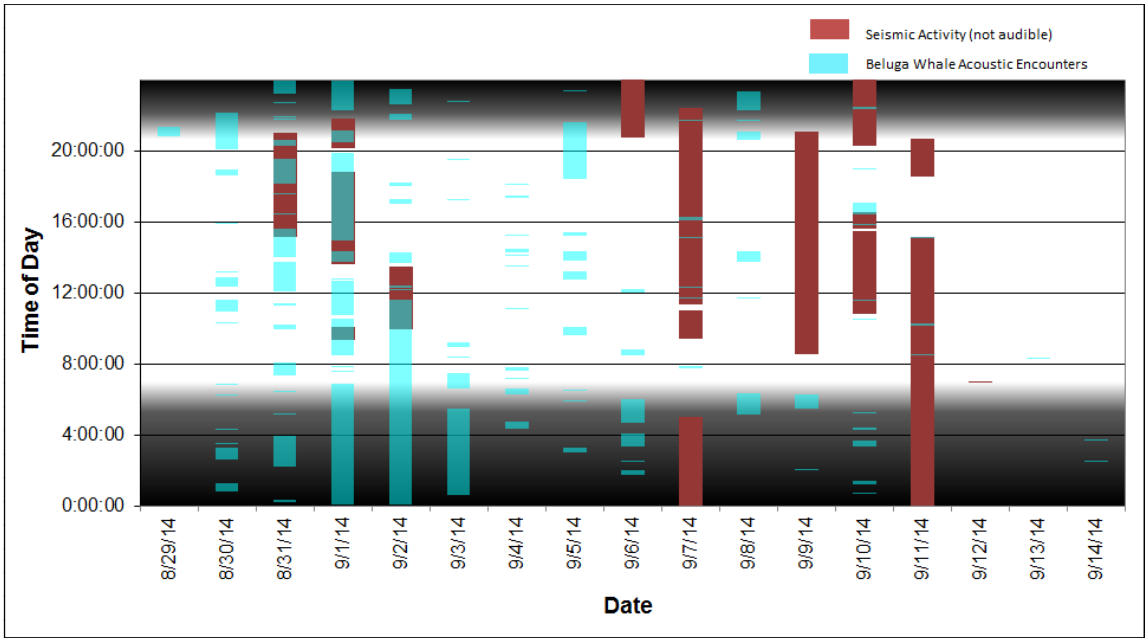

Figure 22. Beluga whale acoustic encounters at all EARs (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

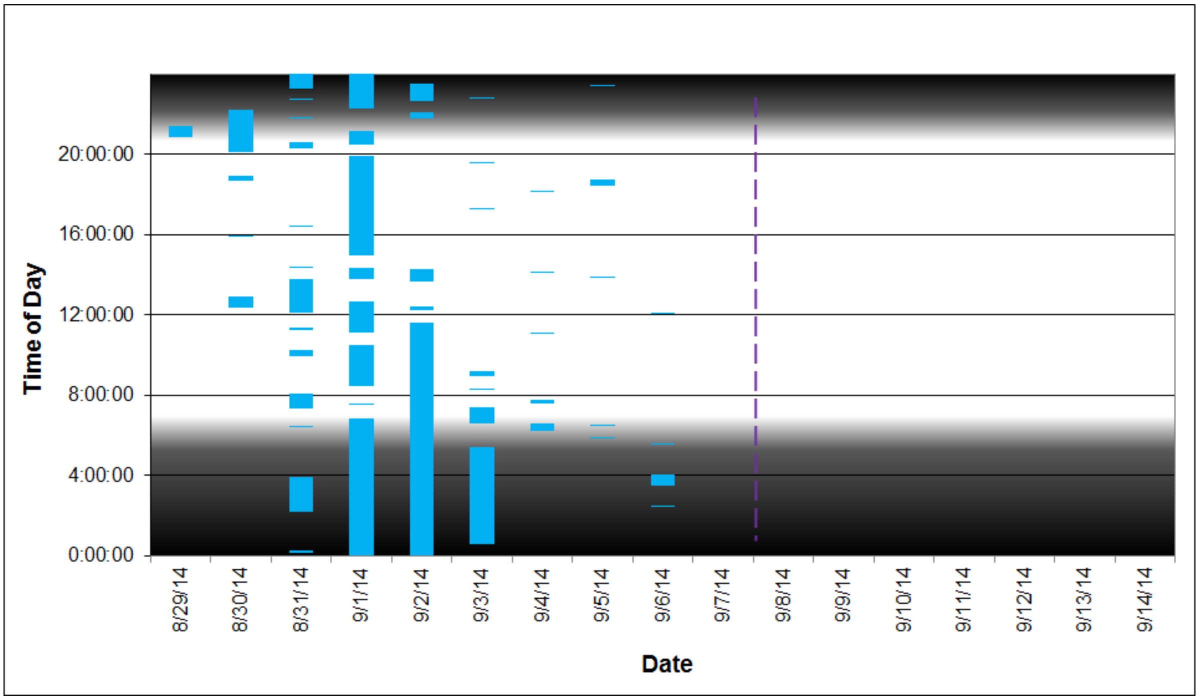

Figure 23. Beluga whale acoustic encounters at EAR 59. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

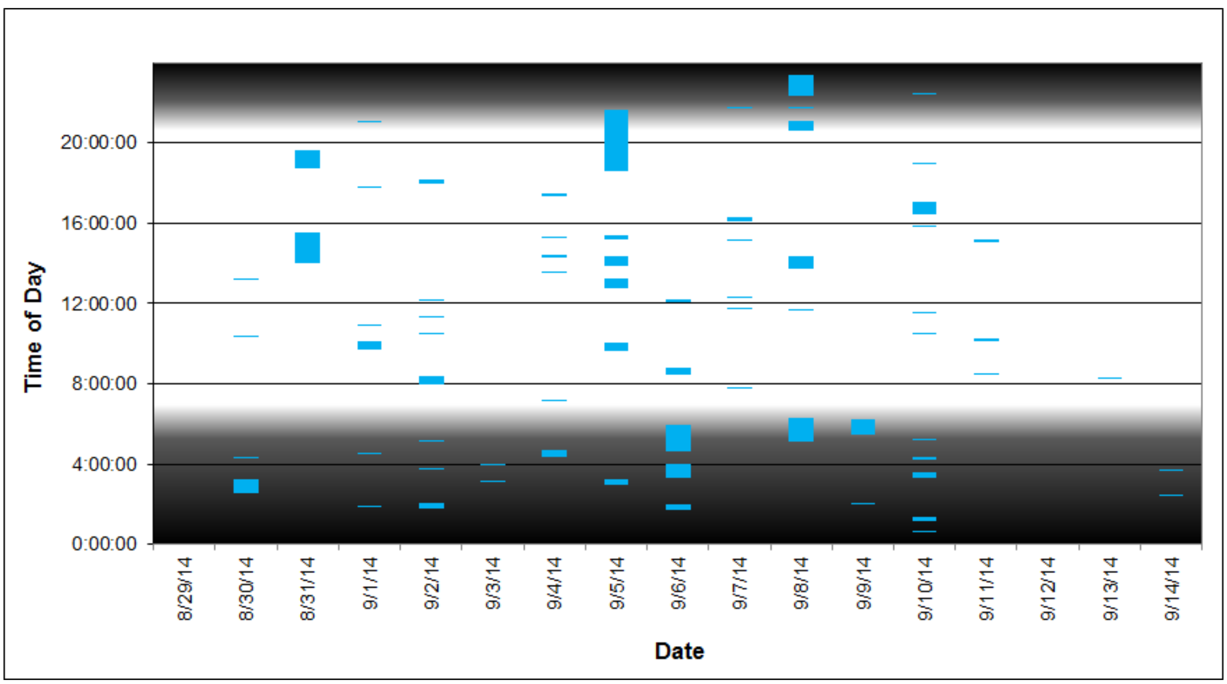

Figure 24. Beluga whale acoustic encounters at EAR 60. Shaded areas denote periods of darkness.

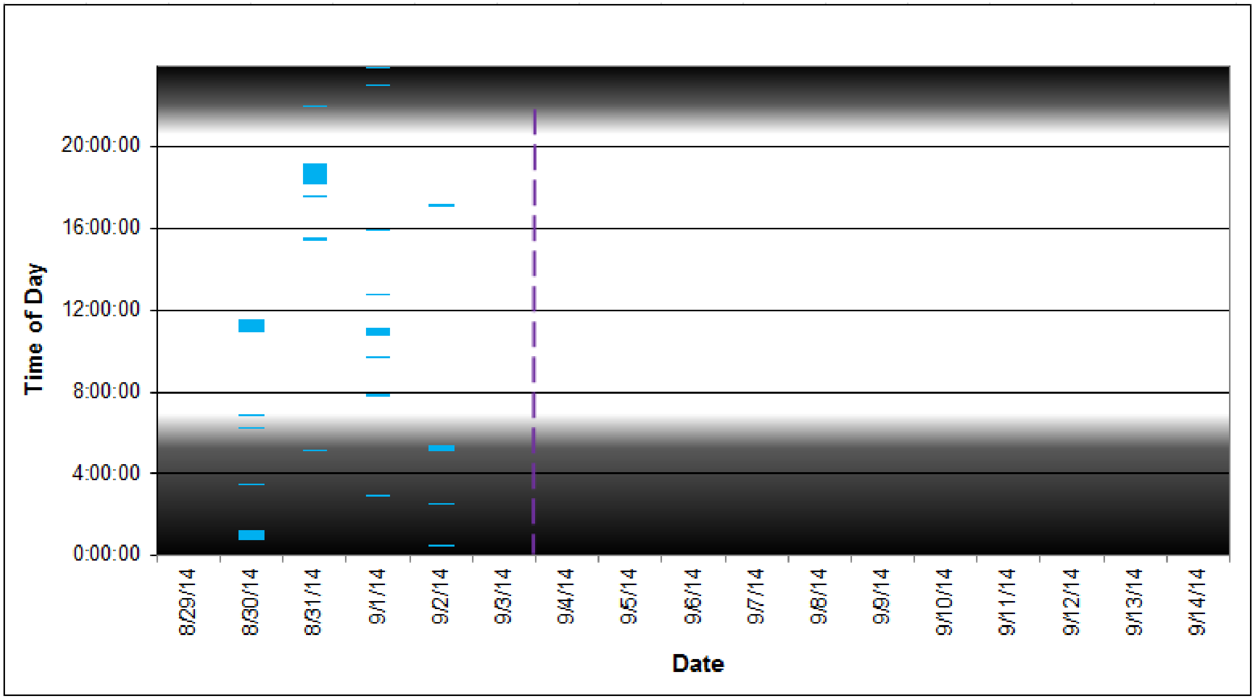

Figure 25. Beluga whale acoustic encounters at EAR 62. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

Table 6. Probability and number of beluga whale acoustic encounters that occurred in the presence and absence of reported seismic activity. The p-values of 2-tailed z-tests are provided (significance level < 0.01) to assess the significance of the difference between probabilities for both conditions.

Location	Presence of Reported Seismic Activity			Absence of Reported Seismic Activity			*p value*
	# encounters	n	Probability (P)	# encounters	n	Probability (P)	
EAR 59	56	159	0.35	248	1281	0.19	0.000*
EAR 60	36	477	0.08	192	1971	0.10	0.139
EAR 62	12	108	0.11	33	756	0.04	0.003*

3.3.3.2 Unidentified Biological

Unidentified biological acoustic encounters were detected only on recordings from EAR 59 (**Figures 26 - 27**). The signals detected may have been produced by fish, pinnipeds, or cetaceans. Bioacousticians and the experts who reviewed these sounds were unable to classify them beyond being of biological origin. These sounds were detected on only two different days and did not occur during seismic activity (**Figure 26**).

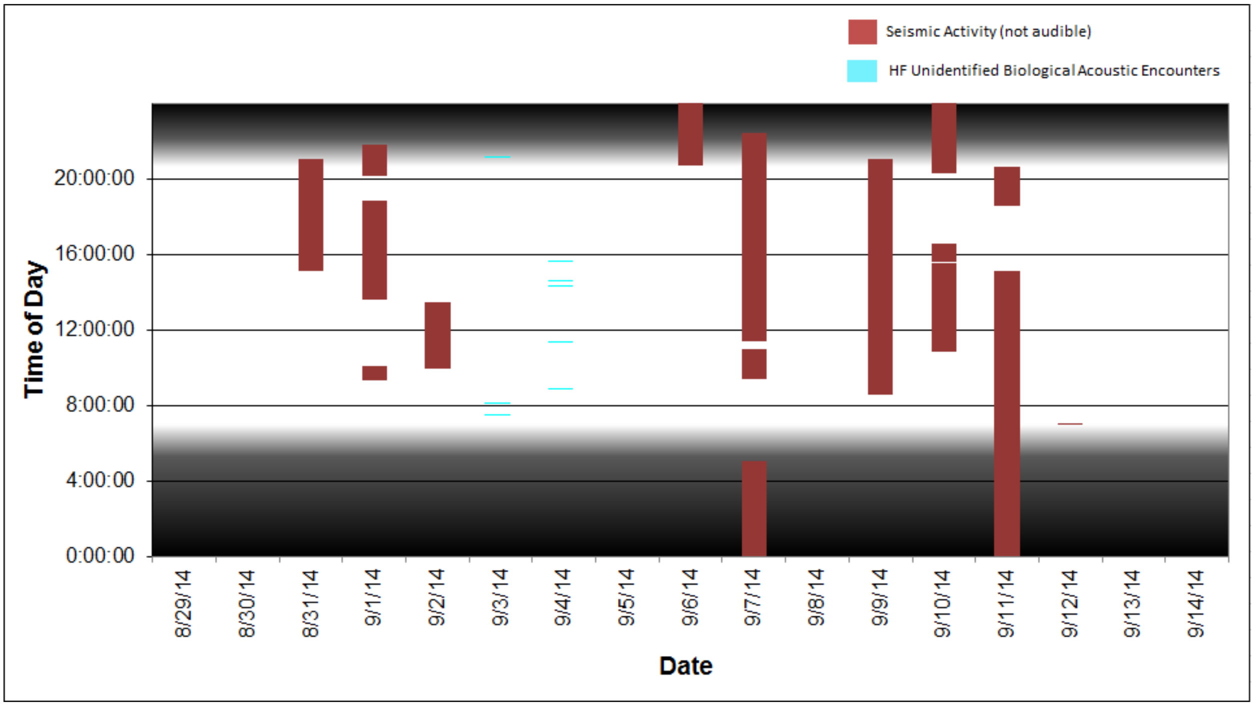

Figure 26. Unidentified biological acoustic encounters recorded by EAR 59 (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

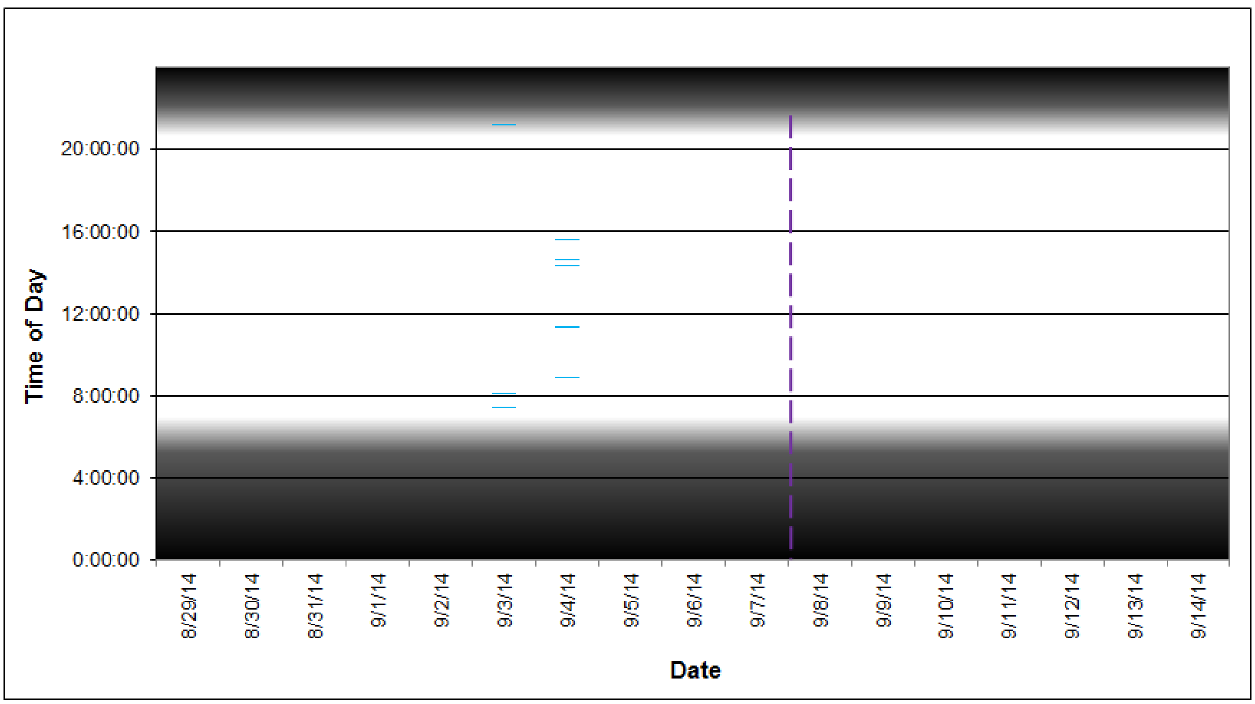

Figure 27. Unidentified biological acoustic encounters recorded by EAR 59. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

3.3.3.3 Unidentified Cetacean

Unidentified cetacean acoustic encounters consisted exclusively of echolocation clicks. The echolocation clicks were considered to be lower frequency than expected for beluga whales (but not impossible) and were thought to possibly be from killer whales, however no final determination could be made with the limited amount of information available from the small number of encounters. There were a total of four unidentified cetacean acoustic encounters (**Figure 28**). These encounters were detected on recordings made by EAR 59 and EAR 60 during three different days (**Figures 29 - 30**). When seismic activity and unidentified cetacean encounters were overlaid, there was no evidence of any relationship between the two (**Figure 28**). Probability statistics were not calculated due to limited sample size.

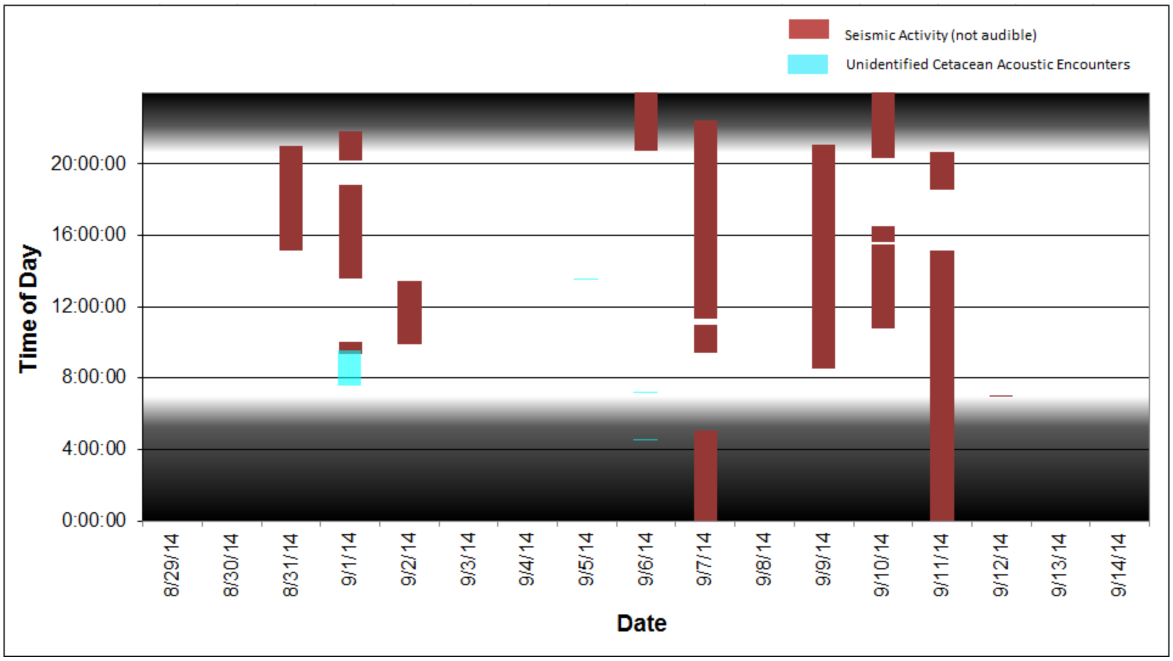

Figure 28. Unidentified cetacean encounters recorded by EAR 59 and EAR 60 (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

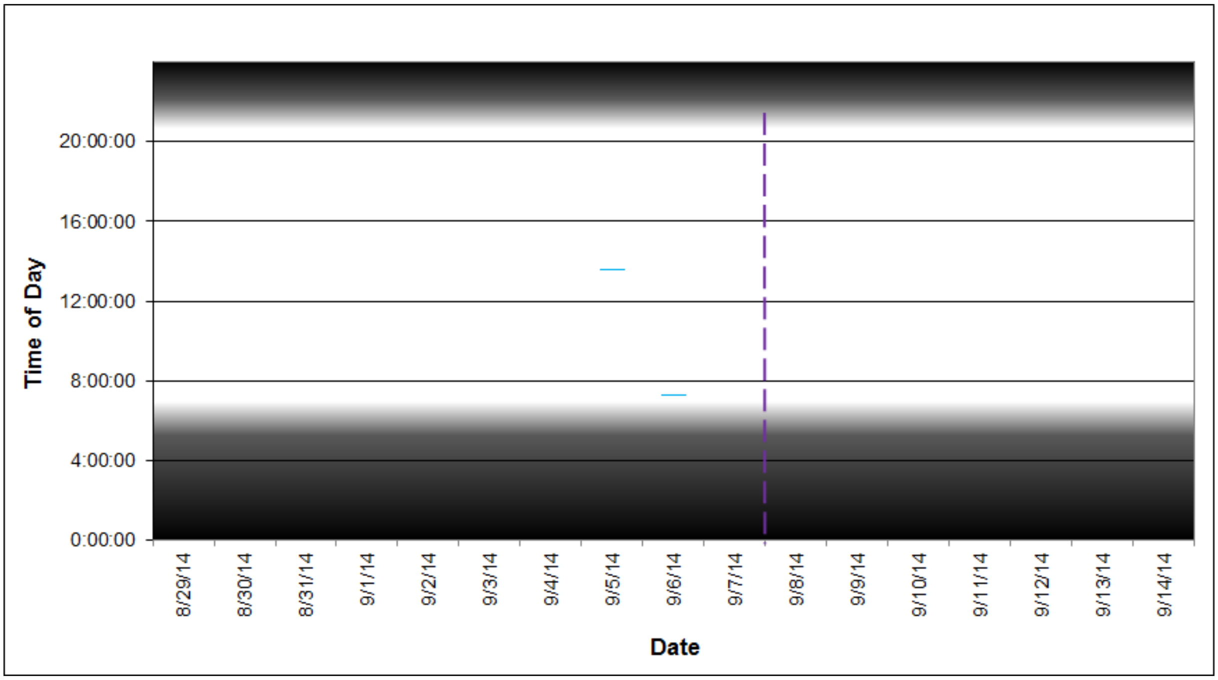

Figure 29. Unidentified cetacean acoustic encounters recorded by EAR 59. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

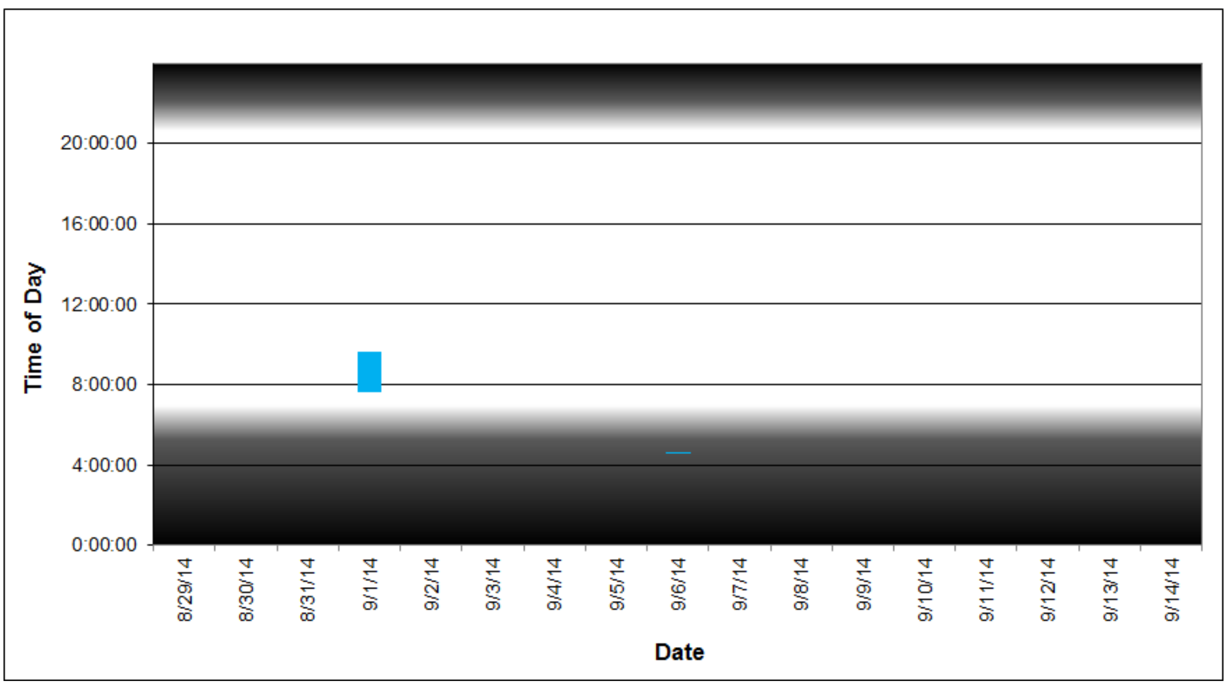

Figure 30. Unidentified cetacean acoustic encounters recorded by EAR 60. Shaded areas denote periods of darkness.

3.3.3.4 Anthropogenic

The only anthropogenic acoustic encounter detected in the high frequency band analysis of the EAR recordings was an unknown signal, classified as anthropogenic - unknown (**Figure 31**). The signal was broadband from approximately 2 to 8 kHz with a visible downsweep at the end of the signal. At times this signal was very regular, and occurred every 16 seconds, but at other times its pattern of occurrence was haphazard. There were 13 occurrences of these unknown anthropogenic acoustic encounters. Encounters occurred at all three EAR sites during three consecutive days (August 31 to September 2) for a total of 16.5 hours (**Figures 32 - 35**). This sound appears to be correlated with seismic activity during those days and therefore may be related to calibration exercises or other seismic activities (**Figure 32**).

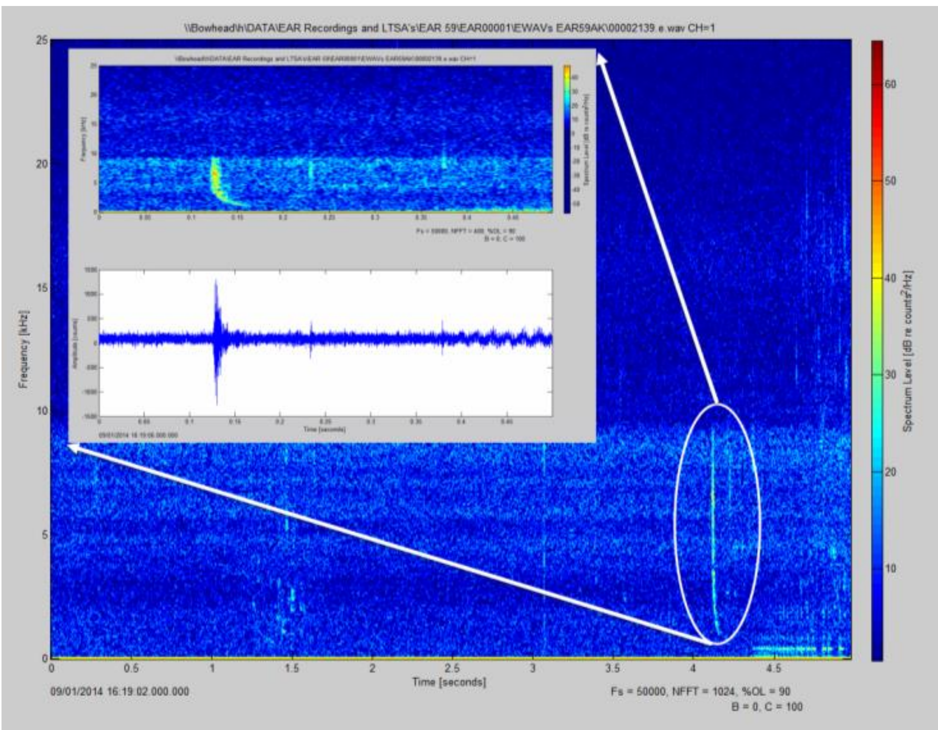

Figure 31. Spectrogram of unknown anthropogenic sound recorded by EAR 59. Spectrogram was produced using a 5s plot length, 1024 point FFT with 90% overlap, and a frequency range of 0-25 kHz. Within the main spectrogram is a 0.5 s clip of the unknown anthropogenic sound along with its corresponding wav form. Frequency range 0 - 25 kHz.

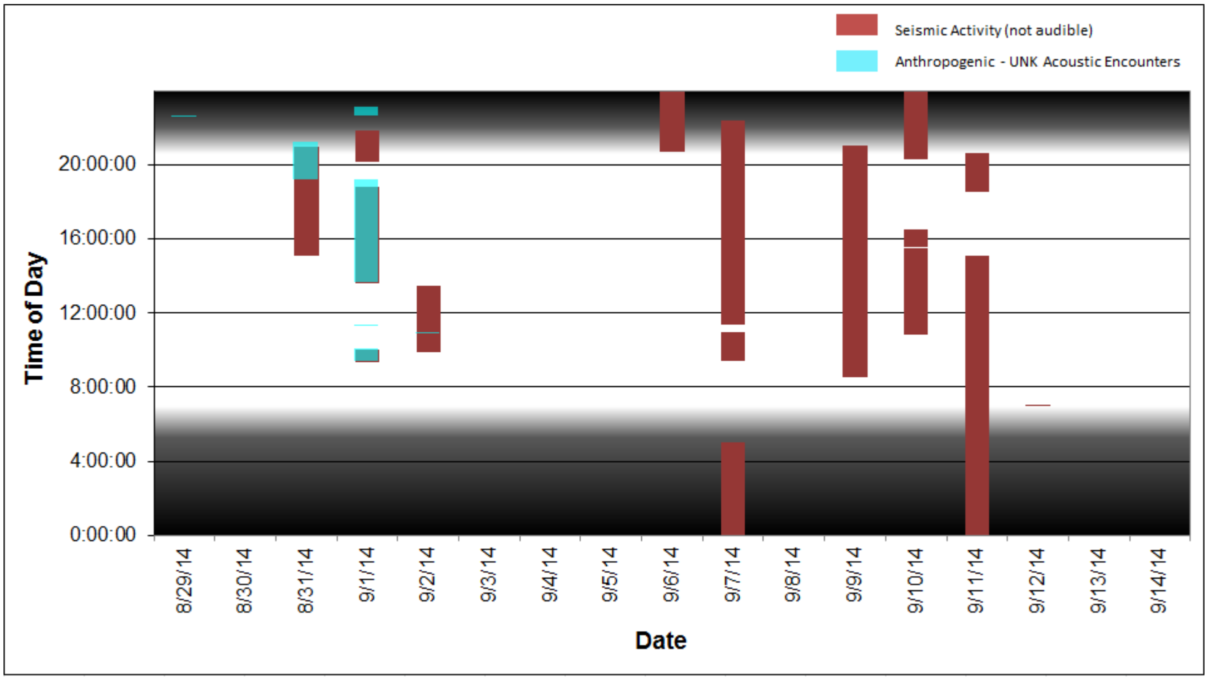

Figure 32. Anthropogenic – Unknown encounters in all EAR data (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

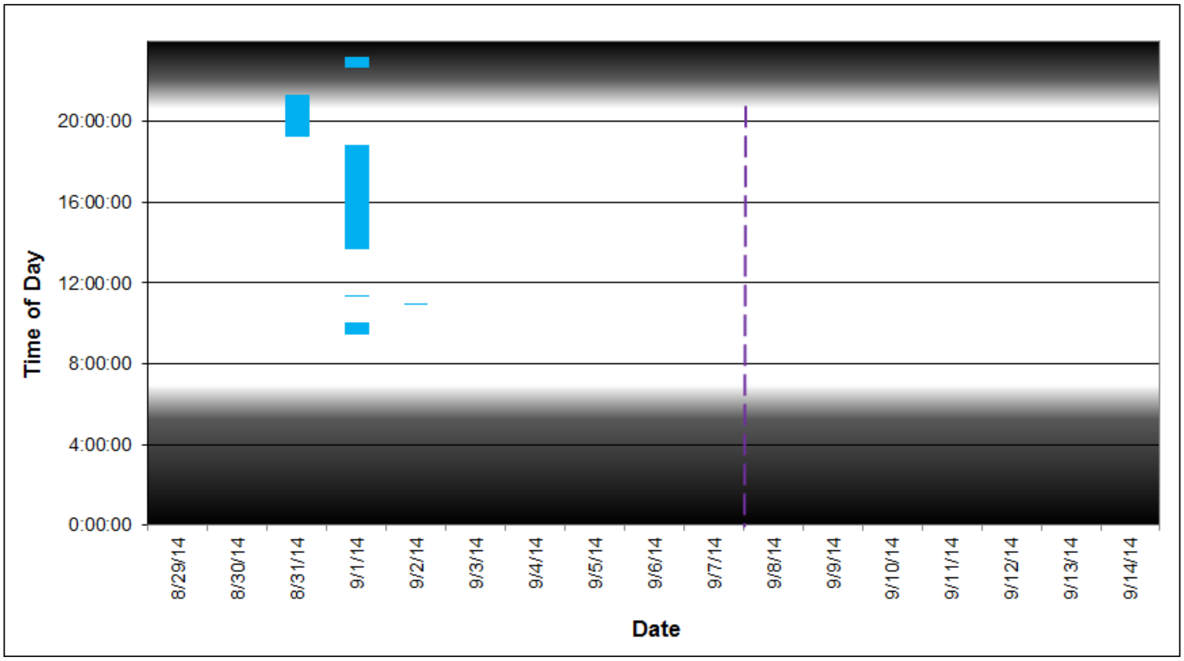

Figure 33. Anthropogenic - Unknown acoustic encounters recorded by EAR 59. Shaded areas denote periods of darkness and purple line denotes end of EAR recording.

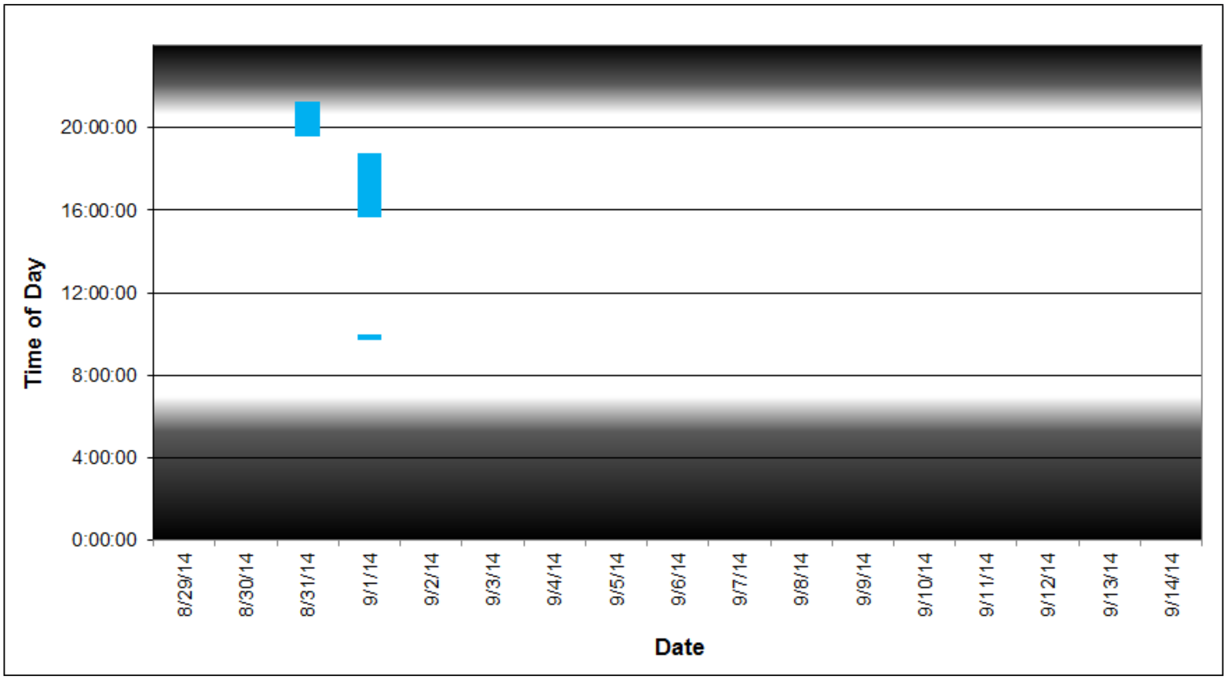

Figure 34. Anthropogenic - Unknown acoustic encounters recorded by EAR 60. Shaded areas denote periods of darkness.

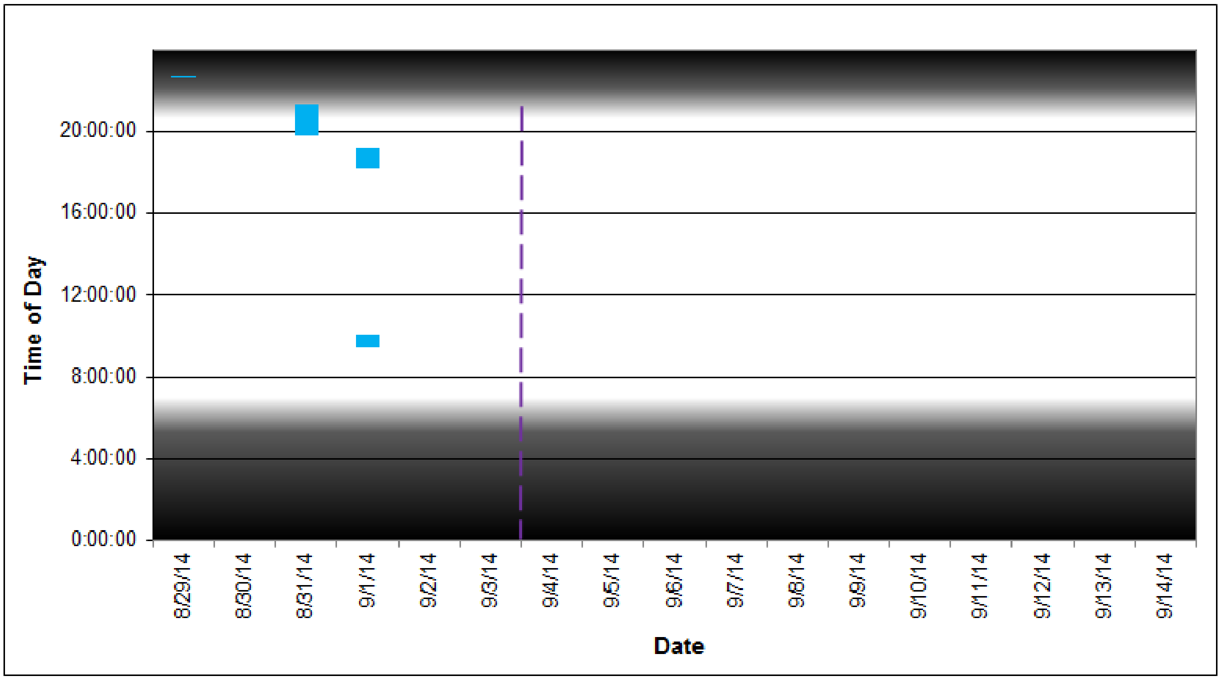

Figure 35. Anthropogenic - Unknown acoustic encounters recorded by EAR 62. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

3.3.4 Low Frequency Logging

3.3.4.1 Bowhead whale

There were a total of 12 bowhead whale acoustic encounters. Moans and songs (**Figures 36 - 37**) from bowhead whales were heard only on recordings made by EAR 60. The encounters occurred during four separate days (**Figure 38**). One encounter was close to the beginning of the deployment (September 2) and the rest of the encounters occurred during a four day period later in the deployment (September 7 – September 10). The majority of encounters occurred during daylight hours. When seismic activity and bowhead whale acoustic encounters were overlaid there was no obvious relationship between the two (**Figure 38**). The probability of the occurrence of a bowhead whale acoustic encounter during reported seismic activity (P= 0.02) was not significantly different (2-tailed z-test, p = 0.072) than the probability of the occurrence of a bowhead whale acoustic encounter when there was no reported seismic activity (P = 0.01) (**Table 7**).

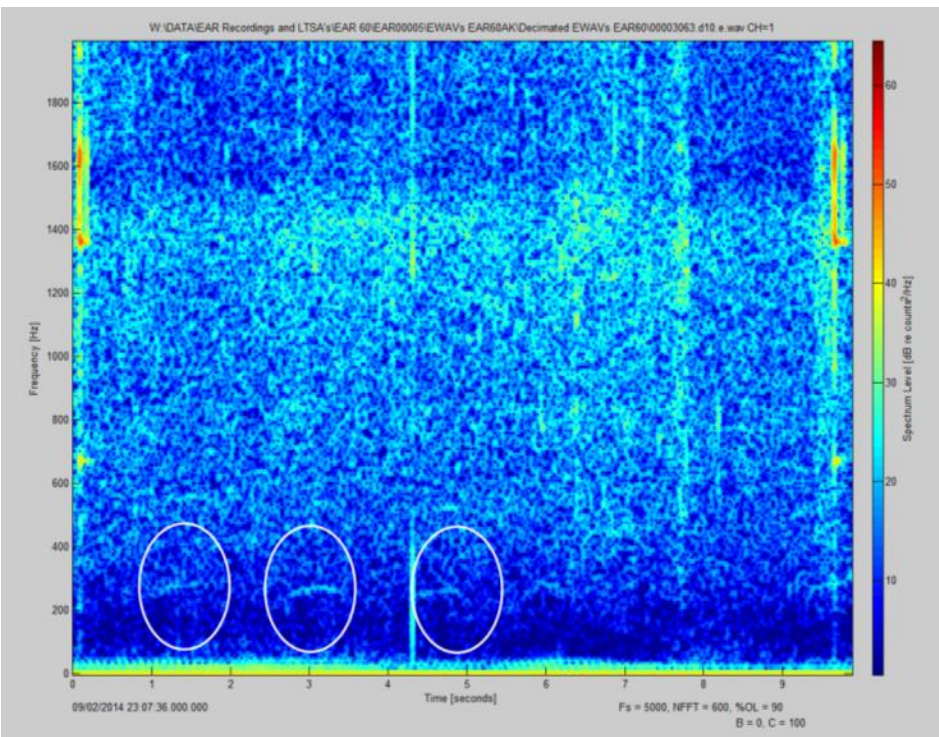

Figure 36. Spectrogram of bowhead whale moans recorded by EAR 60. Spectrogram was produced using a 10s plot length, 600 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz.

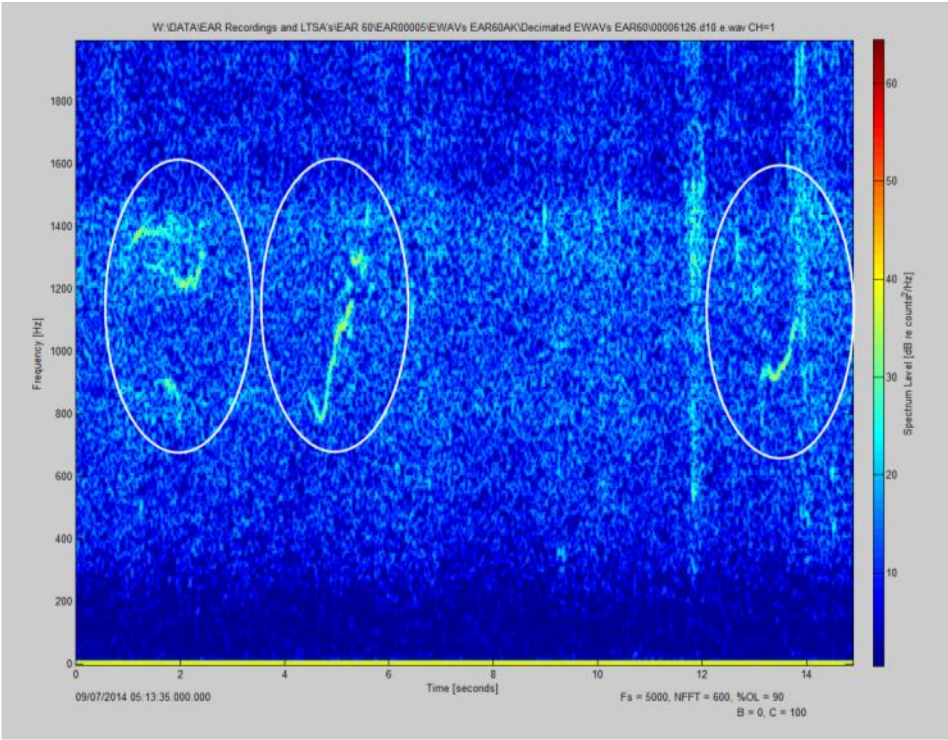

Figure 37. Spectrogram of bowhead whale song recorded by EAR 60. Spectrogram was produced using a 15s plot length, 600 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz.

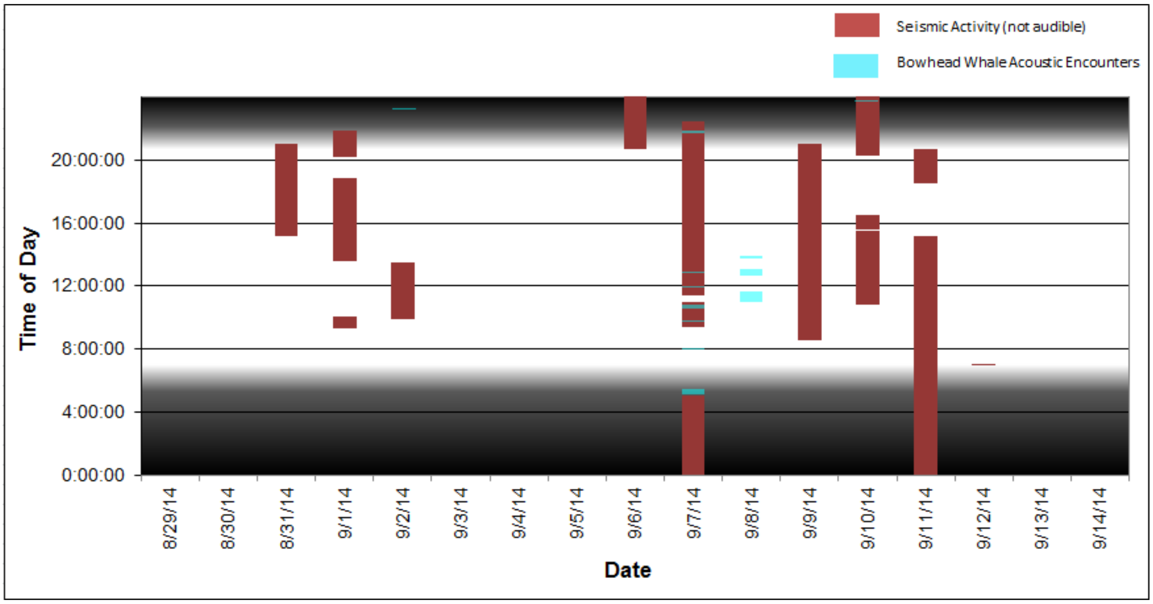

Figure 38. Bowhead whale acoustic encounters (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

Table 7. Probability and number of bowhead whale acoustic encounters that occurred in the presence and absence of reported seismic activity. The p-values of 2-tailed z-tests are provided (significance level < 0.01) to assess the significance of the difference between probabilities for both conditions.

Location	Presence of Reported Seismic Activity			Absence of Reported Seismic Activity			*p value*
	# encounters	n	Probability (P)	# encounters	n	Probability (P)	
EAR 60	9	477	0.02	16	1971	0.01	0.072

3.3.4.2 Ringed Seal

Ringed seal yelps and barks (**Figures 39 - 40**) were detected only on EAR 60. There were a total of three ringed seal acoustic encounters, two of which were barks and one that consisted of two yelps. The encounters occurred during three different days close to the end of the deployment (**Figure 41**). When seismic activity and ringed seal encounters were overlaid there was an obvious relationship between the two (**Figure 41**), however the number of acoustic events was extremely limited and so no probability statistics were calculated.

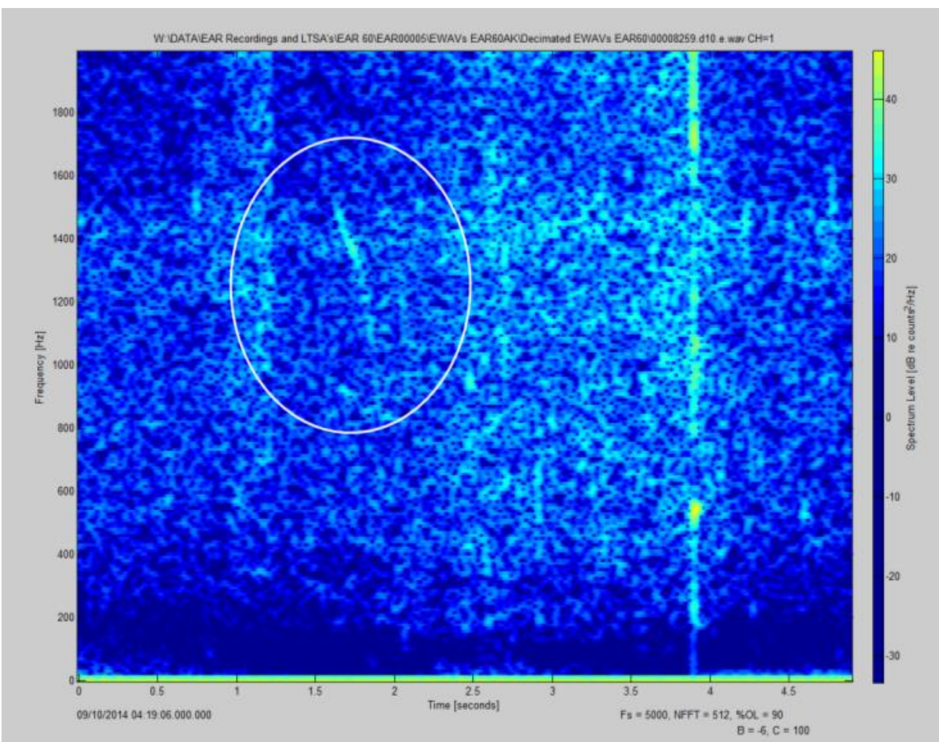

Figure 39. Spectrogram of a ringed seal yelp recorded by EAR 60. Spectrogram was produced using a 5s plot length, 512 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz

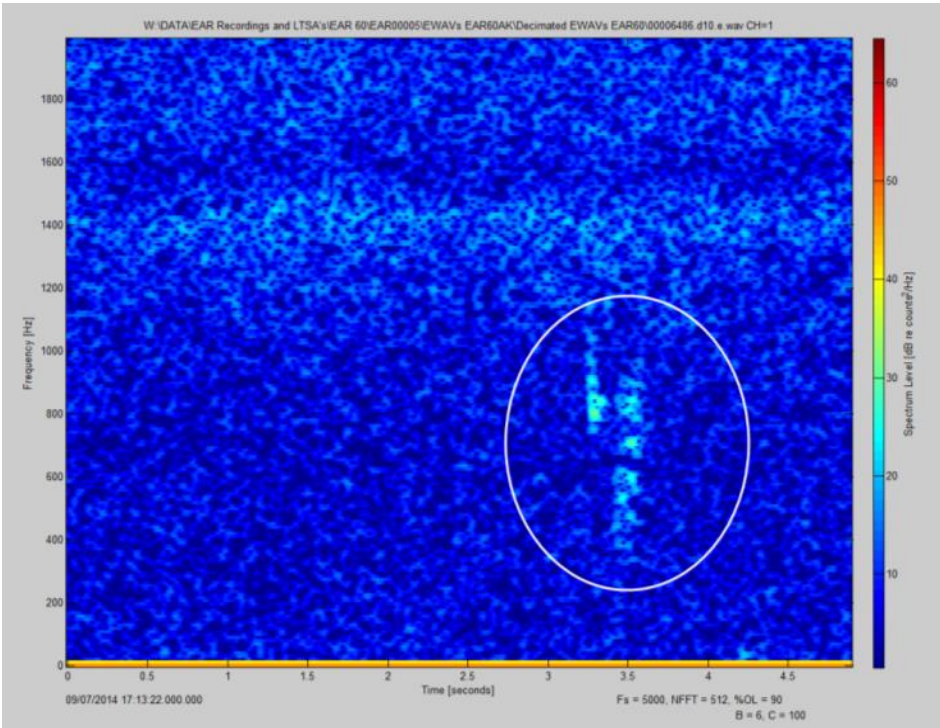

Figure 40. Spectrogram of a ringed seal bark recorded by EAR 60.
Spectrogram was produced using a 5s plot length, 512 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz.

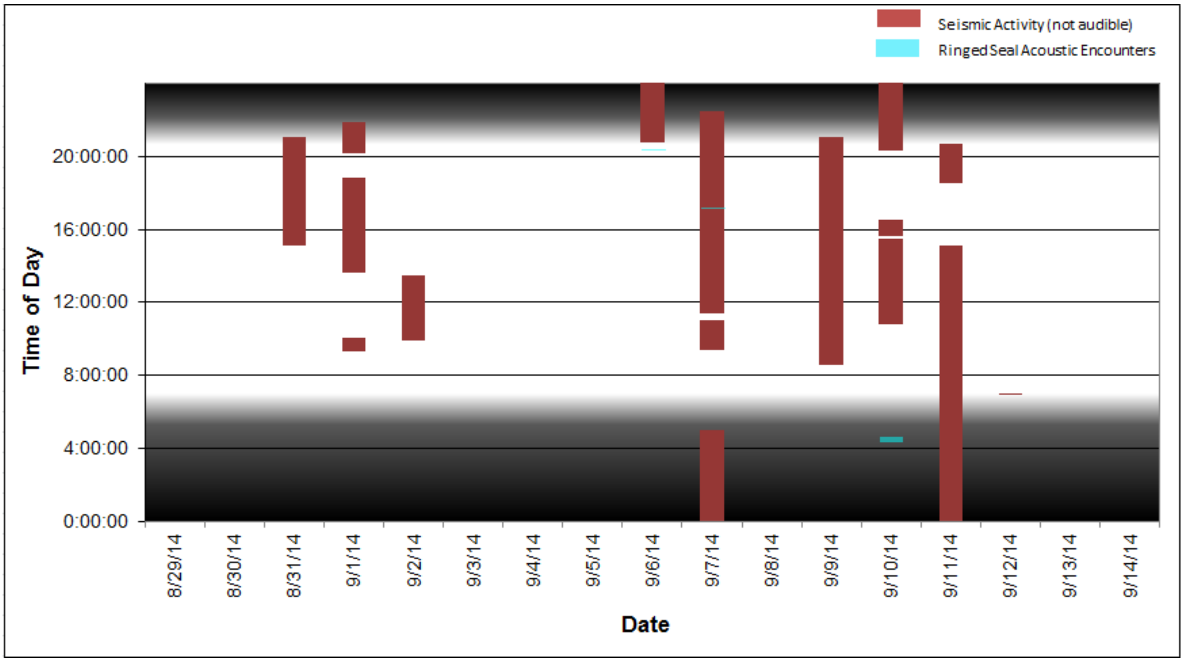

Figure 41. Ringed Seal acoustic encounters (blue) overlaid with reported seismic activity (red). The ringed seal acoustic encounters occurred on September 6th, September 7th and September 10th. Shaded areas denote periods of darkness.

<u>3.3.4.3 Bearded Seal</u>

Bearded seal trills (**Figure 42**) were only present in recordings made by EAR 60. There were a total of seven bearded seal acoustic encounters, which occurred on seven different days (**Figure 43**). All of the detections occurred during nearly consecutive days from September 5 to September 12. Bearded seal trills were detected during both day and night. When seismic activity and bearded seal encounters were overlaid there was no obvious relationship between the two (**Figure 43**) and the very small number of acoustic events precluded the application of probability statistics.

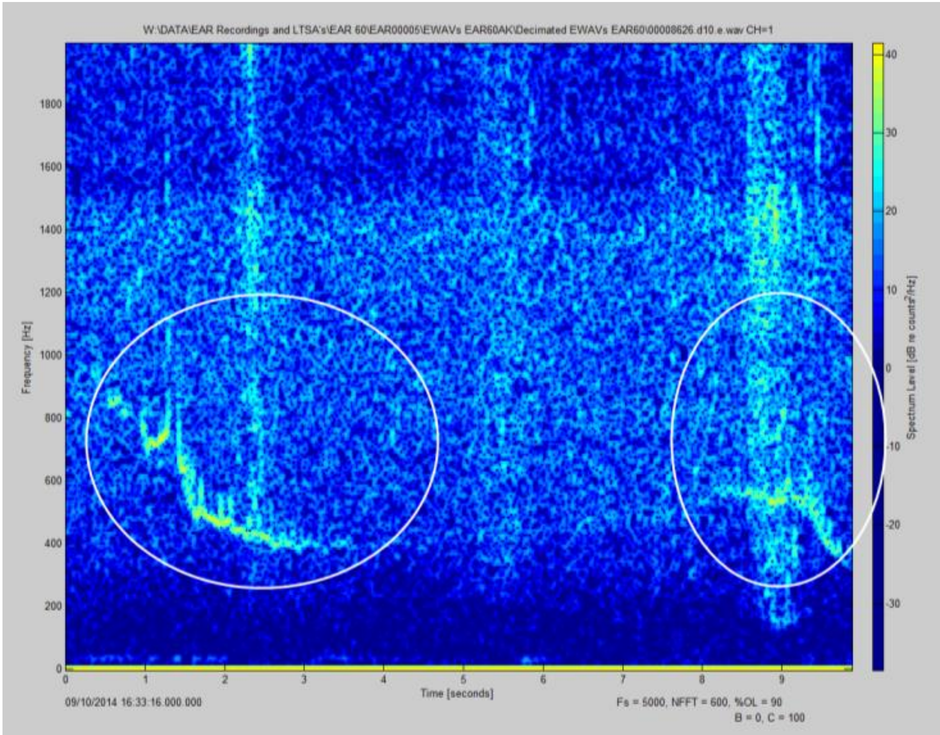

Figure 42. Spectrogram of a bearded seal trills recorded by EAR 60.
Spectrogram was produced using a 10s plot length, 600 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz.

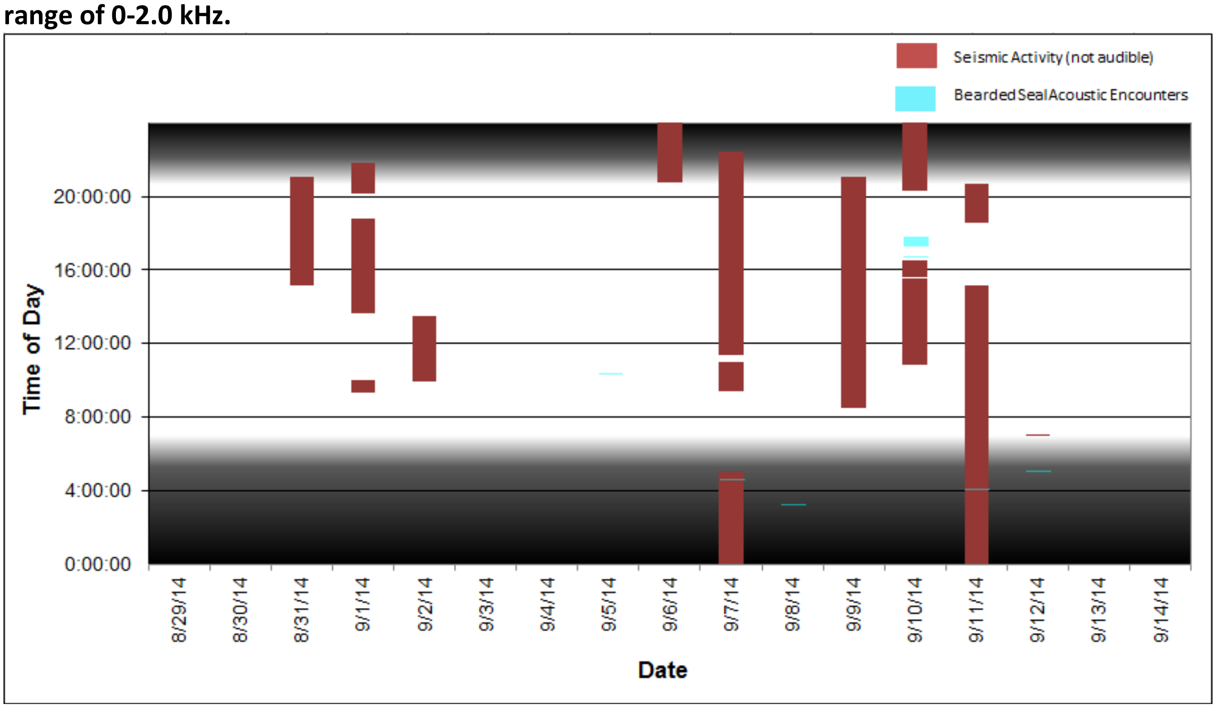

Figure 43. Bearded Seal acoustic encounters (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

3.3.4.4 Unidentified Pinniped

Unidentified pinniped vocalizations were detected in recordings made by EAR 60 and EAR 62. There were a total of 17 unidentified pinniped acoustic encounters (**Figure 44**). Fourteen of the encounters occurred on EAR 60 on seven separate days (**Figure 45**). The three encounters that occurred on EAR 62 all occurred on August 3 (**Figure 46**). The majority of pinniped acoustic encounters (82.4 percent) occurred during periods of dawn and dusk. Probability statistics were not calculated for unidentified pinnipeds due to low sample size and the likelihood of mixed species in this category.

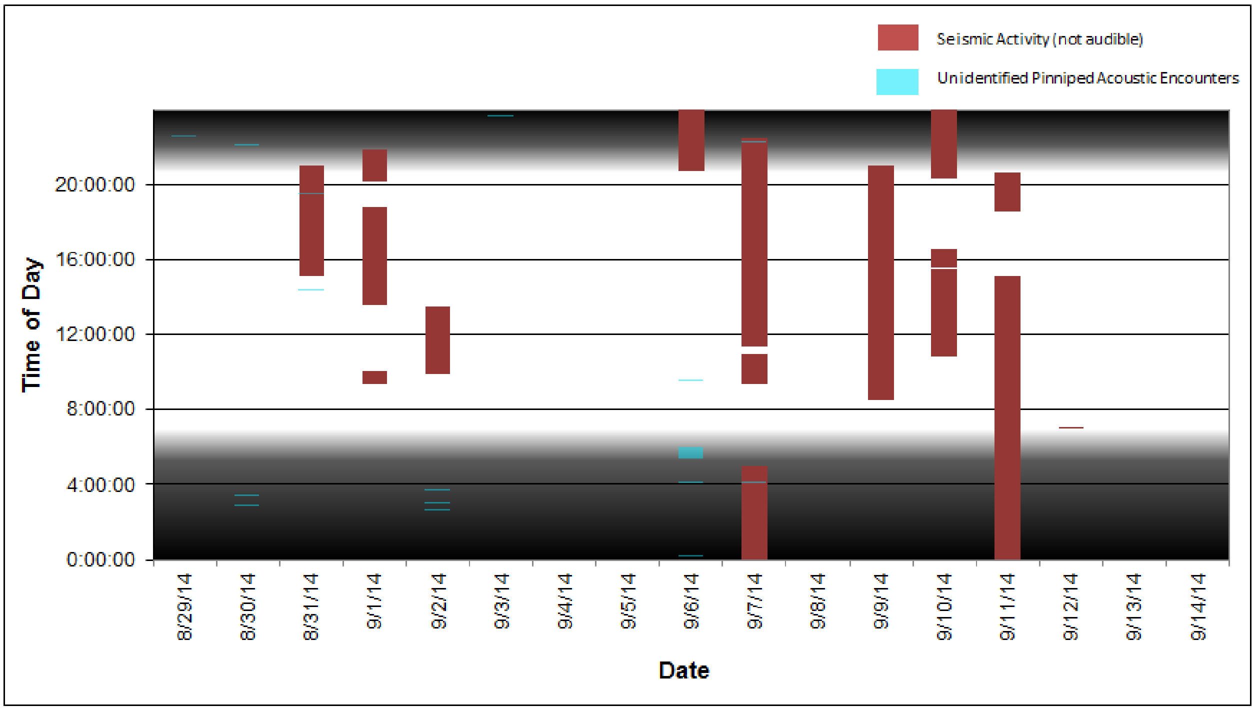

Figure 44. Unidentified pinniped acoustic encounters on EAR 60 and EAR 62 (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

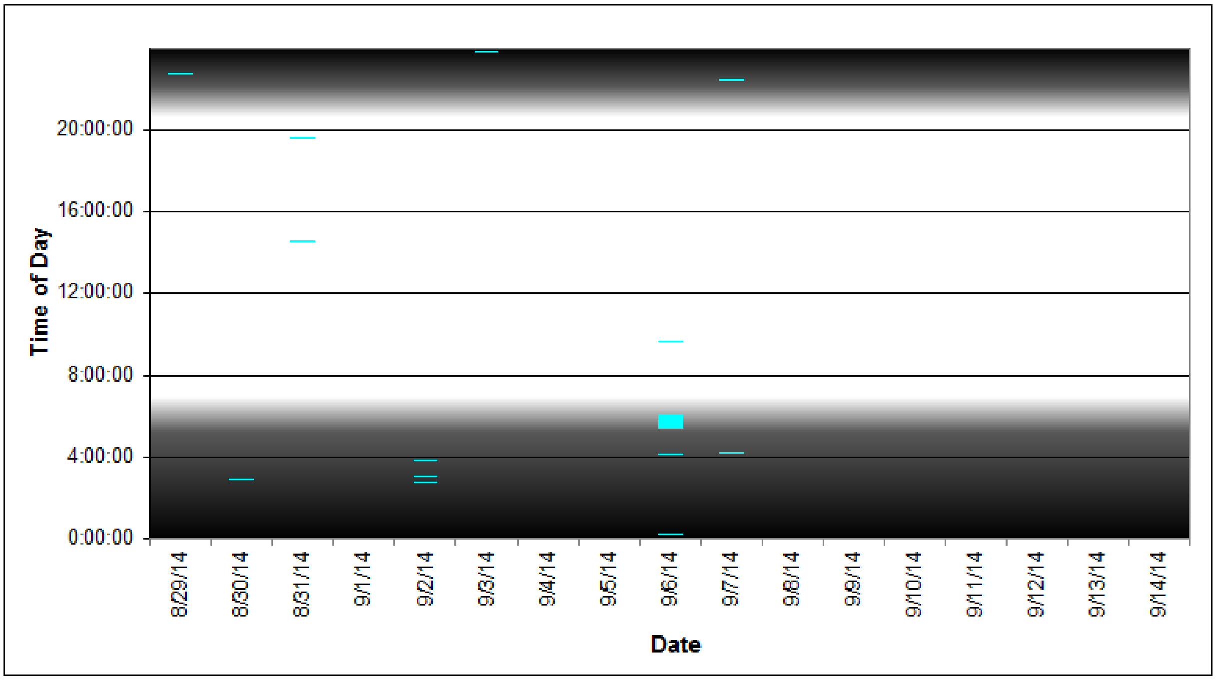

Figure 45. Unidentified pinniped acoustic encounters at EAR 60. Shaded areas denote periods of darkness.

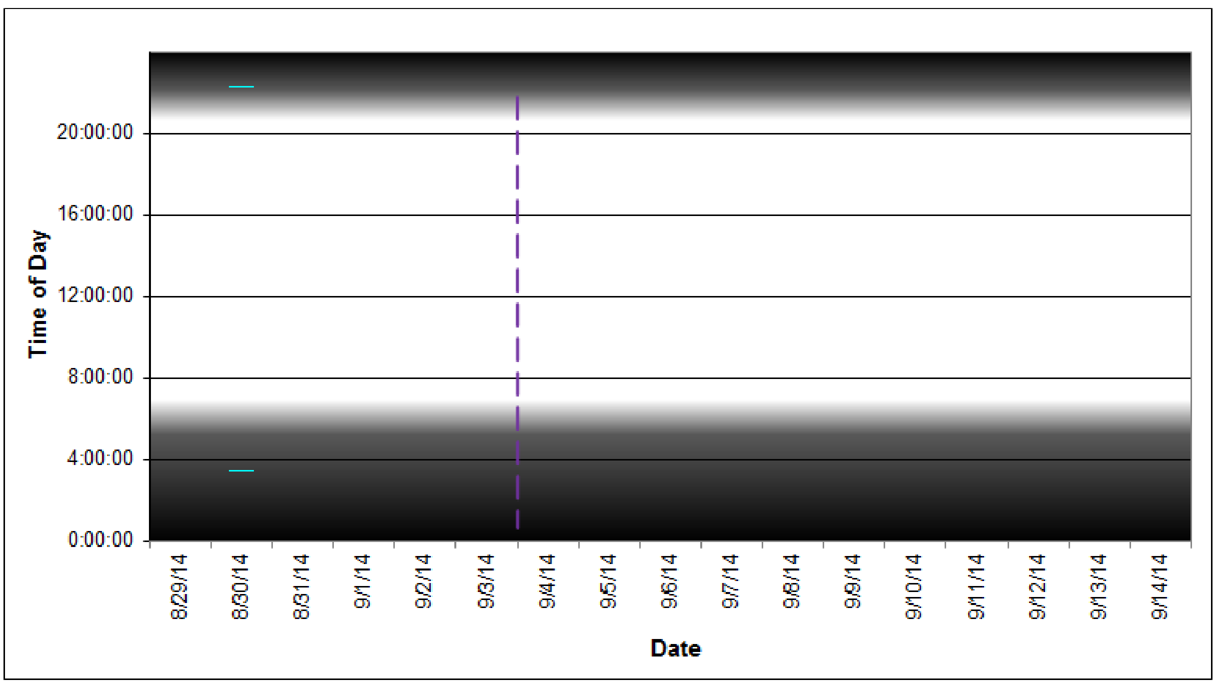

Figure 46. Unidentified pinniped acoustic encounters at EAR 62. Shaded area denotes periods of darkness, and purple line denotes end of EAR recording.

3.3.4.5 Unidentified Marine Mammal

Unidentified marine mammal acoustic encounters occurred only on recordings made by EAR 59 and EAR 60. There were a total of 22 unidentified marine mammal acoustic encounters (**Figure 47**). Eighteen of the encounters occurred at EAR 59 during three consecutive days (September 4 to September 6; **Figure 48**). The remaining four encounters occurred at EAR 60 during two consecutive days (September 7 to September 8; **Figure 49**). When seismic activity and unidentified marine mammal encounters were overlaid there was no obvious relationship between the two (**Figure 47**). Probability statistics were not calculated due to insufficient sample size.

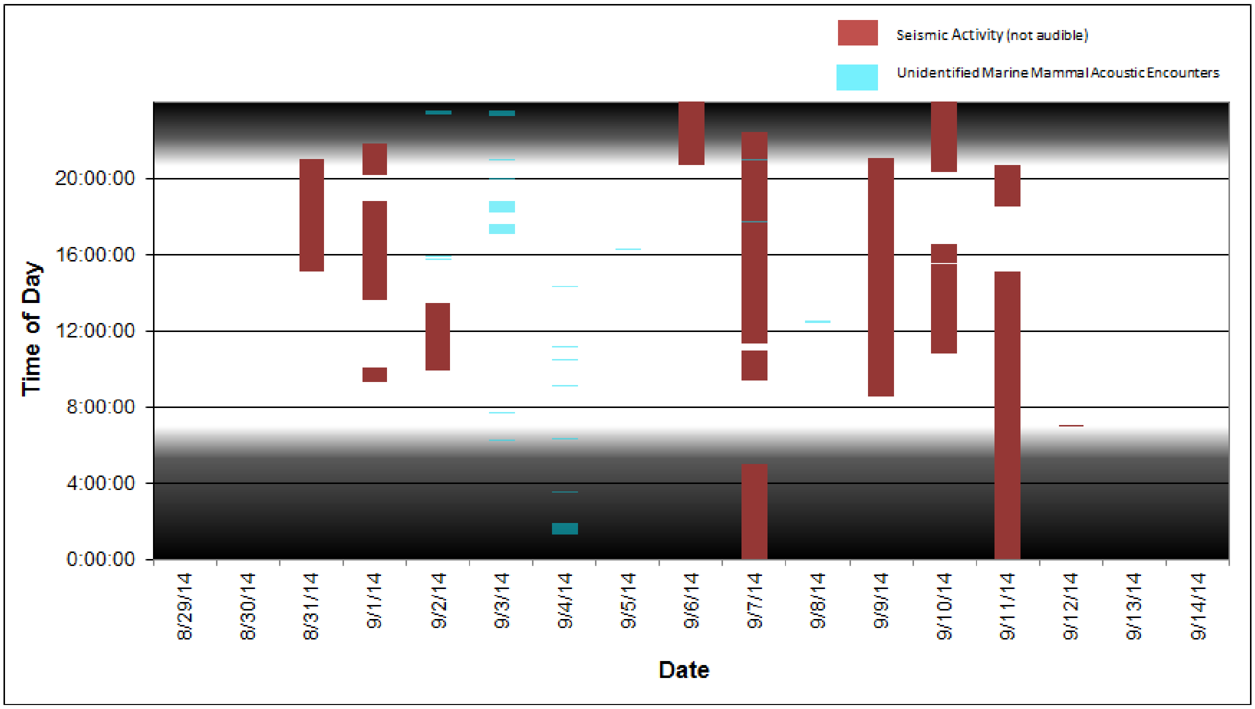

Figure 47. Unidentified marine mammal acoustic encounters at EAR 59 and EAR 60 (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

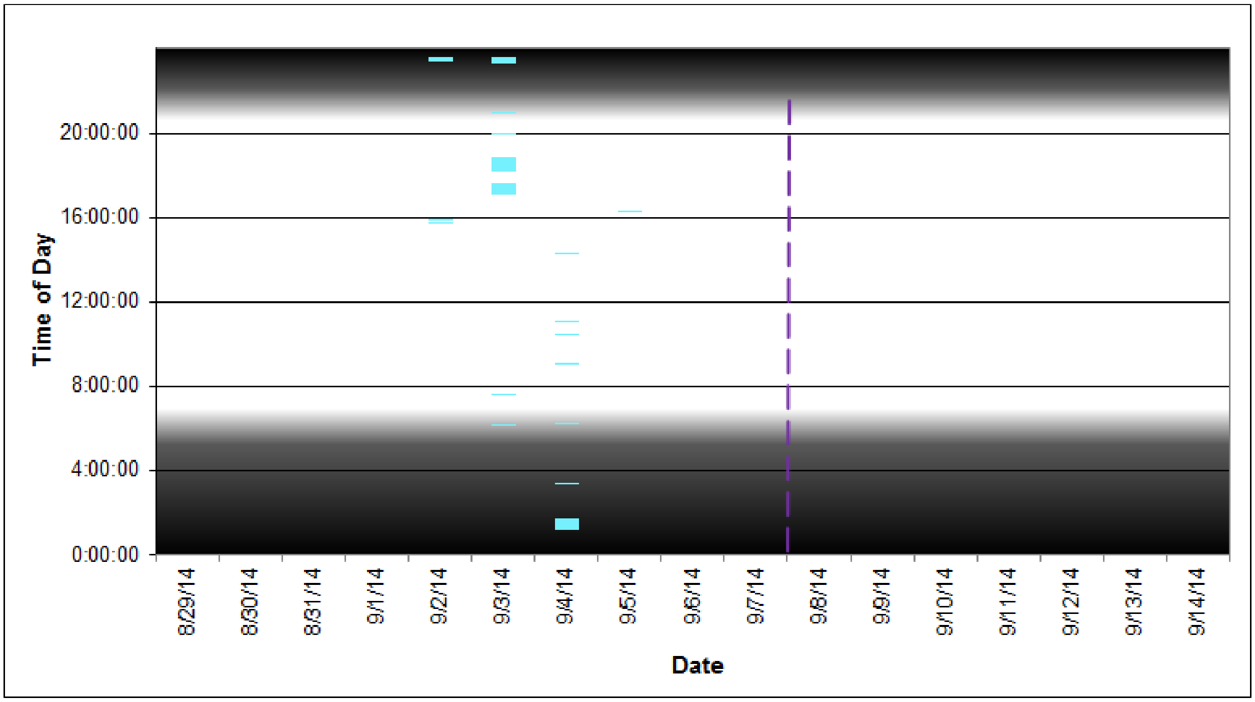

Figure 48. Unidentified marine mammal acoustic encounters at EAR 59. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

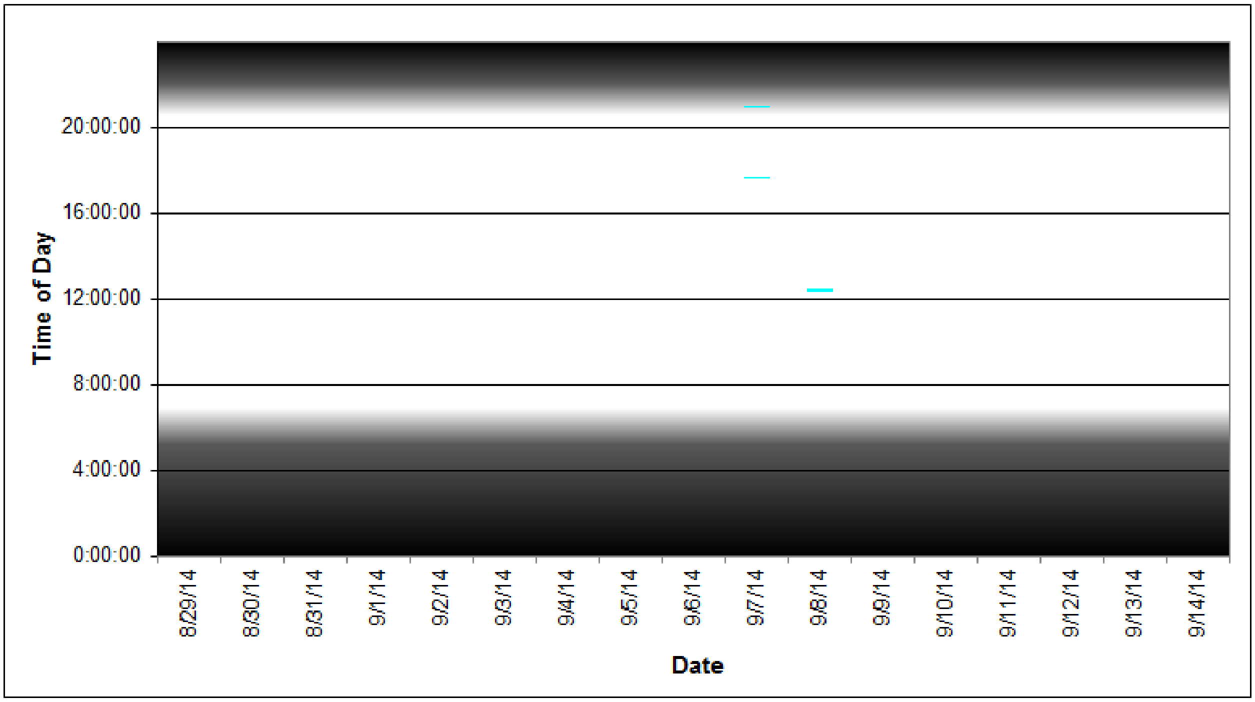

Figure 49. Unidentified marine mammal acoustic encounters at EAR 60. Shaded areas denote periods of darkness.

3.3.4.6 Unidentified Fish

Unidentified fish acoustic encounters were detected in recordings made by all three EARs. There were a total of 66 unidentified fish acoustic encounters (**Figure 50**). EAR 59 data contained 34 of these encounters, occurring during all ten days of recordings (**Figure 51**). EAR 60 data contained 27 of these encounters, occurring during eight different days (**Figure 52**). The remaining five encounters occurred on EAR 62 data, during three different days (**Figure 53**). The probability of an unidentified fish acoustic encounter was significantly higher (2-sample z-test, p = 0.005), during reported seismic activity (P = 0.70) versus when there was no reported seismic activity at EAR 59 (P = 0.58) and significantly lower (2-sample z-test, p = 0.003) during reported seismic activity (P = 0.01) versus when there was no reported seismic activity (P = 0.03) at EAR 60 (**Table 8**). Probability analysis was not conducted for unidentified fish encounters at EAR 62 due to insufficient sample size.

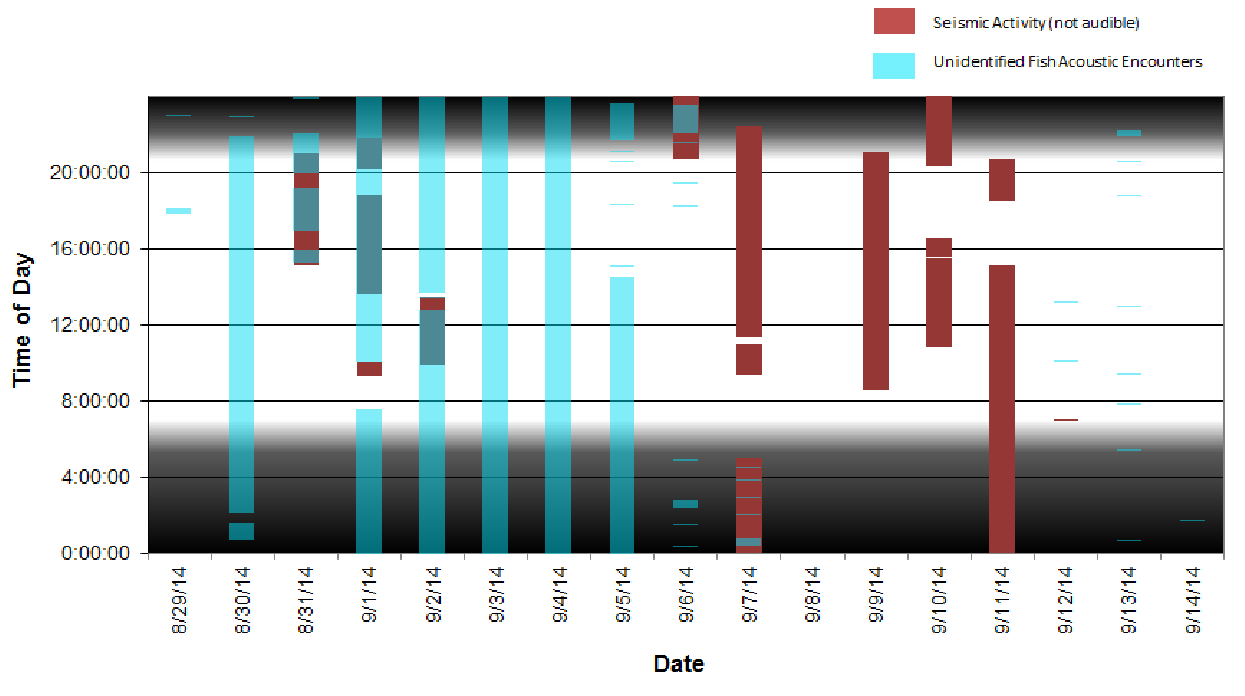

Figure 50. Unidentified fish acoustic encounters (all EARs) overlaid with reported seismic activity. Shaded areas denote periods of darkness.

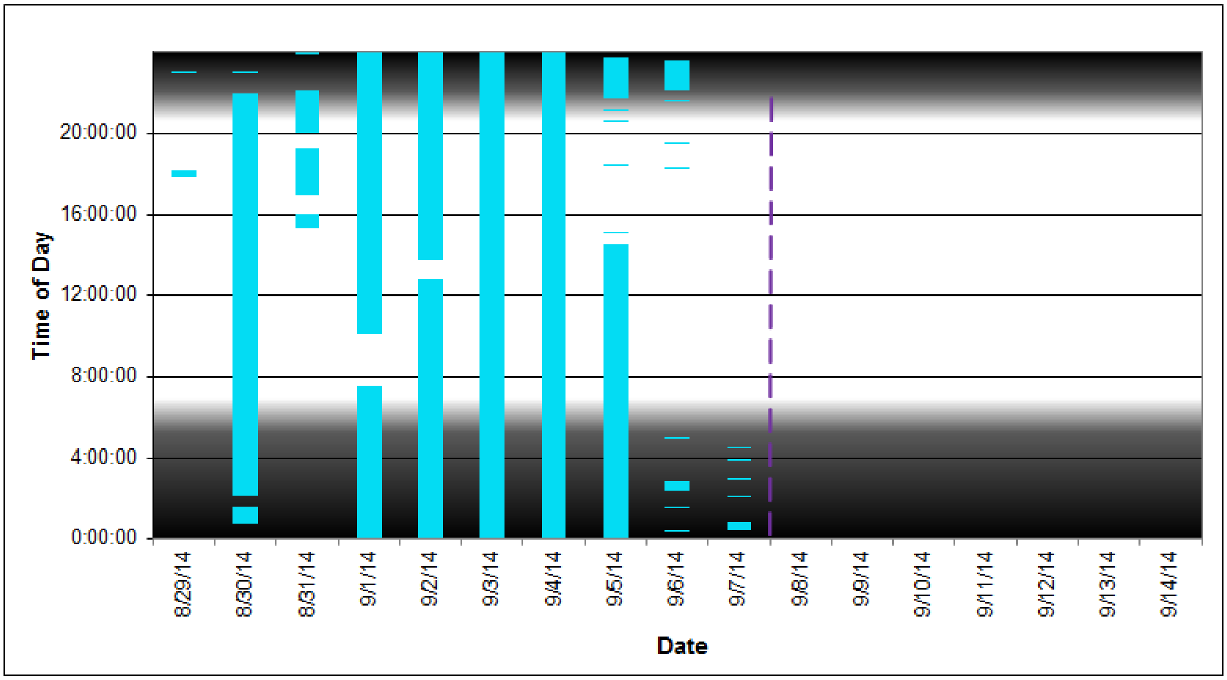

Figure 51. Unidentified fish acoustic encounters at EAR 59. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

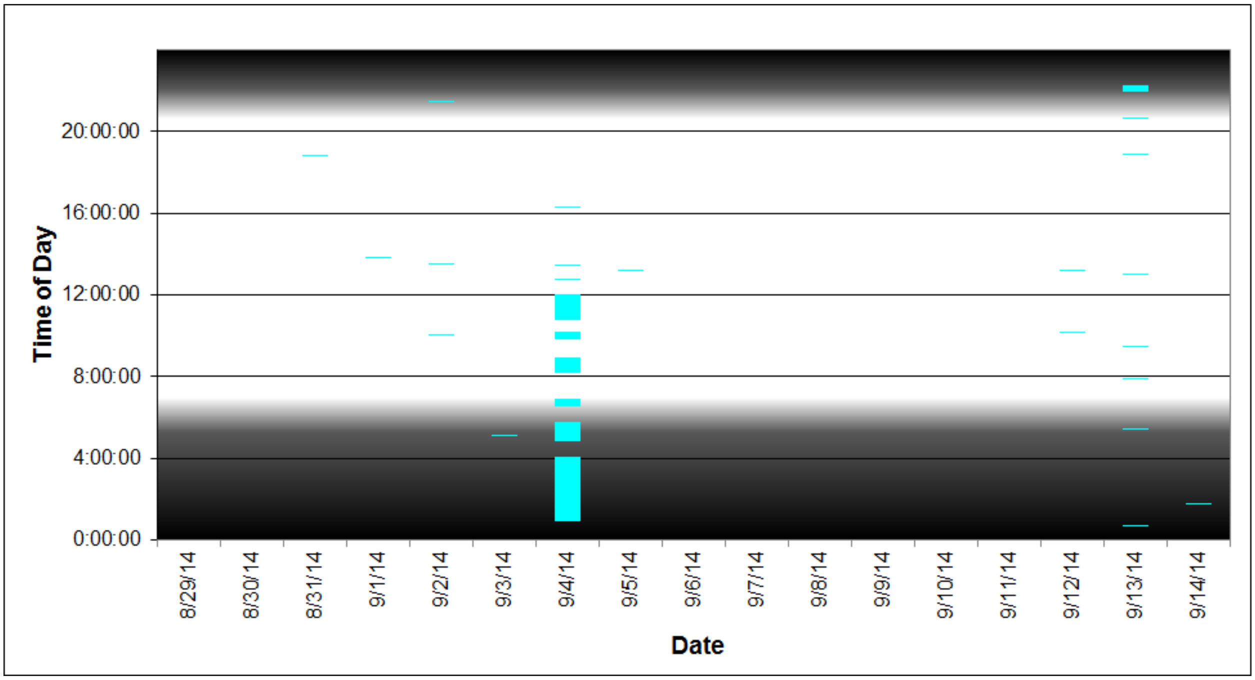

Figure 52. Unidentified fish acoustic encounters at EAR 60. Shaded areas denote periods of darkness.

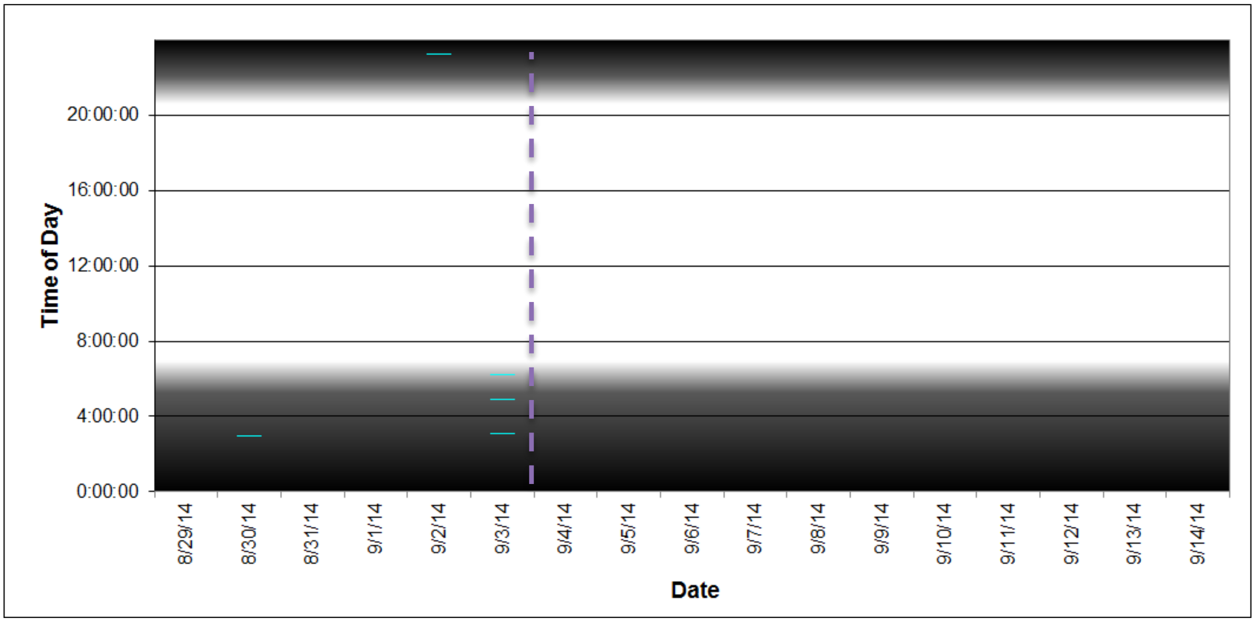

Figure 53. Unidentified fish acoustic encounters at EAR 62. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

Table 8. Probability and number of unidentified acoustic encounters that occurred in the presence and absence of reported seismic activity. The p-values of 2-tailed z-tests are provided (significance level < 0.01) to assess the significance of the difference between probabilities for both conditions.

Location	Presence of Reported Seismic Activity			Absence of Reported Seismic Activity			*p value*
	# encounters	n	Probability (P)	# encounters	n	Probability (P)	
EAR 59	111	159	0.70	746	1281	0.58	0.005
EAR 60	4	477	0.01	67	1971	0.03	0.003

<u>3.3.4.7 Unidentified Biological</u>

Unidentified biological acoustic encounters were detected only in recordings from EAR 60 and EAR 62. There were a total of 12 unidentified biological acoustic encounters (**Figure 54**). EAR 60 data contained 11 of these encounters, occurring during five different days of recordings (**Figure 55**). EAR 62 data contained only one of these encounters (**Figure 56**). When seismic activity and unidentified biological encounters were overlaid there was no obvious evidence of a relationship between the two (**Figure 54**). No probability statistics were run because these encounters could not be identified to species.

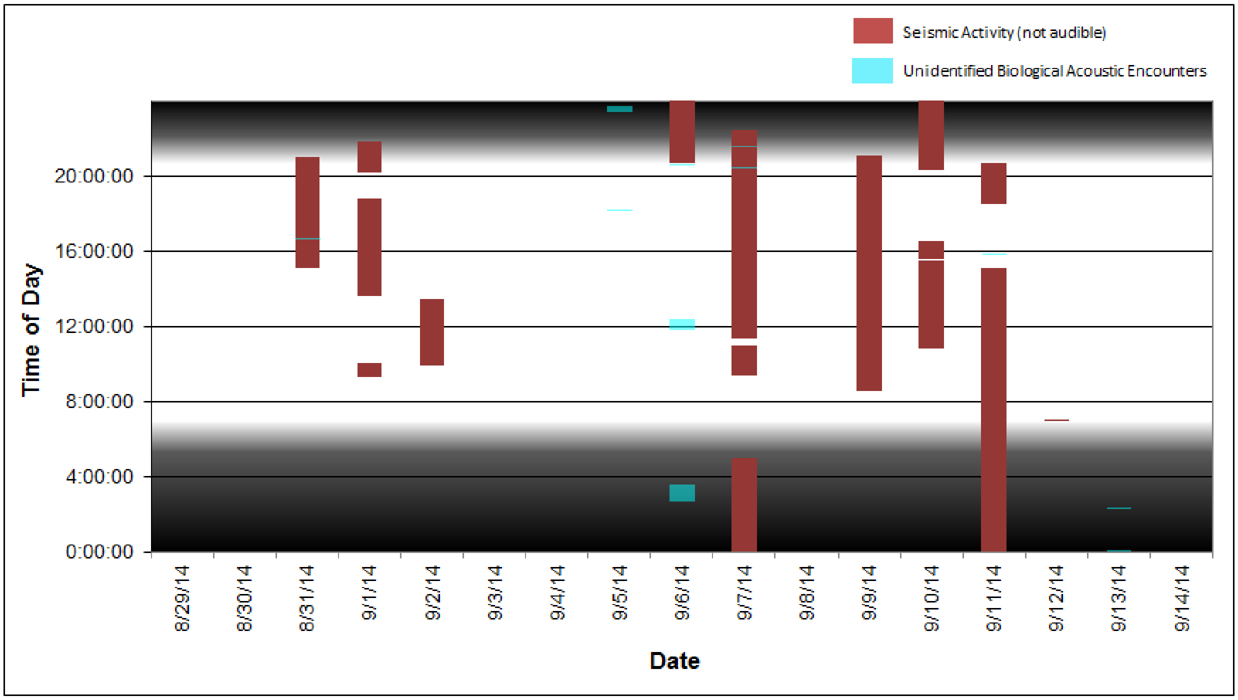

Figure 54. Unidentified Biological acoustic encounters at EAR 60 and EAR 62 (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

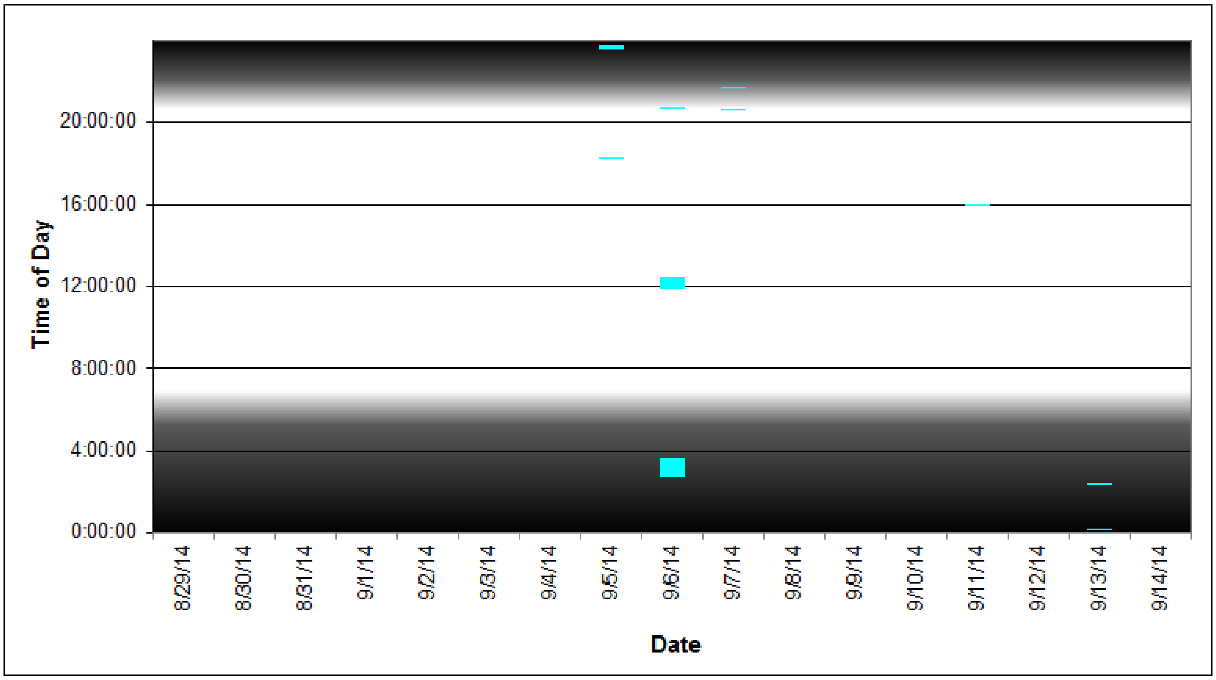

Figure 55. Unidentified biological acoustic encounters at EAR 60. Shaded areas denote periods of darkness.

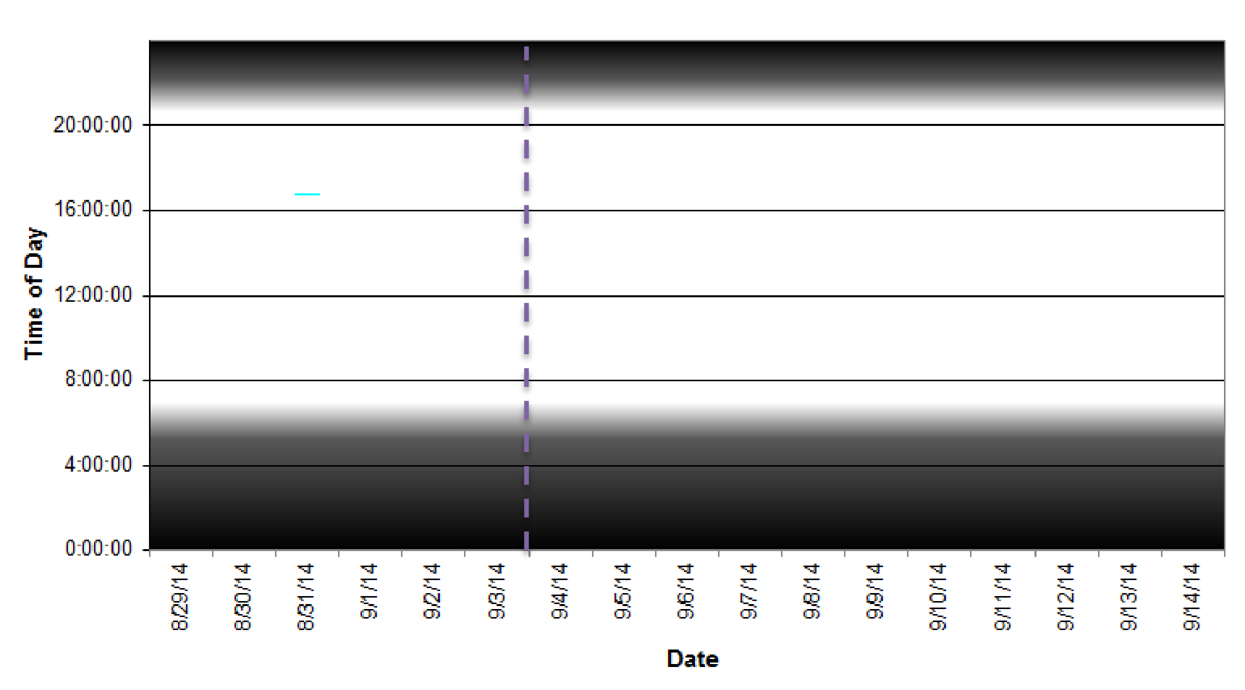

Figure 56. Unidentified biological acoustic encounters at EAR 62. Shaded areas denote periods of darkness.

3.3.4.8 Anthropogenic Sonar

There was a single detection of mid-frequency active sonar recorded by EAR 62. This multiple-tone signal had a duration of approximately 1 second, ranged from 0.8 kHz to 1.8 kHz (**Figure 57**), and occurred during a known period of seismic activity (**Figure 58**).

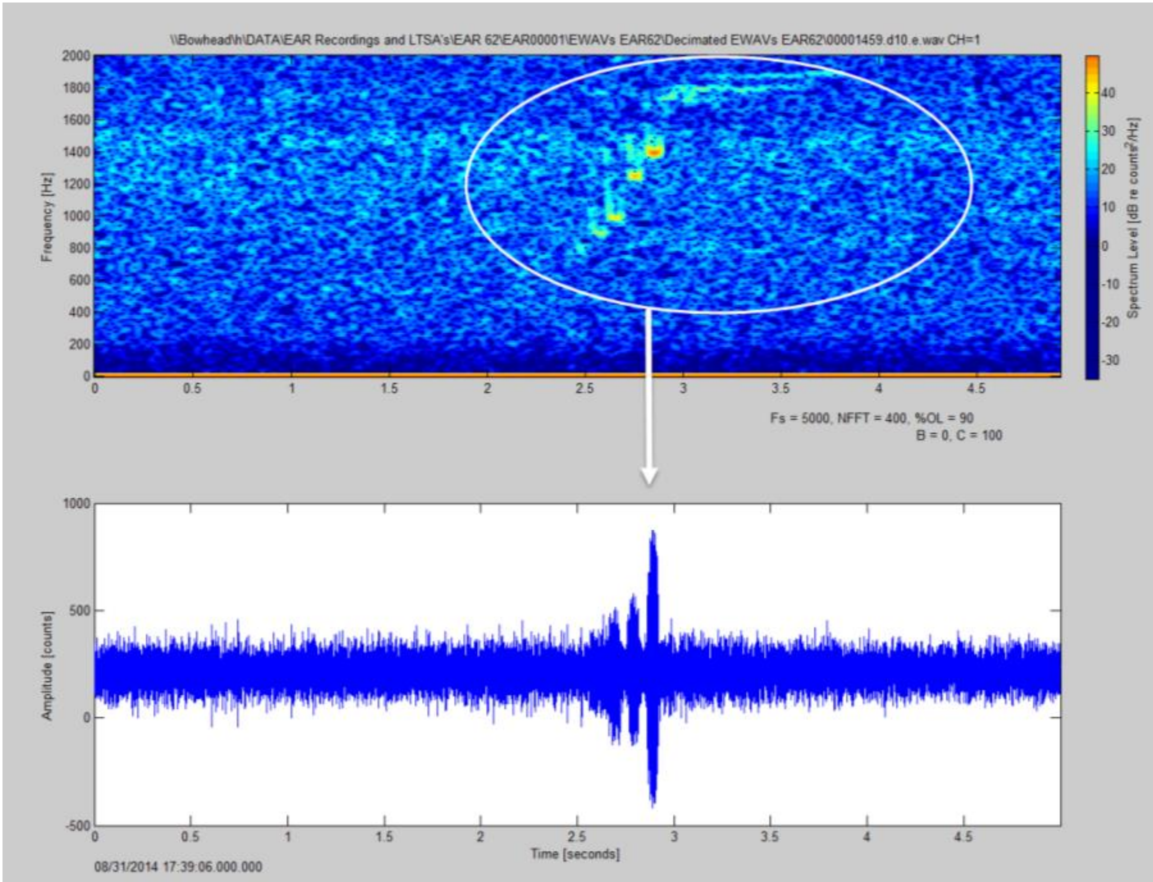

Figure 57. Spectrogram (top panel) and waveform (bottom panel) of mid-frequency active sonar recorded by EAR 62. Spectrogram was produced using a 5s plot length, 400 point FFT with 90% overlap, and a frequency range of 0-2.0 kHz.

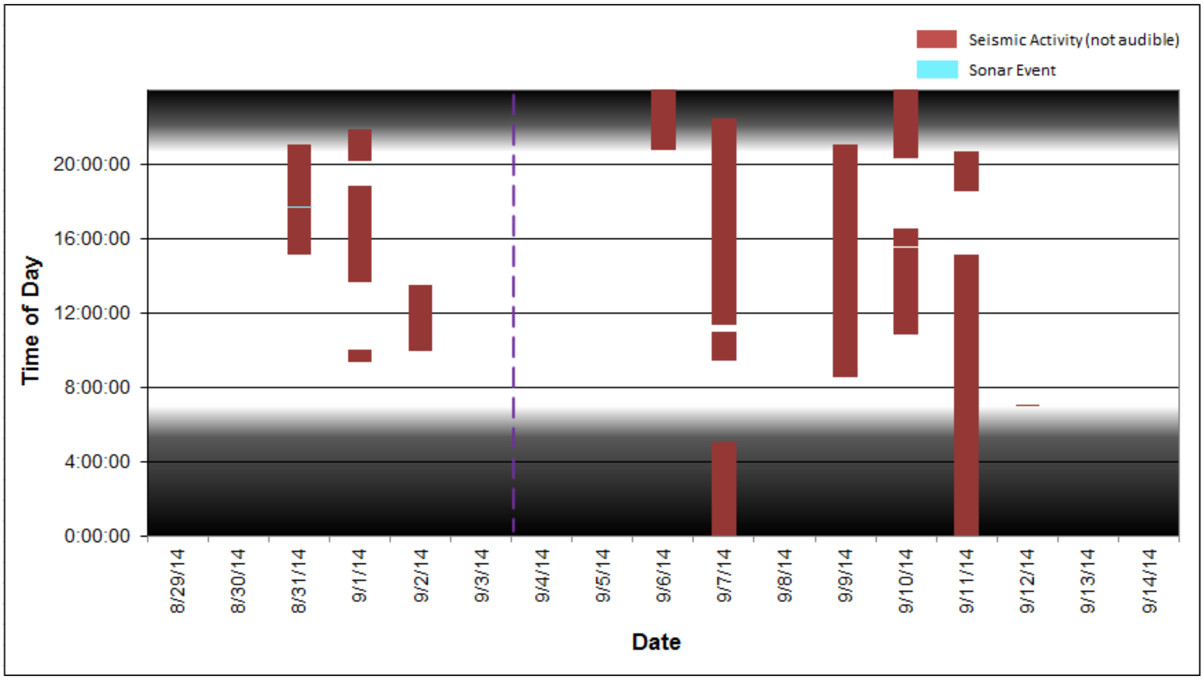

Figure 58. Sonar event at EAR 62 (blue) overlaid with reported seismic activity (red). The sonar event occurs on August 31, 2014. Shaded areas denote periods of darkness, and purple line denotes end of EAR recording.

3.3.4.9 Vessel Noise

Vessel noise was detected in recordings from all three EARs, showing up as a noise band in the low frequency LTSAs (**Figure 59**). It occurred during eight different days and varied in duration (**Figure 60**).

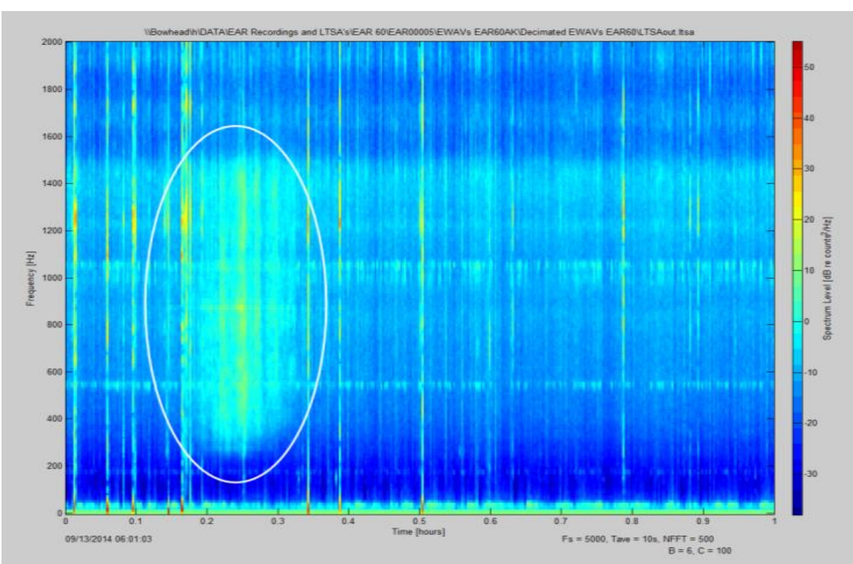

Figure 59. One hour LTSA of recordings made by EAR 60 showing ship noise in the lower frequencies. Frequency range 0 – 2.0 kHz.

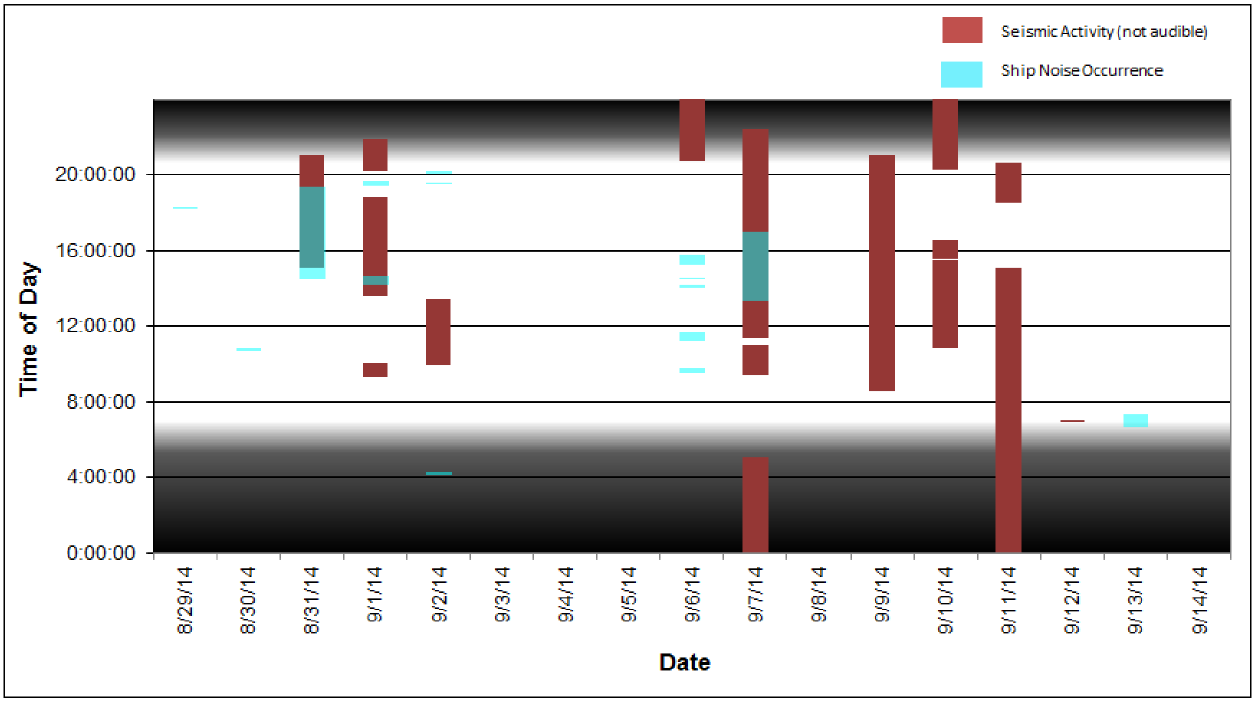

Figure 60. Vessel noise occurrence at all EARs (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

3.3.4.10 Anthropogenic 0-50 Hz Noise

Low frequency noise extending from 0 to 50 Hz was detected on EAR 60 (**Figure 61**). This noise occurred during three different days for long periods of time. It was classified as an anthropogenic source by an experienced acoustician, although the specific source is unknown. When overlaid with seismic activity, there was no obvious relationship between the occurrence of seismic activity and the 0-50 Hz noise (**Figure 62**).

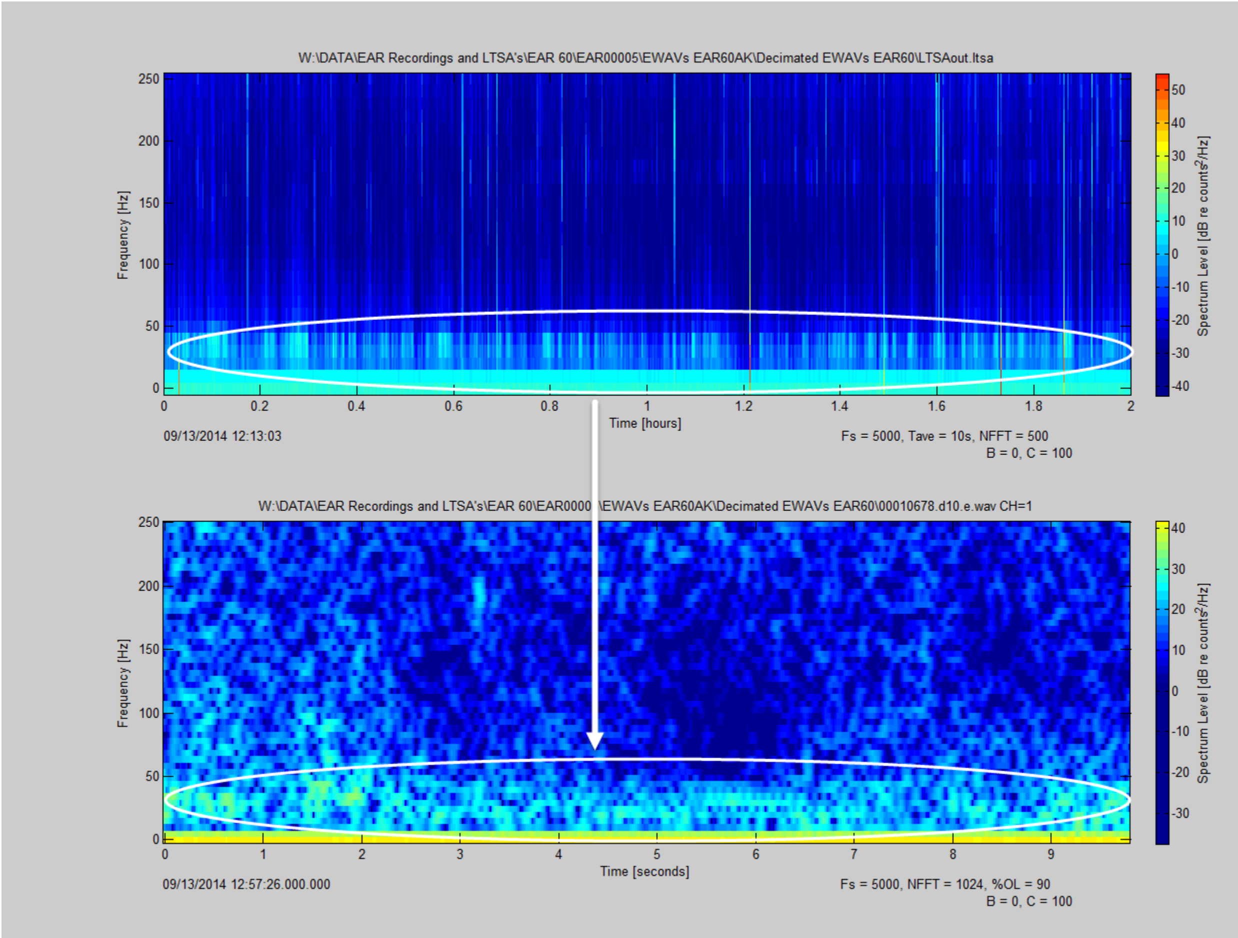

Figure 61. Unknown anthropogenic noise in the 0-50 Hz frequency band, recorded by EAR 60. The top panel shows a 2-hour LTSA image of the anthropogenic noise from 0-50 Hz from EAR 60. The bottom panel shows a 10 second spectrogram of that LTSA.

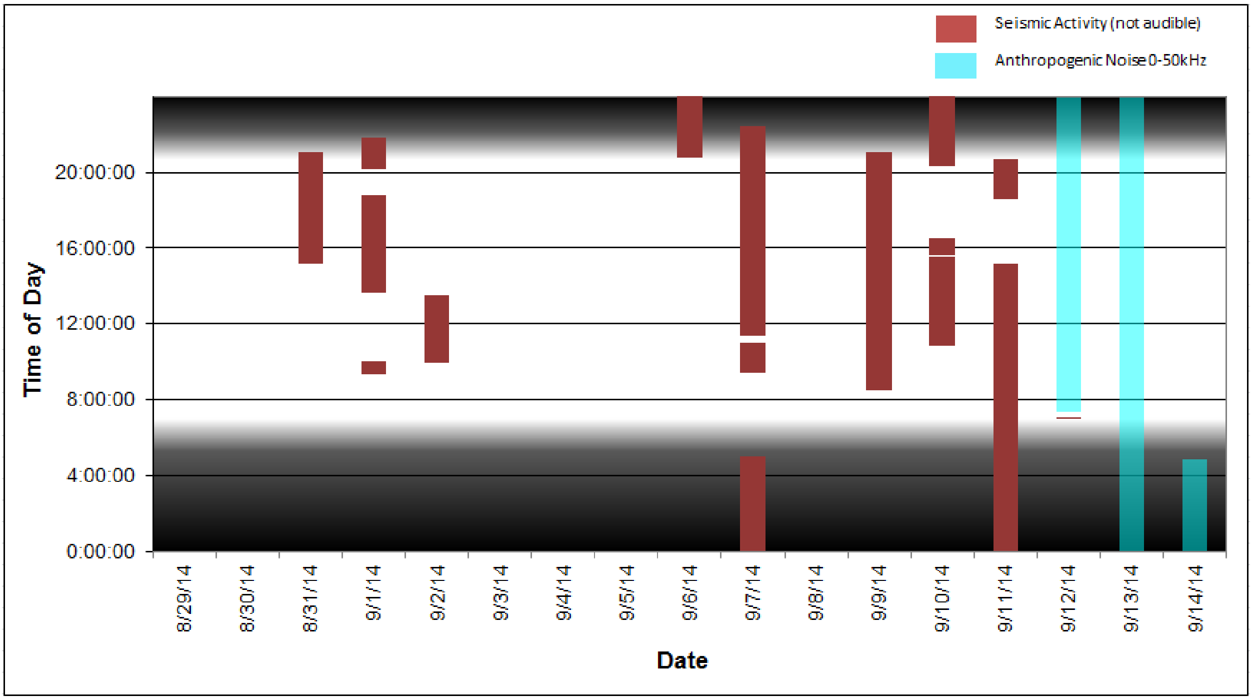

Figure 62. Occurrence of unknown anthropogenic noise in the 0-50 Hz frequency band recorded by EAR 60 (blue) overlaid with reported seismic activity (red). Shaded areas denote periods of darkness.

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4. DISCUSSION

4.1 EAR Deployments

All four EARs were successfully deployed and retrieved but the EARs unexpectedly stopped recording before the end of the monitoring period. Based on a post-project engineering analysis of the EARs, the premature end to the recording process was most likely related to use of solid-state drives (SSDs) for data storage in the new Second Generation EAR (EARII) system. The EARII system used in these deployments was an upgraded version of the original EAR system. SSDs were implemented in the EARIIs in an effort to mitigate against known weaknesses and shortcomings in traditional mechanical hard disk drives that can lead to disk failure. OSI conducted extensive bench and field testing of the new system prior to the current deployments, including testing the reliability of SSDs, but a problem in the software interface between the EAR and SSD apparently went undetected. OSI is analyzing the problem and will resolve the issue for future EAR deployments, but regrettably the lesson comes at the expense of lost data for this project.

4.2 Seismic Activity

Although seismic survey activity occurred near the study area on nine days for a total of more than 100 hours during the EAR recording period, seismic sounds were not detected by bioacousticians on any of the recordings. This was not unexpected given the shallow water area in which EARs were deployed and the absorptive properties of the seafloor in this location. The propagation of sound in very shallow water can be complex, but depends primarily on the property of the bottom substrate, the roughness of the sea surface and the depth of the water column. Generally, the more shallow the water, the lower the cutoff frequency at which sound energy will not propagate effectively (Au and Hastings 2008). Shallow water essentially functions as a high-pass filter, filtering out the lower frequency energy from sound waves propagating horizontally. Additionally, during the period of recordings, seismic activity occurred only in the eastern portion of the study area, which is at least 10 km from the nearest recording EAR. The effects of sound propagation, absorption, and natural ambient noise in the shallow water environment, as well as range to the activity may have reduced seismic acoustic energy below what was detectable. An unknown Anthropogenic ‘pinging’ activity was detected in the high frequency data from August 29 through September 2. We do not know the source of these signals, but they did occur at the same time that seismic activity was reported.

4.3 Noise Analysis

Noise levels (RMS SPL) varied greatly between EARs. EAR 59 had the lowest noise levels, with an overall average full frequency band noise level of 98.8 dB, which was 2.9 dB less than the overall average noise level at EAR 60 and 6.6 dB less than the overall average noise level at EAR 62. The variations in noise levels observed at each EAR location and in the five analyzed octave bands were likely due in part to acoustic energy from wind-driven, surface-breaking waves (broadband noise increases as wind speeds increase; Farmer and Lemon 1984, Bannister 1986). Also prominent in the recordings from EAR 60 and 62 was self-noise caused by parts of the EAR mooring (e.g., shackle movement). Repeated jarring movements of the mooring system, presumably caused by strong currents, are believed to have caused the rhythmic broadband pulses observed in approximately 50-70 percent of recordings in these two EARs. Although the pulses did not negatively affect the detectability of marine mammal calls by bioacousticians, they did influence the calculated noise levels at the two locations, effectively raising the overall noise levels.

Noise from vessel traffic was occasionally detected in each of the data sets. However, it was not possible to determine whether the vessel noise recorded was associated with SAE's vessels or other normally occurring vessel traffic in the area. Overall, noise from vessel traffic was relatively insignificant when compared to the noise contributed from natural sources.

4.4 Marine Mammal Occurrence

Only two species of cetaceans, beluga and bowhead whales, were detected on the EAR recordings. Based on the acoustic encounters, beluga whales appear to be common in the study area, comprising the majority of acoustic encounters and the greatest percent of acoustic encounter duration at all EAR locations. The high number of beluga whale acoustic encounters was expected because they are known to inhabit nearshore coastal and shallow waters near rivers, and have been documented as resident in the general area of our deployment sites in summer months (Richard et al. 2001). In addition, beluga whales produce a wide repertoire of sounds and are known to be very acoustically active (Chmelnitsky and Ferguson 2012). Sounds produced by beluga whales were present during 24 percent of the total recording period at EAR 59, compared to 5 percent at EAR 60 and 3 percent at EAR 62. The greater duration of beluga whale acoustic encounters at EAR 59 could be explained in several ways. First, it is possible that beluga whales may use this inshore habitat more frequently than the two offshore (EAR 60 and 62) locations. Alternatively, the lower ambient noise levels recorded at EAR 59 and/or differences in sound propagation among sites may have resulted in higher signal-to-noise ratios, and therefore, better detectability of beluga signals at EAR 59. Another alternative is that the belugas were spending more time near EAR 59 than the other recorder deployment sites due to some aspect of the habitat (e.g., prey availability). The probability of an unidentified fish acoustic encounter occurring was significantly higher during periods of reported seismic activity versus when there was no reported seismic activity at EAR 59 (2-sample z-test, $p = 0.01$), significantly lower during periods of reported seismic activity versus when there was no reported seismic activity at EAR 60 (2-sample z-test, $p = 0.003$). This suggests that fish may move from EAR 59 to EAR 60, potentially in response to seismic activity. Beluga whales may, in turn, be following potential prey. Finally, it is possible that beluga whales were responding to the seismic activity in the eastern portion of the study area by moving to a quieter area or an area with less human activity, near the western EAR locations. The results of the probability tests may be explained by one or some combination of these hypotheses. It is not possible to draw conclusions based on the data collected here and more research is needed to elucidate the biological significance of these results. EAR 59 was deployed in the shallowest water depths (~ 4m) and was located inshore of Thetis Island. Thetis Island may have provided a barrier to seismic acoustic energy, resulting in lower noise levels at EAR 59. The probability of a beluga whale acoustic encounter occurring during reported seismic was significantly higher at EARs 59 and 60 versus the probability of a beluga whale acoustic encounter in the absence of reported seismic activity. This supports the hypothesis that beluga whales may be increasing the use of these areas during seismic activity. Alternatively, they may be increasing their vocalization rates in response to seismic activity, but we currently have no evidence to support this hypothesis.

More research is required in order to study any potential response to seismic activity for beluga whales.

Based on the acoustic repertoire (i.e., whistles, vs. clicks vs. burst pulses) that comprised the beluga whale acoustic encounters, it is important to note that these animals may be utilizing the different EAR deployment sites in different ways (e.g., foraging versus socializing). No echolocation clicks were detected from EAR 62, and the majority of acoustic encounters recorded at this EAR contained only whistles. In comparison, all sound types were relatively common at EARs 59 and 60. The lack of echolocation clicks detected at EAR 62 suggests that the belugas were not foraging in the area during the recording period. It is difficult to make generalizations about habitat use based on the limited dataset from this monitoring effort, but it is important to note that behavioral context has been demonstrated to affect the type and magnitude of marine mammal responses to anthropogenic sound (Ellison et al. 2011). This is an important factor to take into consideration when evaluating the impact of anthropogenic activities on marine mammals. The lack of echolocation clicks at EAR 60 may simply be a factor of animal location, orientations and sound propagation characteristics in the area. For example, it is possible that the beluga whales were not as close to EAR 62 as they were to EAR 59 and 60. Echolocation clicks attenuate more quickly than whistles and therefore have a shorter acoustic detection range than whistles (Au and Hastings 2008). As such, when animals are located further away from the recorder it is less likely that echolocation clicks will be detected. Modification to recorder spatial configuration and time-synchronization (e.g., deploying an array of time-synchronized recorders) will provide the capability to localize sound sources. This in turn would provide the information necessary to determine whether the differences in sound types detected at the EAR deployment sites were due to differences in habitat use, animal location, propagation effects or some combination thereof.

Sounds produced by bowhead whales, ringed seals and bearded seals were only detected on recordings made at EAR 60. Bowhead whales present in the study area during August and September were likely migrating through the area using a deeper water corridor (Braham et al. 1980, Moore and Reeves 1993) and as such, it is not surprising that they were only audible on the EAR that was nearest to deep water. It was not possible to determine whether or not Bowhead whales changed aspects of their migration or vocalization rates in response to seismic activity using the data available here. As proposed above, the ability to locate or track individuals would provide the necessary information to address these issues.

Sounds produced by ringed seals and bearded seals were detected during a very small percentage (0.1 percent and 0.2 percent, respectively) of the total recording duration of EAR 60, and on no other EARs. This suggests that these two species of pinnipeds were either uncommon in the study area during the recording period, or that they were present but were not vocalizing frequently in the vicinity of the EARs. Due to the small number of recording days, it is difficult to draw conclusions about the presence, distribution, and occurrence of these species in the study area relative to seismic events. Sounds produced by unidentified pinnipeds were detected at both EAR 60 and EAR 62. Because there have been no descriptions of spotted seal vocalizations and very little is known about them, some of the unidentified pinniped sounds could be spotted seals. More research is needed to obtain baseline information about the vocal behavior and occurrence of spotted seals in the study area in order to classify these sounds. It is also possible that some of these unidentified pinniped sounds may have been produced by walrus, but SNR was too poor to be able to confirm the species identity.

4.5 Marine Mammal Occurrence and Noise

There are a number of responses of marine mammals to seismic activity (e.g., associated anthropogenic sound and vessel presence) that have been observed, including avoidance resulting in habitat displacement, effects on behavior of prey (e.g., fish), and changes in vocalization frequency or rates (see Gordon et al. 2003, Popper and Hawkins 2012, and Hawkins et al. 2014 for detailed reviews). Our analyses showed a significant difference between the probabilities of marine mammal acoustic encounters occurring in the presence versus absence of seismic activity for only one species of marine mammal – beluga whales (2-sample z-test, p = 0.000; p = 0.003, EARs 59 and 60, respectively). Sample sizes were too low to conduct statistical analyses for most other species and the lack of a significant difference for bowhead whales may have been a result of low sample sizes providing low statistical power. Our results for beluga whales suggest that the animals may either be moving from the eastern portion of the study area to the western portion around EARs 59 and 60 during seismic activity or alternatively, increasing vocalization rates in response to seismic activity. However, correlation between acoustic activity and seismic activity does not necessarily mean that changes in acoustic behavior were caused by the presence of seismic activity. To better understand the relationship between acoustic encounters of beluga whales and seismic activity will require collecting a larger dataset of recordings made before, during and after seismic activity both inside and outside the areas of the seismic surveys. The limited number of biological acoustic events and the sporadic nature of seismic events (i.e., many irregularly timed seismic events) make statistical testing of effects of seismic activity on marine mammal acoustic behavior difficult. However, more rigorous statistical methods are currently being developed and tested to look at the relationship between mid-frequency sonar events and marine mammal acoustic data from single-hydrophone autonomous recorders similar to those used here (Oswald et al., in preparation). With an improved monitoring effort design, and with sufficient sample sizes, it might be possible to detect subtle changes in vocalization behaviors of marine mammals and relate these to anthropogenic noise events using statistical methods. Unfortunately given the scope of the effort and the limited dataset collected during this project, this was not possible.

The seismic survey activity that was reported to us was not detectable by bioacousticians who aurally and visually reviewed the recordings, LTSAs and spectrograms. However this does not mean that sounds produced by seismic activity were not detected animals present in the study area. Hearing sensitivity for humans and marine mammals is quite different (Au et al. 2000) and thus some species of marine mammals or fish may have been able to detect sounds that were not audible to human bioacousticians or visible on spectrograms. In addition, the marine mammals detected acoustically were not necessarily in the same location as the EARs and thus may have been exposed to different sound fields than the recording sites. The addition of localization capabilities to the data collection protocols (i.e., with multiple recording devices that are time-synchronized) would make it possible to locate the animals, track their movements, and determine their proximity to seismic activity.

Other considerations and caveats to consider are that we can only detect the presence of animals that are vocalizing. Animals that are in the area but are not vocalizing will not be detected.

Therefore absence of acoustic events cannot be assumed to equal an absence of animals, especially over short periods of time. For acoustically active groups of animals like beluga whales or migrating bowhead whales, the probability of detecting them if they are present is likely quite high over periods of several hours or more. However if seismic survey activity causes a reduction in rates of sound production for the animals, this would negatively bias the results with respect to occurrence. It would only be possible to determine whether this is happening with a sufficient sample of acoustic events recorded before, during, and after seismic surveys.

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5. CONCLUSIONS

Although the EARs did not record as much data as was originally planned for, the results of this study provide some valuable insights to the presence of marine mammals during seismic activities in the Colville River Delta. There was no audible seismic activity detected by bioacousticians during the recording period at any of the recording sites. The effects of sound propagation, absorption, and natural ambient noise in the shallow water environment, as well as range to the activity may have reduced the acoustic energy of seismic activity below that which was detectable. This finding, in and of itself, is an important result that would not have been possible without the acoustic data collected herein or a prior acoustic modeling effort to determine whether the EAR deployment sites were in the sound field of the seismic sources. In spite of the technological setbacks, we were able to assess and compare the variation in ambient noise levels among three different recording locations. We determined that the EAR 59 site had the lowest overall ambient noise levels. We also documented the occurrence of four species of marine mammals in the study area: beluga whales, bowhead whales, ringed seals and bearded seals. Beluga whales were the most commonly detected marine mammal, and this species appeared to use the study area frequently during the recording period. Results of the probability analysis showed that the probability of beluga acoustic events was significantly higher during seismic events versus in the absence of seismic events at two of the EAR locations. There are several possible explanations for this finding, including animal movement in response to anthropogenic noise or movement of prey, and changes in acoustic behavior in noisier environments, however additional research is necessary to determine what factors caused this difference. Sounds produced by bowhead whales, bearded and ringed seals were rare in the recordings, suggesting that these species were not common during the recording period or that animals were present but not producing sound. Finally, fish were detected frequently, especially in recordings from EAR 59. We recommend that future work include longer recording periods before and after seismic operations in order to better evaluate possible differences in occurrence and sound production of marine mammals in relation to seismic survey activities. The capability to localize and track sound sources will allow data to be better interpreted. Additionally, more advanced planning will allow adequate time for configuration and testing of equipment and for appropriate data collection protocols to be developed.

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APPENDIX A:

ACOUSTIC RECORDING SUMMARY BY EAR RECORDING SITE

Appendix A
Acoustic Recording Summary by EAR Recording Site

Table A1. Acoustic encounter summary by EAR recording site, including the total number of encounters, the percent of encounters by site (total number of encounters within the category divided by the total number of encounters for the given EAR), total encounter duration, real time recording duration (total elapsed time during which each EAR was recording), percent of deployment duration (total encounter duration divided by the total elapsed recording time), number of days with encounters ,and the percent of days with encounters (number of days with encounters divided by the total recording days).

EAR	Encounter Type	Total Number of Encounters	Percent of Encounters by Site	Total Encounter Duration (HH:MM:SS)	Percent of Deployment Duration	Total Time Recording Time (HH:MM:SS)	Number of Days with Encounter	Total Recording Days	Percent of Days with Encounters
59	Anthropogenic - Ship	6	5%	01:38:03	0.8%	204:38:58	2	10	20%
59	Anthropogenic - Unknown	6	5%	08:24:41	4.1%	204:38:58	3	10	30%
59	Beluga Whale	52	41%	48:39:38	23.8%	204:38:58	9	10	90%
59	Unidentified Biological - HF	8	6%	00:00:23	0.003%	204:38:58	2	10	20%
59	Unidentified Cetacean	2	2%	00:00:32	0.004%	204:38:58	2	10	20%
59	Unidentified Fish	34	27%	137:42:44	67.3%	204:38:58	10	10	100%
59	Unidentified Marine Mammal	18	14%	02:21:39	1.2%	204:38:58	4	10	40%
60	Anthropogenic - 0-50 kHz Noise	3	2%	45:30:57	12.2%	371:48:57	3	17	18%
60	Anthropogenic - Ship	3	2%	04:28:14	1.2%	371:48:57	3	17	18%
60	Anthropogenic - Unknown	3	2%	05:08:25	1.4%	371:48:57	2	17	12%
60	Bearded Seal	7	4%	00:34:40	0.2%	371:48:57	6	17	35%
60	Beluga Whale	74	45%	19:24:56	5.2%	371:48:57	15	17	88%
60	Bowhead Whale	12	7%	02:08:52	0.6%	371:48:57	4	17	24%
60	Ringed Seal	3	2%	00:20:26	0.1%	371:48:57	3	17	18%
60	Unidentified Biological - LF	11	7%	01:49:18	0.5%	371:48:57	5	17	29%
60	Unidentified Cetacean	2	1%	02:00:05	0.5%	371:48:57	2	17	12%
60	Unidentified Fish	27	17%	07:16:18	2.0%	371:48:57	9	17	53%
60	Unidentified Marine Mammal	4	2%	00:00:20	0.001%	371:48:57	2	17	12%
60	Unidentified Pinniped	14	9%	00:45:29	0.2%	371:48:57	7	17	41%
62	Anthropogenic - Ship	6	14%	05:52:10	4.9%	118:38:58	3	6	50%
62	Anthropogenic - Sonar	1	2%	00:00:01	0.001%	118:38:58	1	6	17%
62	Anthropogenic - Unknown	4	10%	03:06:27	2.6%	118:38:58	3	6	50%
62	Beluga Whale	22	52%	03:51:49	3.3%	118:38:58	4	6	67%
62	Unidentified Biological - LF	1	2%	00:00:01	0.001%	118:38:58	1	6	17%
62	Unidentified Fish	5	12%	00:00:06	0.001%	118:38:58	3	6	50%
62	Unidentified Pinniped	3	7%	00:00:43	0.01%	118:38:58	1	6	17%
N/A	Siesmic Activity Reported Occurrence	51	NA	93:22:14	25.1%	371:48:57	15	17	88%

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