Passive Acoustic Monitoring for Marine Mammals in the Olympic Coast National Marine Sanctuary 2004 – 2014: Executive Summary

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Fin whale. Photo by Amanda J. Debich

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Executive Summary

Passive acoustic monitoring was conducted in the Navy's Northwest Training Range Complex from July 2004 to August 2013 to detect marine mammal and anthropogenic sounds. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at two locations: an offshore shelf slope site near Quinault Canyon (site QC, 1,384 m depth) and an inshore site on the shelf near Cape Elizabeth (site CE, 120 m depth).

Data analysis was performed using automated computer algorithms, augmented with analyst scans of long-term spectral averages (LTSAs) and spectrograms. Three frequency bands were analyzed for marine mammal vocalizations and anthropogenic sounds.

Four baleen whale species were detected: blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), humpback whales (*Megaptera novaeangliae*), and minke whales (*B. acutorostrata*). Seasonal patterns for Northeast Pacific blue whale B and D calls as well as humpback whale calls were similar with peaks in detections during the late-fall through winter months. Fin whale 20 Hz call detections peaked in late-December. Minke whale boings were detected in low numbers at site QC in 2012.

Risso's dolphins (*Grampus griseus*), Pacific white-side dolphins (*Lagenorhynchus obliquidens*), and sperm whales (*Physeter macrocephalus*) were detected in lower numbers at site CE than at site QC which suggests site QC might be an important habitat for these odontocetes. Risso's dolphin detections peaked during summer months and had an overall higher number of detections in 2011-2013 than in 2004-2008. Pacific white-sided dolphin and sperm whale detections also peaked during summer months; however, there were more detections for these species in 2004-2008 than in 2011-2013. Risso's dolphins and Pacific white-sided dolphins showed clear diel patterns at site QC.

Two beaked whale species were monitored for and detected: Stejneger's beaked whale (*Mesoplodon stejnegeri*) and Cuvier's beaked whale (*Ziphius cavirostris*). Stejneger's beaked whale detections were more common than Cuvier's beaked whale detections though both species were detected in low numbers.

Project Background

The Navy's Northwest Training Range Complex (NWTRC) contains an offshore area that extends west 250 nautical miles beyond the coasts of Washington, Oregon, and Northern California. This region is a productive ecosystem inhabited by many species of marine mammals. The area includes deep water habitats, utilized by beaked and sperm whales, as well as continental shelf waters that are frequented by coastal cetaceans, pinnipeds, and porpoises. Endangered species known to occupy this area include blue whales, fin whales, North Pacific right whales, humpback whales, sperm whales, and killer whales.

An acoustic and visual monitoring effort for marine mammals was initiated within the boundaries of the NWTRC with a focus on the Quinault Underwater Tracking Range (QUTR), off the coast of Washington, beginning in July 2004. Two High-frequency Acoustic Recording Packages (HARPs) have been intermittently deployed near the QUTR since 2004, one in deeper waters on the shelf slope within Quinault Canyon (QC) and a second on the continental shelf off Cape Elizabeth (CE). In 2014, support for continuation of acoustic monitoring in the NWTRC was provided by the Pacific Fleet to Scripps Institution of Oceanography under the Californian Cooperative Ecosystems Studies Unit 08-09a administered by the US Army Corps of Engineers. The goal of this effort was to characterize the vocalizations of marine mammal species present in the area, to determine their seasonal presence patterns, and to evaluate the potential for impact from naval operations.

This report summarizes the analysis of data recorded by two HARPs that were deployed within the NWTRC at sites QC and CE (Figure 1).

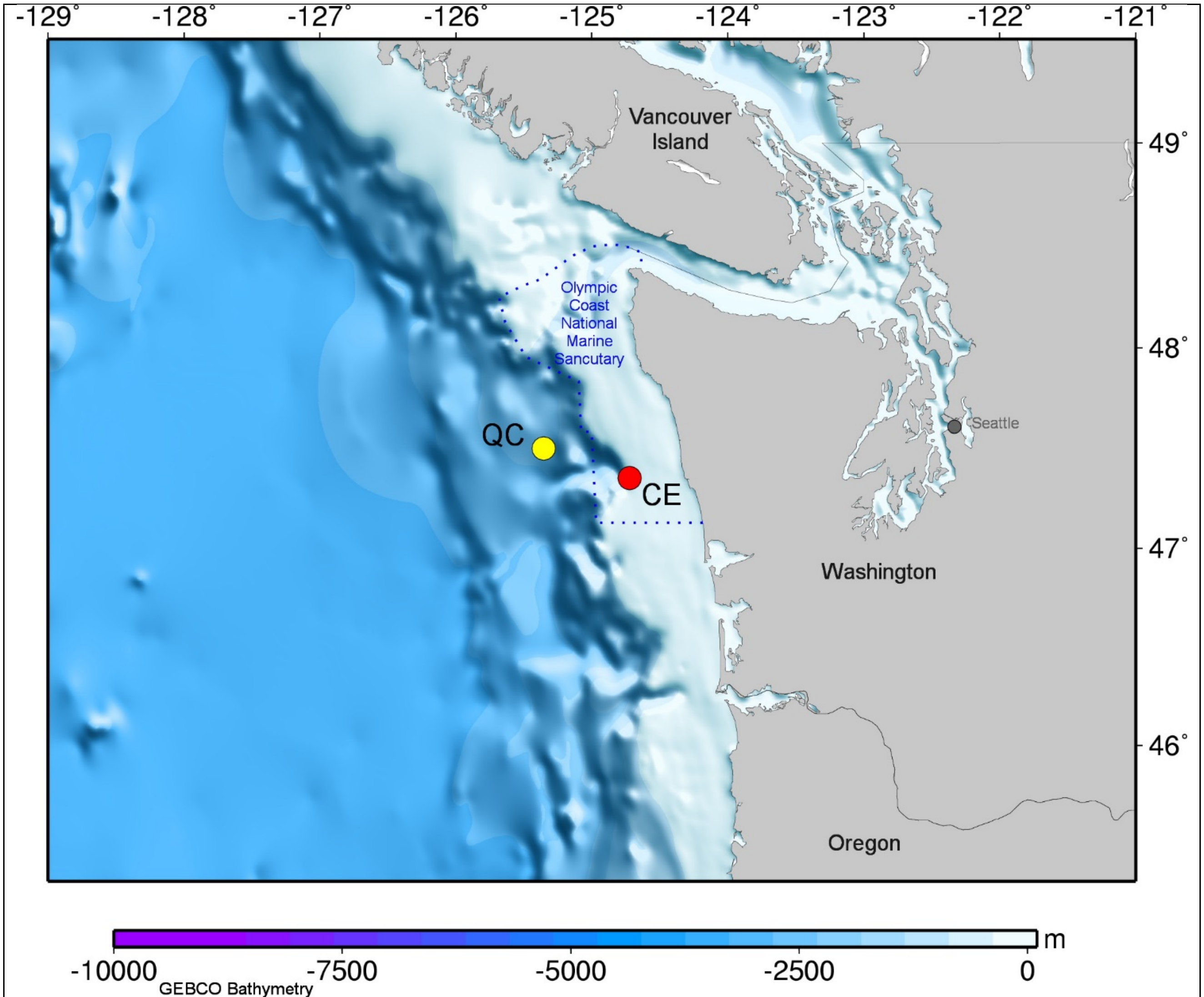


Figure 1. Locations of the High-frequency Acoustic Recording Packages (HARPs) at sites QC and CE deployed in the NWTRC study area July 2004 through August 2013. The purple dotted line represents the Olympic Coast National Marine Sanctuary boundary. Color is bathymetric depth.

Methods

High-frequency Acoustic Recording Package (HARP)

HARPs were used to record marine mammal sounds and characterize anthropogenic sounds and ambient noise in the NWTRC area. HARPs can record underwater sounds from 10 Hz up to 160 kHz, and are capable of approximately 300 days of continuous data storage. The HARPs were in a seafloor package configuration with the hydrophones suspended 10 m above the seafloor. Each HARP was calibrated in the laboratory to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones were also calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations (Wiggins and Hildebrand, 2007).

Data Collected

Acoustic data were collected at two sites within the NWTRC using autonomous HARPs sampling continuously at 200 kHz (Table 1). The sites are designated site QC (47° 30.04'N, 125° 21.26'W, depth 1,384 m) and site CE (47° 21.17'N, 124° 42.47'W, depth 120 m). Site CE yielded 28,711 hours (1196 days) of data and site QC yielded 46,070 hours (1920 days) of data.

Table 1. Acoustic monitoring in the NWTRC since 2004.

Deployment Name	Depth (m)	Start Date	End Date	Recording Duration (days)	Recording Duration (hours)
OCNMS01-CE	150	7/12/2004 0:00	10/5/2004 11:05	85	2,051
OCNMS01-QC	-	Lost at sea	Lost at sea	-	-
OCNMS02-QC	915	10/19/2004 0:00	1/25/2005 0:31	98	2,352
OCNMS03-QC	823	7/28/2005 0:00	2/20/2006 18:07	208	4,986
OCNMS04-CE	150	8/18/2006 10:00	3/11/2007 1:43	205	4,911
OCNMS04-QC	615	8/18/2006 5:00	2/8/2007 16:13	174	4,187
OCNMS05-CE	100	4/21/2007 0:00	7/3/2007 15:57	74	1,767
OCNMS05-QC	620	4/21/2007 6:00	7/3/2007 20:34	74	1,766
OCNMS06-QC	653	7/5/2007 0:00	6/15/2008 0:19	346	8,304
OCNMS07-CE	150	10/14/2007 0:00	6/16/2008 6:12	246	5,910
OCNMS08-CE	100	6/17/2008 0:00	6/9/2009 11:05	357	8,579
OCNMS09-CE	-	Lost at sea	Lost at sea	-	-
OCNMS12-QC	650	1/27/2011 6:00	10/7/2011 7:23	253	6,073
OCNMS13-CE	118	5/21/2011 0:00	11/6/2011 10:12	169	4,066
OCNMS14-CE	150	12/7/2011 0:00	1/17/2012 13:25	41	997
OCNMS14-QC	1,394	12/7/2011 6:00	7/11/2012 7:00	217	5,209
OCNMS15-QC	1,394	9/14/2012 0:00	6/30/2013 9:22	289	6,943
OCNMS16-CE	120	7/17/2013 2:51	8/4/2013 1:25	18	430
OCNMS16-QC	1,384	7/17/2013 0:00	4/3/2014 10:09	260	6,250
OCNMS17-QC	1,383	No data	No data	-	-
Total Recording Duration				3,115 days	74,781 hours

Data Quality

The recordings at each site varied in data quality. Specifics about data quality have been described in previous reports (Table 2).

Table 2. Summary reports for acoustic monitoring in the NWTRC since 2004.

Deployment Name	Summary Report
OCNMS01-CE OCNMS02-QC OCNMS03-QC OCNMS04-CE OCNMS04-QC OCNMS05-CE OCNMS05-QC OCNMS06-QC OCNMS07-CE	Oleson et al, 2009, Acoustic and visual monitoring for cetaceans along the outer Washington coast
OCNMS08-CE	Širović et al, 2011, Marine mammal demographics of the outer Washington coast during 2008-2009
OCNMS12-QC OCNMS13-CE	Širović et al, 2012, Passive acoustic monitoring for marine mammals in the Northwest Training Range Complex 2011
OCNMS14-CE OCNMS14-QC	Kerosky et al, 2013, Passive acoustic monitoring for Marine Mammals in the Northwest Training Range Complex 2011-2012
OCNMS15-QC	Debich et al, 2014, Passive acoustic monitoring for Marine Mammals in the Northwest Training Range Complex 2012-2013
OCNMS16-CE OCNMS16-QC	Trickey et al, 2015, Passive acoustic monitoring for Marine Mammals in the Northwest Training Range Complex July 2013 – April 2014

Data Analysis

To visualize the acoustic data, frequency spectra were calculated for all data using a time average of 5 seconds and variable size frequency bins (1, 10, and 100 Hz). These data, called Long-Term Spectral Averages (LTSAs), were then examined as a means to detect marine mammal and anthropogenic sounds. Data were analyzed by visually scanning LTSAs in source-specific frequency bands or, when appropriate, using automatic detection algorithms (described below).

Recording over a broad frequency range of 10 Hz – 100 kHz allows detection of baleen whales (mysticetes), toothed whales (odontocetes), and anthropogenic sounds. The presence of acoustic signals from multiple marine mammal species was evaluated in the data. To document the data analysis process, we describe the major classes of marine mammal calls and anthropogenic sounds in the NWTRC, as well as the procedures used to detect them.

For effective analysis, the data were divided into three frequency bands: (1) Low-frequency, between 10-300 Hz, (2) Mid-frequency, between 10-5,000 Hz, and (3) High-frequency, between 1-100 kHz. Each band was analyzed for the sounds of an appropriate subset of species or sources. Blue and fin whale sounds were classified as low-frequency. Humpback and minke whale sounds were classified as mid-frequency. The remaining odontocete sounds were considered high-frequency.

We summarize acoustic data collected between July 2004 and August 2013. We discuss seasonal occurrence and relative abundance of calls for different species that were consistently identified in the acoustic data.

Low-Frequency Marine Mammals

The hourly presence of Northeast Pacific blue whale (*Balaenoptera musculus*) D calls and gray whale M3 (*Eschrichtius robustus*) calls was determined by manual scrutiny of low-frequency LTSAs using the custom software program *Triton*. The same LTSA and spectrogram parameters were used for manual detection of all call types. During scrutiny of the data, the LTSA frequency was set to display between 1-500 Hz. To observe individual calls, spectrogram windows were typically set to 120 seconds by 200 Hz. The FFT was generally set between 1500 and 2000 data points, yielding about 1 Hz frequency resolution, with an 85-95% overlap. When a call of interest was identified in the LTSA or spectrogram, its presence during that hour was logged using *Triton*. Blue whale B calls and fin whale 20 Hz pulses were detected automatically using computer algorithms described below.

Blue Whales

Blue whales produce a variety of calls worldwide (McDonald *et al.*, 2006). Blue whale calls recorded in the eastern North Pacific include the Northeast Pacific blue whale B call (Figure 2), which is a geographically distinct call potentially associated with mating functions (McDonald *et al.*, 2006; Oleson *et al.*, 2007). B calls are low-frequency (fundamental frequency < 20 Hz), have long duration (> 10 s), and often are regularly repeated. The call generally contains multiple harmonically-related tonals and, owing to greater noise at low frequency, is best identified based on the presence of the 3rd harmonic. Blue whale B calls were detected automatically from January 27, 2011 through June 30, 2013 using the spectrogram correlation method (Mellinger and Clark, 1997). Specifics about the kernels used for each deployment can be found in the individual summary reports. Blue whale B calls were detected manually from June 17, 2008 through June 9, 2009 and July 17, 2013 through August 4, 2013 since there were not enough calls to develop the kernel for those time periods.

Blue whales also produce D calls, which are downswept in frequency (approximately 100-40 Hz) with durations of several seconds (Figure 3). These calls are similar worldwide and are associated with feeding animals; they may be produced as call-counter call between multiple animals (Oleson *et al.*, 2007). Blue whale D calls were detected manually by human analysts.

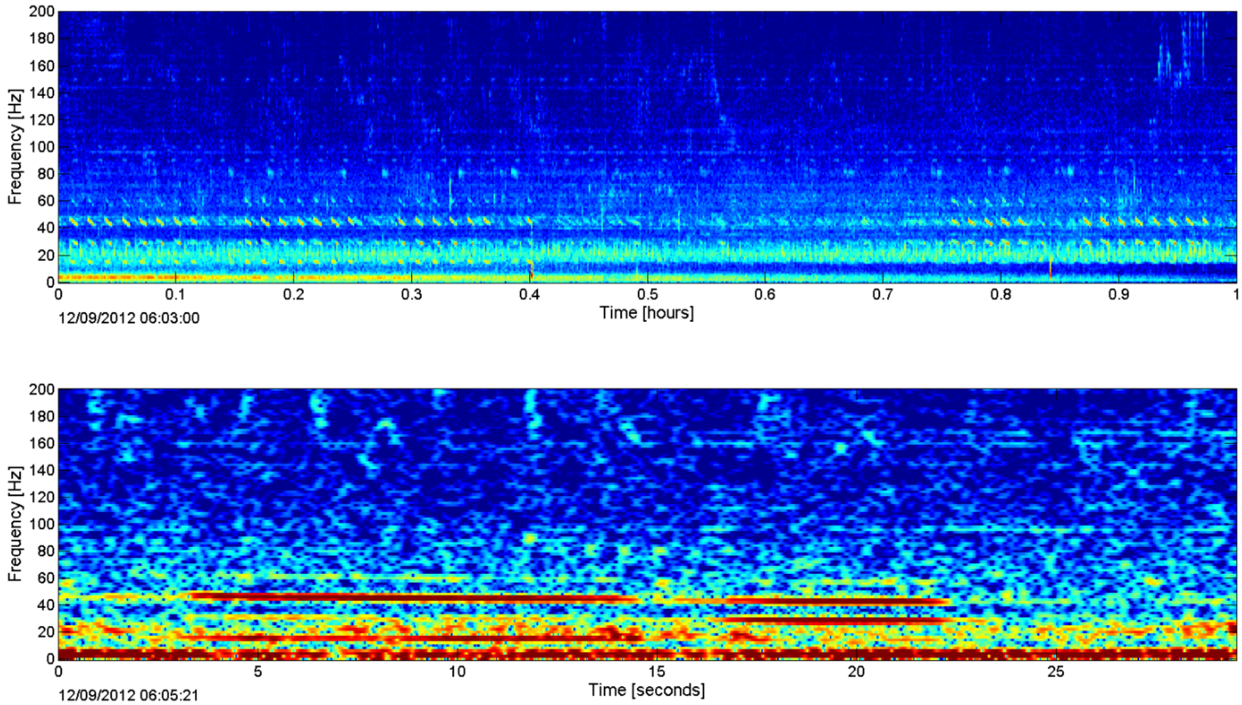


Figure 2. Blue whale B call in LTSA (top) and spectrogram (bottom) at site QC.

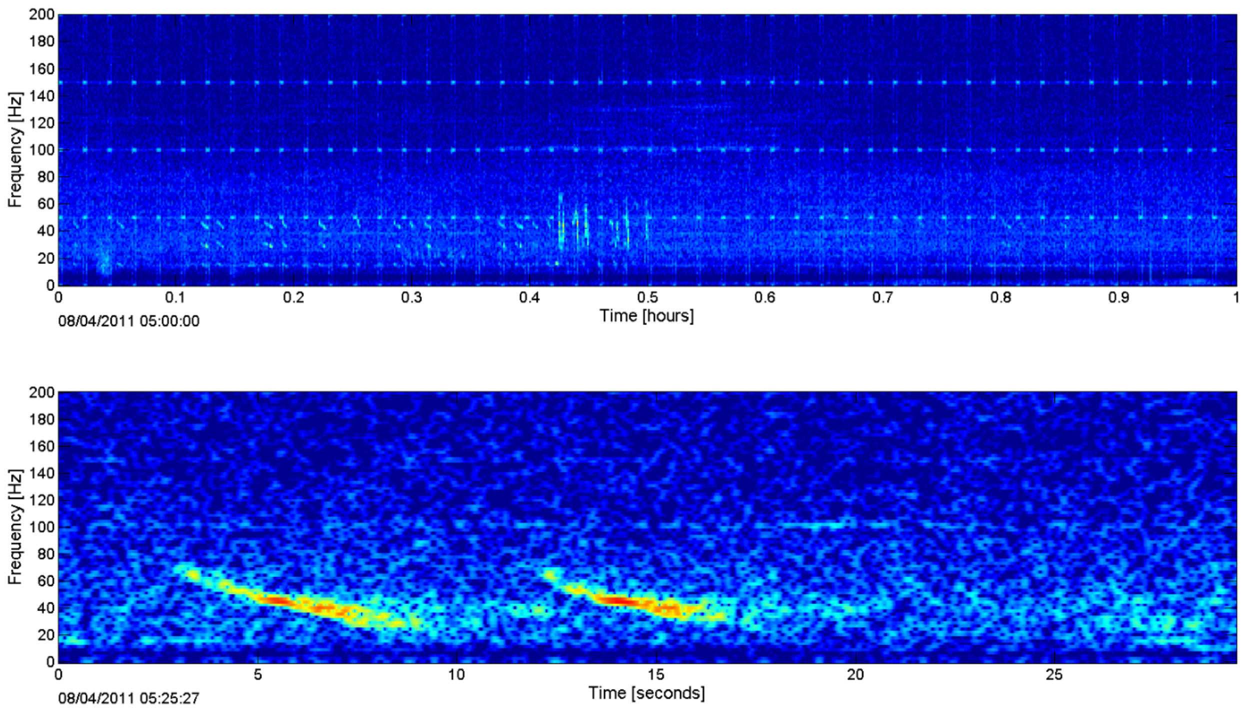


Figure 3. Blue whale D calls in LTSA (top) and spectrogram (bottom) at site QC.

Fin Whales

Fin whale (*B. physalus*) calls recorded in the eastern North Pacific include short (~ 1 s duration), low-frequency calls that are downswept in frequency from 30-15 Hz and are referred to as 20 Hz calls (Watkins, 1981) (Figure 4). The 20 Hz calls can occur at regular intervals as song (Thompson *et al.*, 1992), or irregularly as call counter-calls among multiple, traveling animals (McDonald *et al.*, 1995).

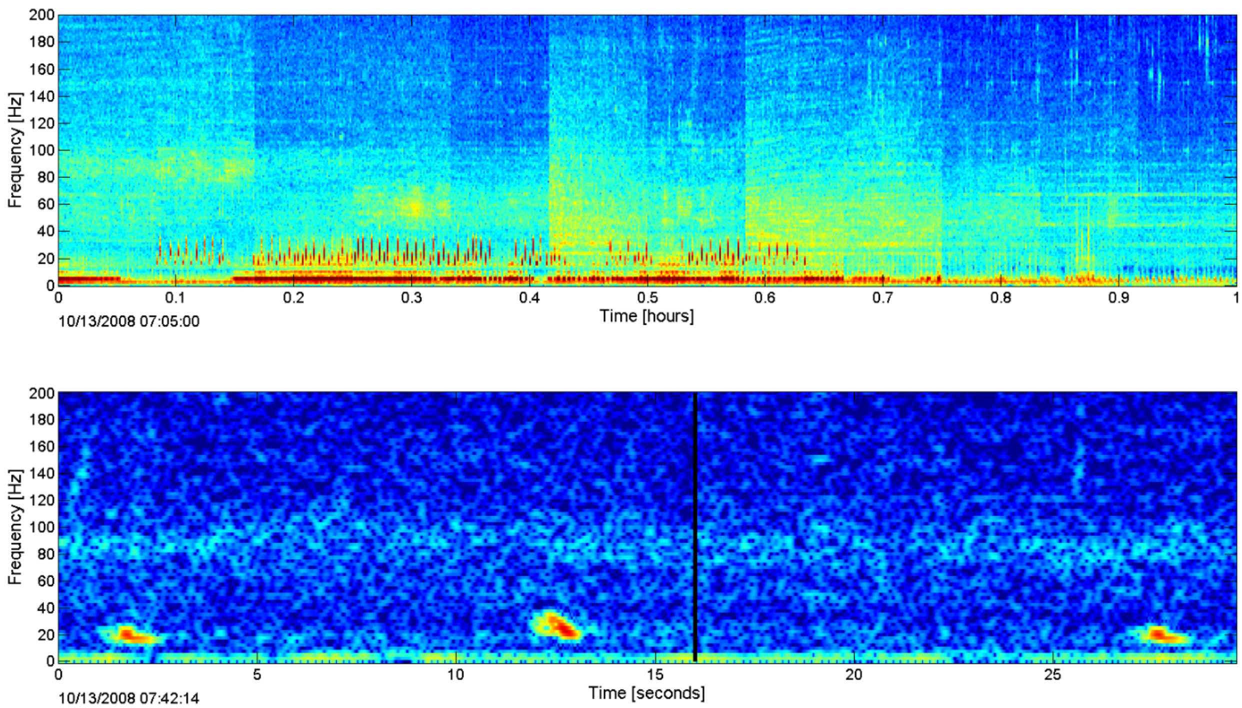


Figure 4. Fin whale 20 Hz calls in LTSA (top) and spectrogram (bottom) at site CE.

Mid-Frequency Marine Mammals

Marine mammal species with sounds in the mid-frequency range expected off Washington include humpback whale (*Megaptera novaeangliae*) and minke whales (*B. acutorostrata*). For mid-frequency data analysis, the 100 kHz HARP data were decimated by a factor of 20 for an effective bandwidth of 5 kHz. The LTSAs for mid-frequency analysis were created using a time average of 5 seconds, and a frequency bin size of 10 Hz.

Humpback Whales

Humpback whales produce song and non-song calls. The song is categorized by the repetition of units, phrases, and themes of a variety of calls as defined by Payne and McVay (1971) (Figure 5). Non-song vocalizations such as social and feeding sounds consist of individual units that can last from 0.15 to 2.5 seconds (Dunlop *et al.*, 2007; Stimpert *et al.*, 2011). Most humpback whale vocalizations are produced between 100-3,000 Hz. We automatically detected humpback calls (both song and non-song) using an automatic detection algorithm based on the power law (Helble *et al.*, 2012) from July 12, 2004 through October 5, 2004, and December 7, 2011 through August 4, 2013. The detections were subsequently verified for accuracy by a trained analyst. Humpback calls were manually detected from October 19, 2004 through November 6, 2011.

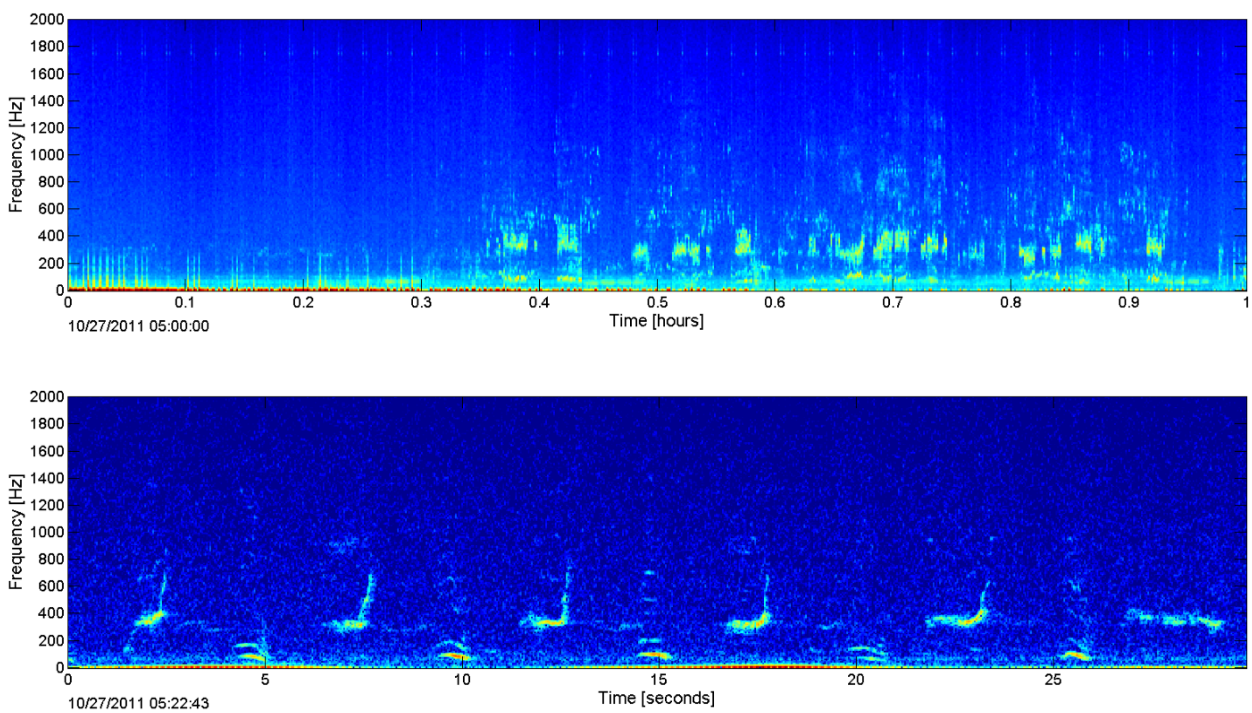


Figure 5. Humpback whale song in LTSA (top) and spectrogram (bottom) at site CE.

Minke Whales

Minke whale "boings" consist of 2 parts, beginning with a burst followed by a long buzz, with the dominant energy band just below 1,400 Hz (Figure 6). Boings are divided geographically into an eastern and a central Pacific variant, with a dividing line at about 135°W. Eastern boings have an average duration of 3.6 seconds and a pulse repetition rate of 92 s^{-1} (Rankin and Barlow, 2005). Boing sounds were recently reported from the Chukchi Sea, and seem to match the central Pacific boings (Delarue and Martin, 2013). Minke boings were detected automatically using an automatic detection algorithm based on the power law (Helble *et al.*, 2012).

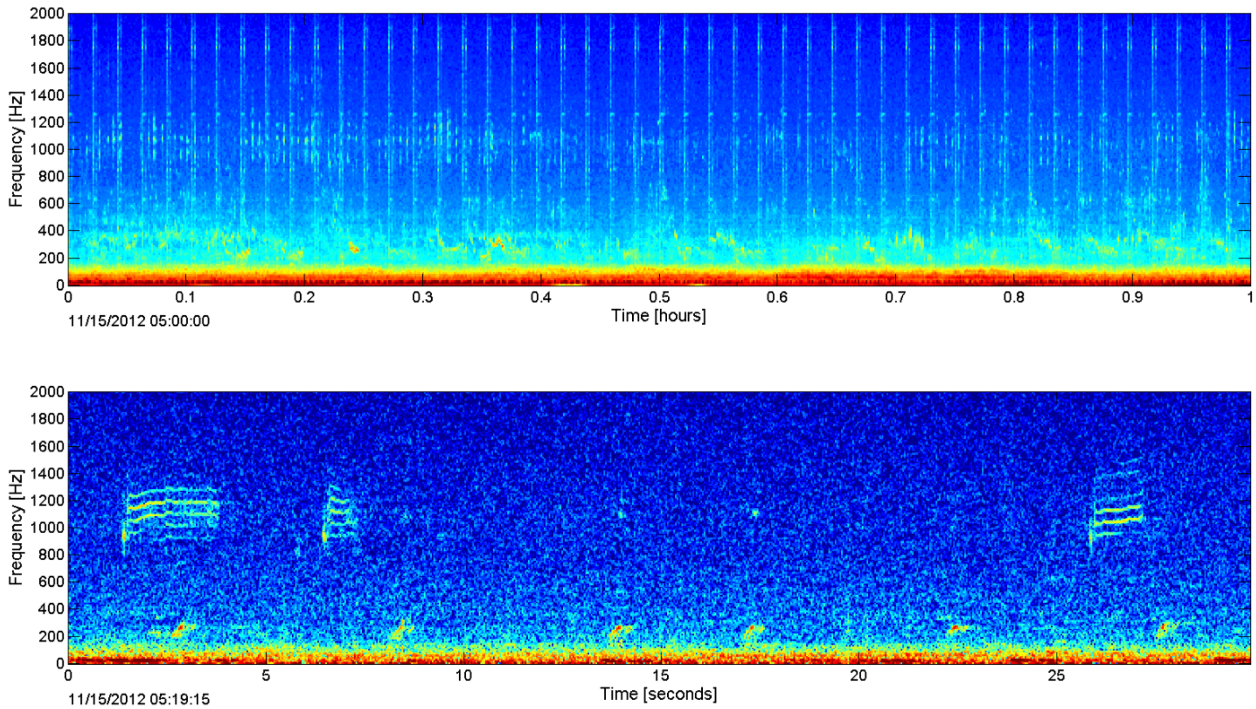


Figure 6. Minke whale boings in LTSA (top) and spectrogram (bottom) at site QC.

High-Frequency Marine Mammals

High-frequency, species-specific sounds monitored in this report include: Risso's and Pacific white-sided dolphins, sperm whales, Stejneger's beaked whales, Cuvier's beaked whales. The start and end of each acoustic encounter was logged and their durations were added to estimate cumulative hourly presence of each high-frequency sound source in the two datasets.

High-Frequency Call Types

Odontocete sounds can be categorized as echolocation clicks, burst pulses, or whistles. Echolocation clicks are broadband impulses with peak energy between 5 and 150 kHz, dependent on species. Buzz or burst pulses are rapidly repeated clicks that have a creak or buzz-like sound quality; they are generally lower in frequency than echolocation clicks. Dolphin whistles are tonal calls predominantly between 1 and 20 kHz that vary in frequency content, their degree of frequency modulation, as well as duration. These signals are easily detectable in an LTSA as well as the spectrogram (Figure 7).

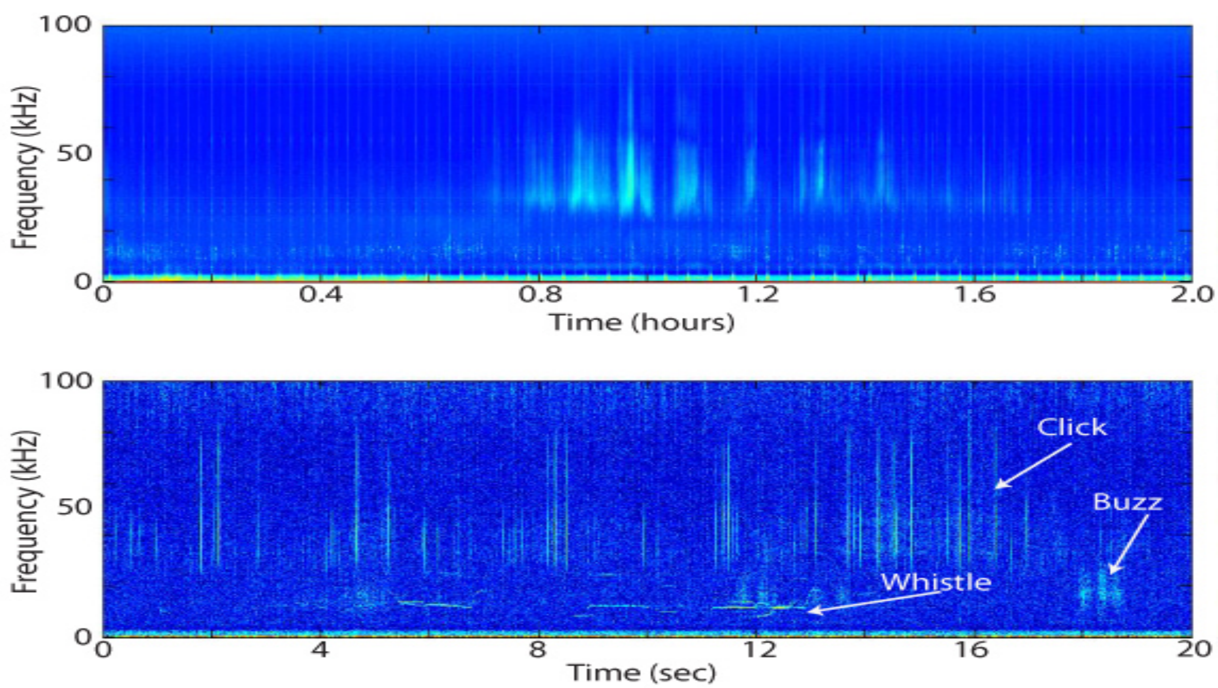


Figure 7. LTSA (top) and spectrogram (bottom) demonstrating the odontocete signal types.

Risso's Dolphins

Risso's dolphin echolocation clicks can be identified to species by their distinctive banding patterns observable in the LTSA (Figure 8). Risso's dolphin echolocation clicks recorded offshore southern California have energy peaks at 22, 26, 30, and 39 kHz (Soldevilla *et al.*, 2008), and it is expected that their energy peaks will be similar in the NWTRC area.

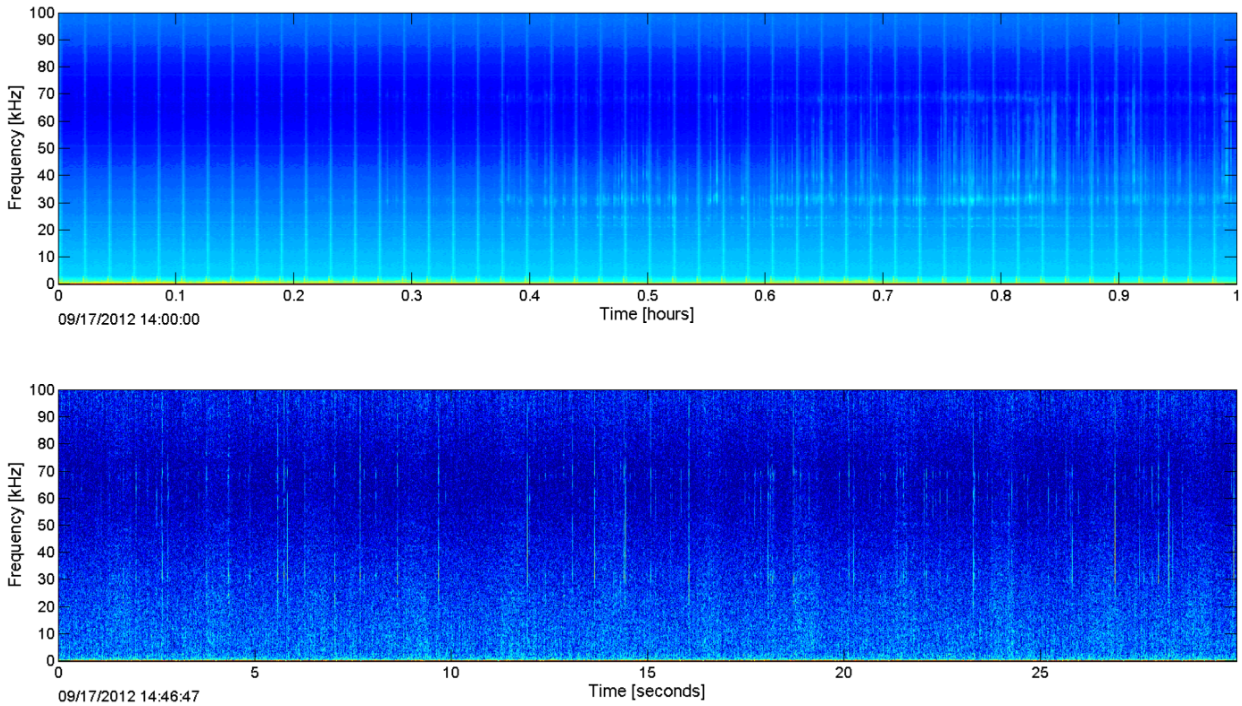


Figure 8. Risso's dolphin echolocation clicks in LTSA (top) and spectrogram (bottom) at site QC.

Pacific White-sided Dolphins

Pacific white-sided dolphin echolocation clicks also can be identified to species by their distinctive banding patterns (Figure 9). Pacific white-sided dolphin echolocation clicks recorded offshore southern California have two distinctive patterns of energy peaks, designated type A and type B (Soldevilla *et al.*, 2010). The type A group occupies the northern portion of the southern California Bight, whereas both groups are known from the southern portion of the Bight. Soldevilla *et al.* (2010) hypothesize that type A signals may be produced by the California/Oregon/Washington population while type B signals may originate from a southern Baja California population. Since these Pacific white-sided dolphin populations are thought to seasonally migrate, the type A group is more likely to be found within the NWTRC. The type A dolphins' echolocation clicks have energy peaks at 22, 27, 33, and 37 kHz (Soldevilla *et al.*, 2008).

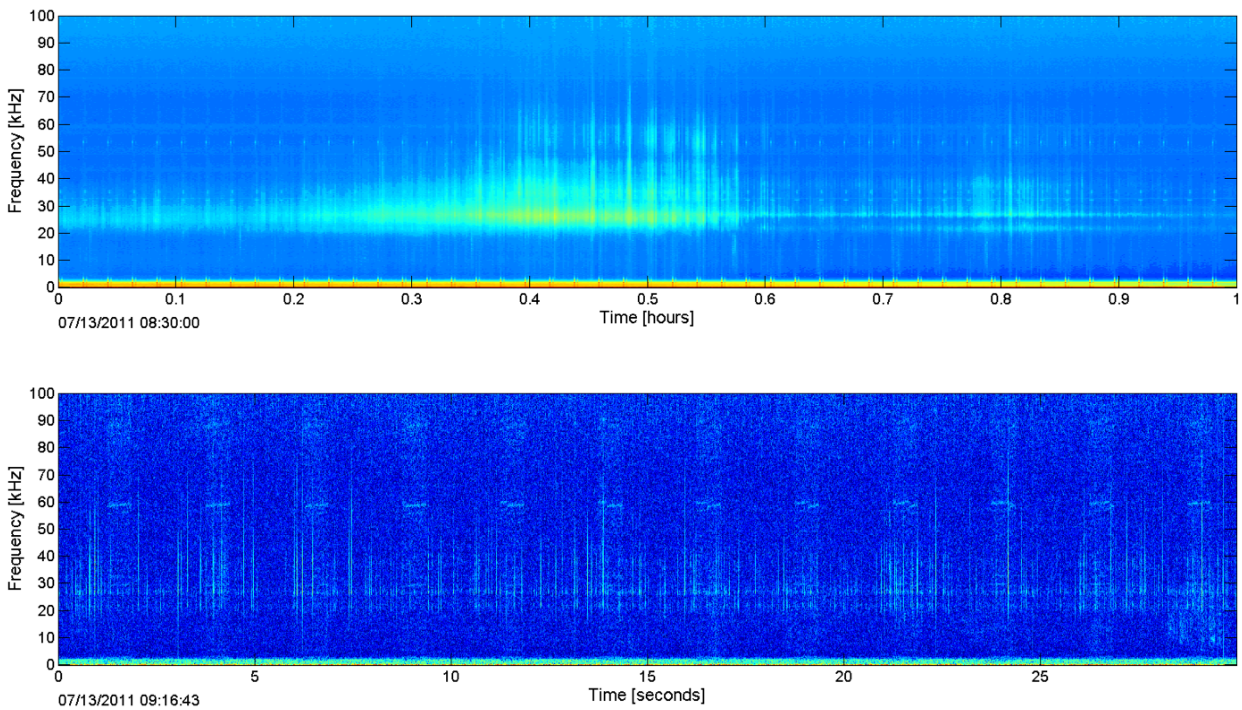


Figure 9. Pacific white-sided dolphin echolocation clicks in LTSA (top) and spectrogram (bottom) at site QC.

Sperm Whales

Sperm whale clicks generally contain energy from 2-20kHz, with the majority of energy between 10-15 kHz (Møhl *et al.*, 2003). Regular clicks, observed during foraging dives, demonstrate a uniform inter-click interval from 0.25-2 seconds (Goold and Jones, 1995; Madsen *et al.*, 2002a; Møhl *et al.*, 2003). Short bursts of closely spaced clicks called creaks are observed during foraging dives and are believed to indicate a predation attempt (Watwood *et al.*, 2006). Sperm whales also produce other clicks, which can be classified as slow clicks and codas. Slow clicks are used only by males and are more intense than regular clicks with long inter-click intervals (Madsen *et al.*, 2002b). Codas are stereotyped sequences of clicks which are less intense and contain lower peak frequencies than regular clicks (Watkins and Schevill, 1977). Multiple foraging dives and rest periods are often observed over a long period of time in the LTSA (Figure 10).

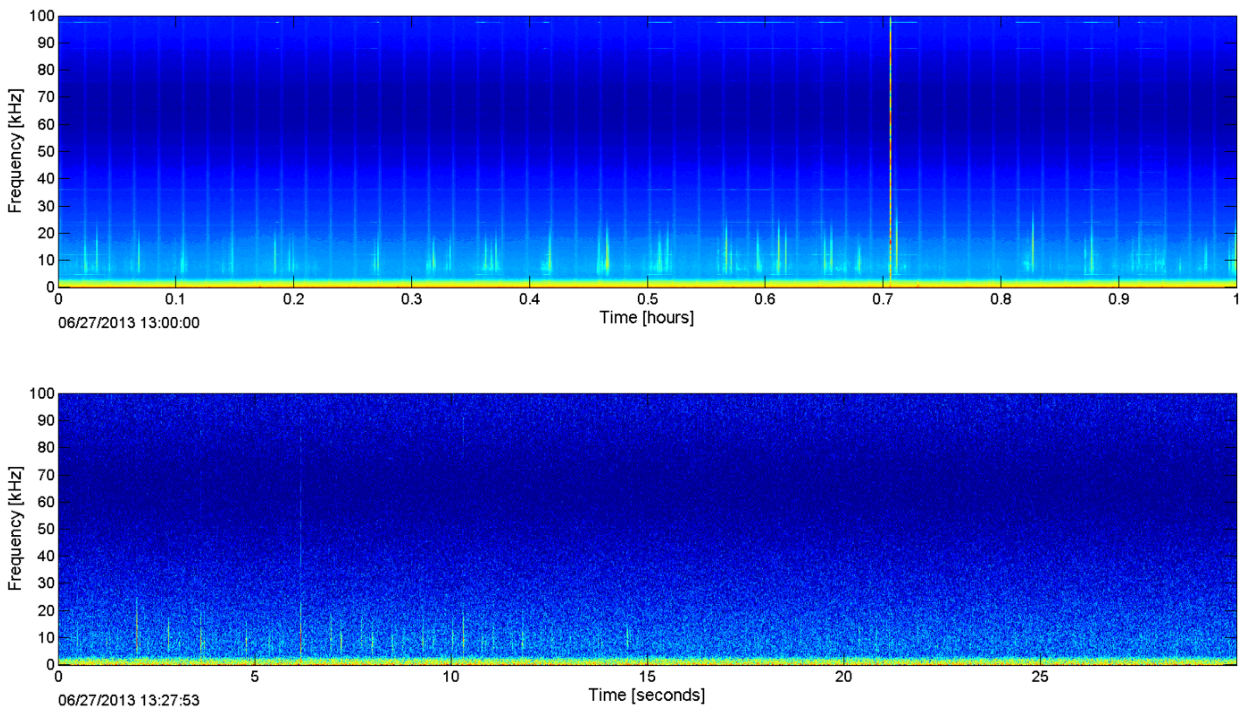


Figure 10. Sperm whale echolocation clicks in LTSA (top) and spectrogram (bottom) at site QC.

Beaked Whales

Beaked whales found in the NWTRC include Baird's (*Berardius bairdii*), Cuvier's (*Ziphius cavirostris*), and Stejneger's (*Mesoplodon stejnegeri*) beaked whales (Jefferson *et al.*, 2008). Only Cuvier's and Stejneger's beaked whales were analyzed for this report. Advances have been made in acoustically identifying beaked whales by their echolocation signals (Baumann-Pickering *et al.*, 2014). These signals are frequency-modulated (FM) upsweep pulses, which appear to be species-specific and distinguishable by their spectral and temporal features. Identifiable signals are known for the three aforementioned species of beaked whales.

Beaked whale FM pulses, except for those produced by Baird's beaked whales, were detected with an automated method. After all echolocation signals were identified with a Teager Kaiser energy detector (Soldevilla *et al.*, 2008; Roch *et al.*, 2011), an expert system discriminated between delphinid clicks and beaked whale FM pulses. A decision about presence or absence of beaked whale signals was based on detections within a 75 second segment. Only segments with more than 7 detections were used in further analysis. All echolocation signals with a peak and center frequency below 32 and 25 kHz, respectively, a duration less than 355 μs, and a sweep rate of less than 23 kHz/ms were deleted. If more than 13% of all initially detected echolocation signals remained after applying these criteria, the segment was classified to have beaked whale FM pulses. A third classification step, based on computer assisted manual decisions by a trained analyst, labeled the automatically detected segments to pulse type level and rejected false detections (Baumann-Pickering *et al.*, 2013b). The rate of missed segments was approximately 5%, varying slightly between deployments.

Stejneger's Beaked Whales

Stejneger's beaked whales are known to occur with some regularity in the northern Pacific Ocean. Their echolocation signals are easily distinguished from other species' acoustic signals; they have the typical beaked whale polycyclic structure and frequency-modulated (FM) pulse upsweep with a peak frequency around 50 kHz and uniform inter-pulse interval around 90 ms (Figure 11) (Baumann-Pickering *et al.*, 2013a; Baumann-Pickering *et al.*, 2013b).

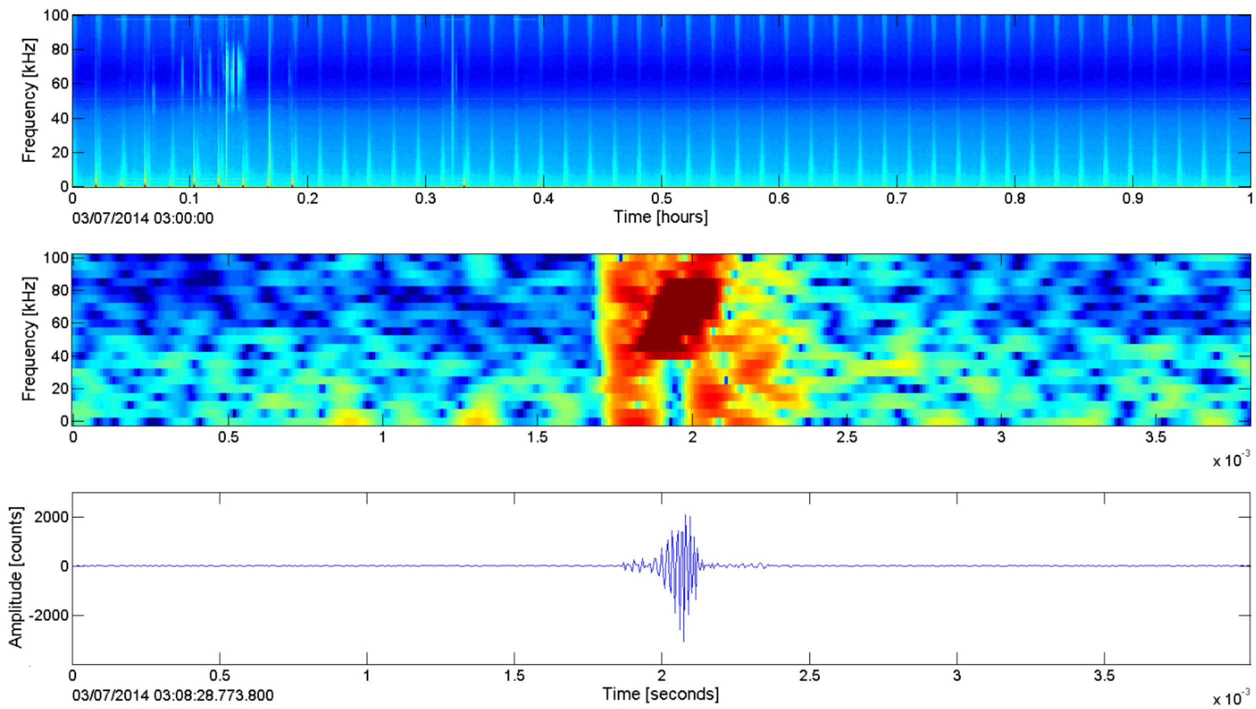


Figure 11. Echolocation sequence of Stejneger's beaked whale in LTSA (top) and example FM pulse in spectrogram (middle) and time series (bottom) at site QC.

Cuvier's Beaked Whales

Cuvier's echolocation signals are polycyclic, with a characteristic FM pulse upsweep, peak frequency around 40 kHz, and uniform inter-pulse interval of about 0.5 s (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). An additional feature that helps with the identification of Cuvier's FM pulses is that they have two characteristic spectral peaks around 17 and 23 kHz (Figure 12).

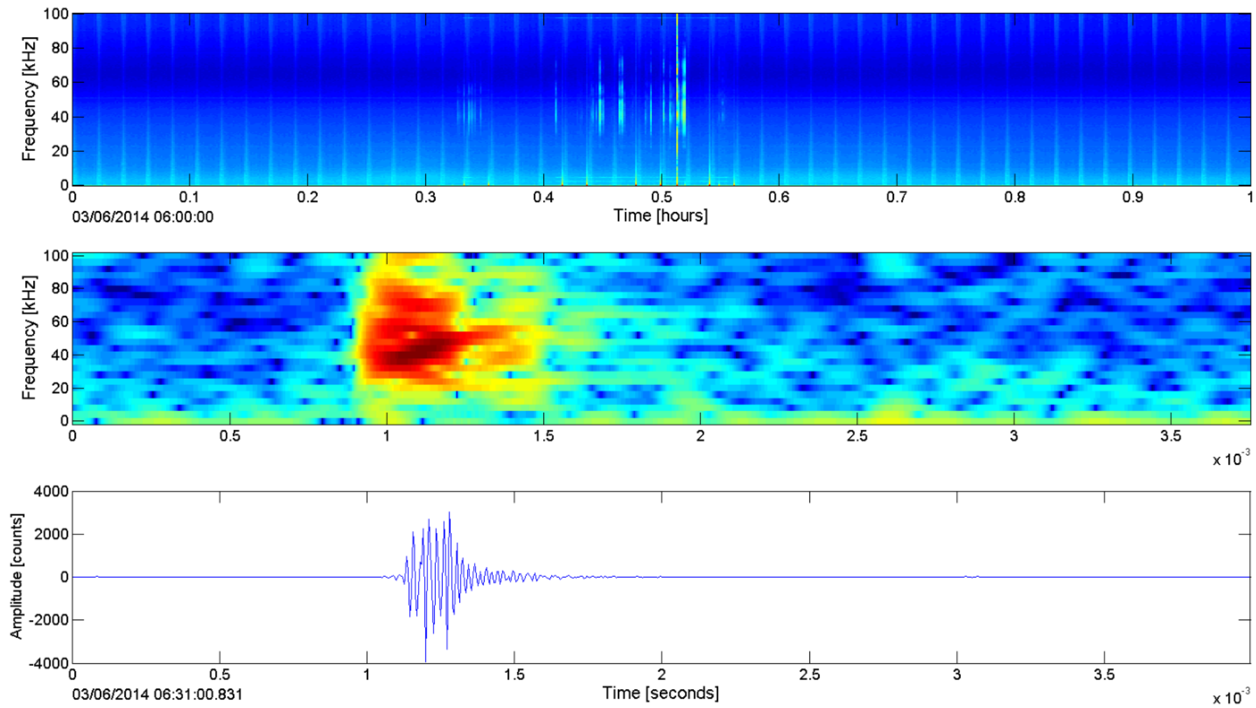


Figure 12. Echolocation sequence of Cuvier's beaked whale in LTSA (top) and example FM pulse in spectrogram (middle) and time series (bottom) at site QC.

Results

Mysticetes

Four species of baleen whales were detected between 2004 and 2013: blue whales, fin whales, humpback whales, and minke whales. Seasonality and presence at each site varied by species.

Blue Whales

- Blue whale Northeast (NE) Pacific B call detections were present seasonally during the fall through early winter at both sites. Detections peaked November through January (Figure 13).
- NE Pacific B calls were more common than D calls (Figure 13, Figure 15).
- There were no diel patterns for blue whale NE Pacific B calls (Figure 14).
- Blue whale D calls were present seasonally during the fall through late winder at both sites (Figure 15).
- There was no discernable diel pattern for blue whale D calls at site CE. Blue whale D calls occurred at all hours at site QC, though more calls occurred around sunset (Figure 16).

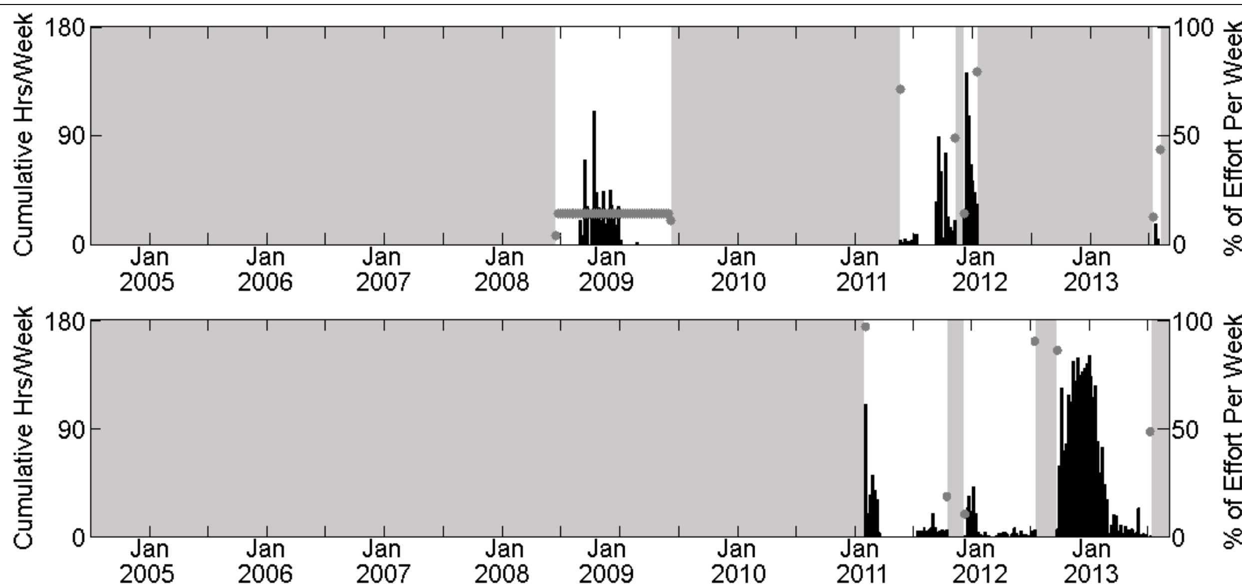


Figure 13. Weekly presence of Northeast Pacific blue whale B calls between 2008 and 2013 at site CE (top) and QC (bottom). Gray dots represent percent of effort per week with in weeks with less than 100% recording effort, and gray shading represents periods with no recording effort. Where gray dots or shading are absent, full recording effort occurred for the entire week.

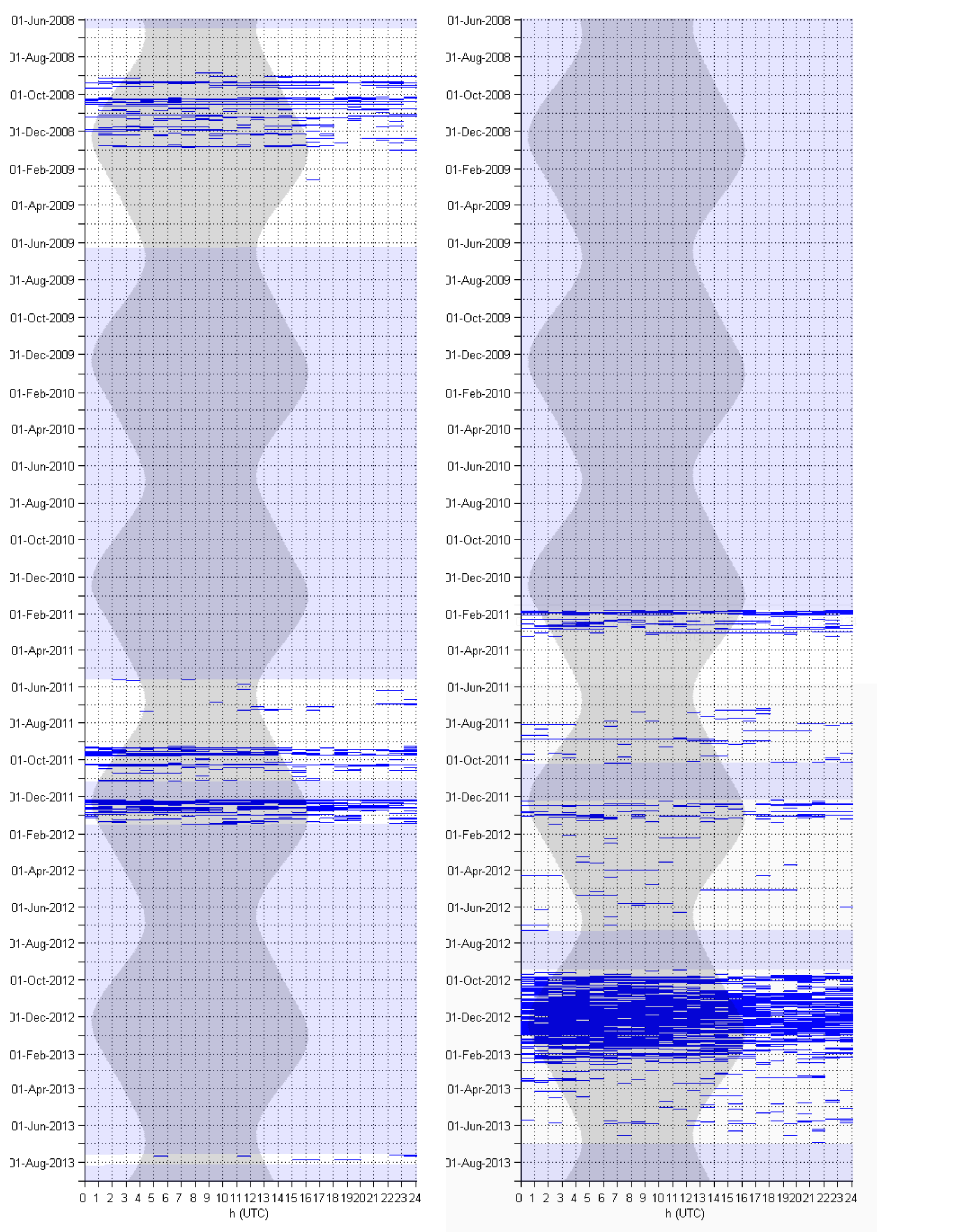


Figure 14. Northeast Pacific blue whale B calls in one-hour bins between 2008 and 2013 at sites CE (left) and QC (right) between 2008 and 2013. Gray shading denotes nighttime, and light purple horizontal shading denotes periods with no recording effort.

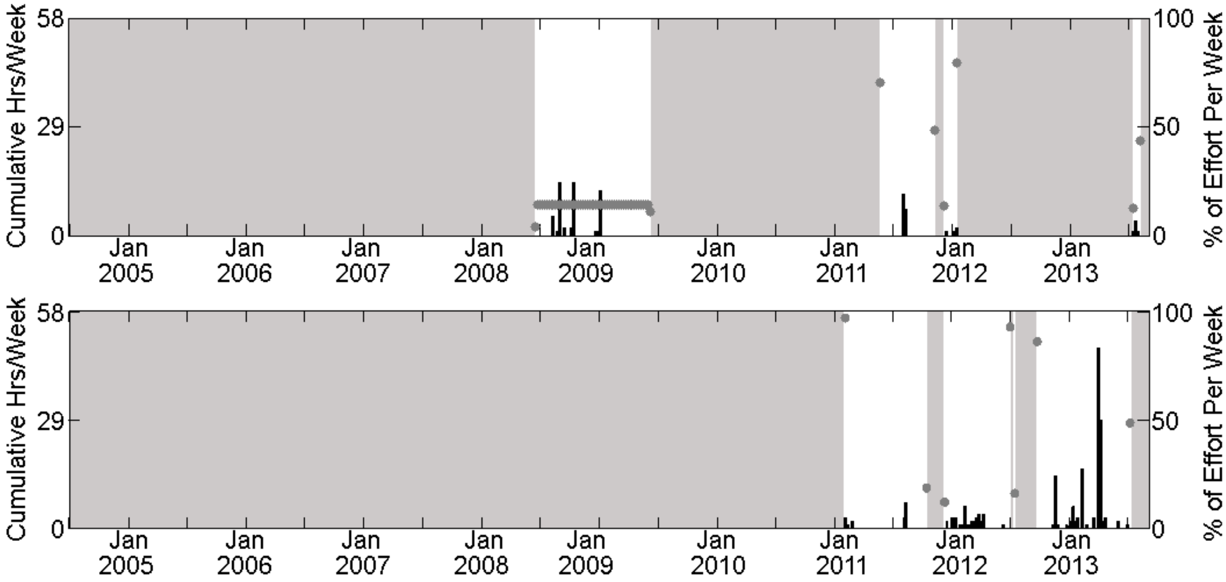


Figure 15. Weekly presence of blue whale D calls between 2008 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.

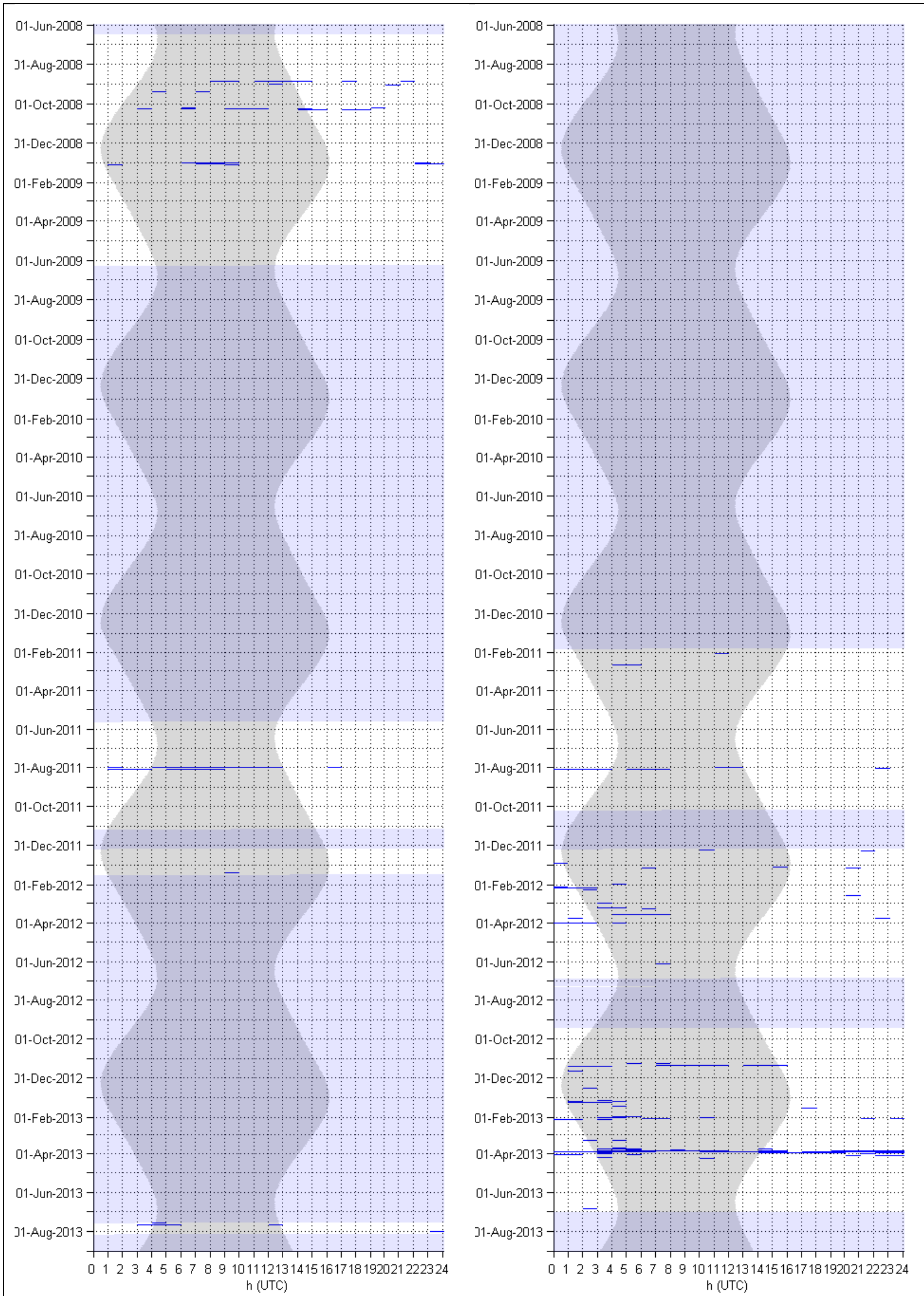


Figure 16. Blue whale D calls in one-hour bins at site CE (left) and QC (right) between 2008 and 2013. Effort markings are described in Figure 14.

Fin Whales

- Fin whale 20 Hz calls were detected throughout the deployments at each site.
- More calls were detected at site QC than at site CE (Figure 17).
- Peaks in detections occurred late-December through early January at both sites. The greatest peaks in detections occurred in late 2011/early 2012 and late 2012/early 2013 at site QC (Figure 17).

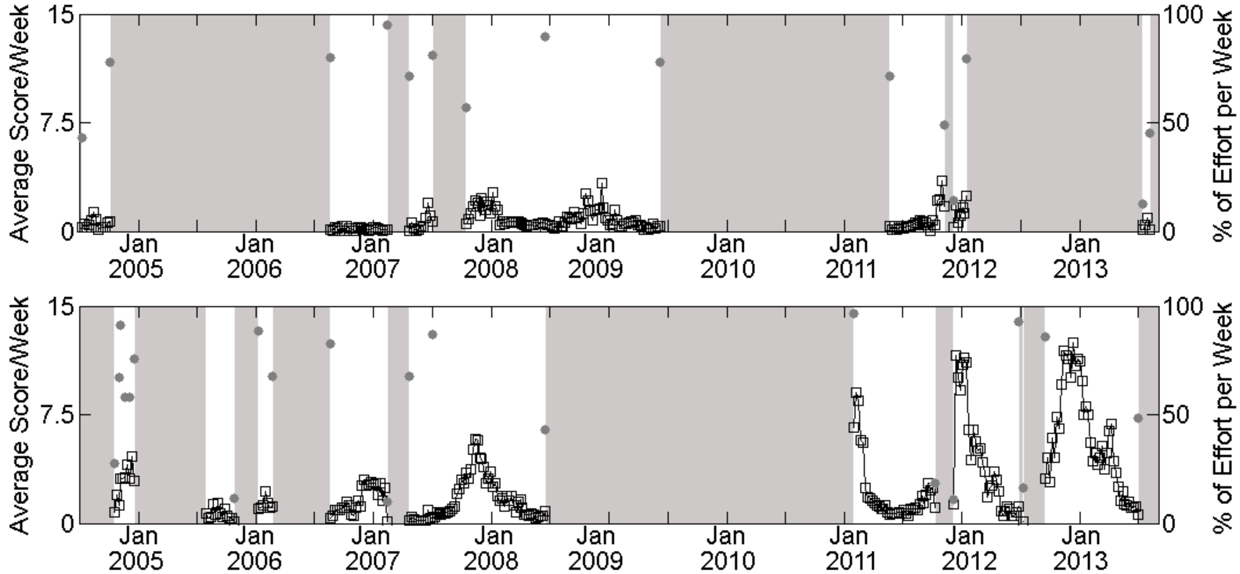


Figure 17. Weekly presence of fin whales between 2008 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.

Humpback Whales

- Humpback whale calls were most common December through February at both sites (Figure 18).
- There was no discernable diel pattern for humpback calls at either site (Figure 19).

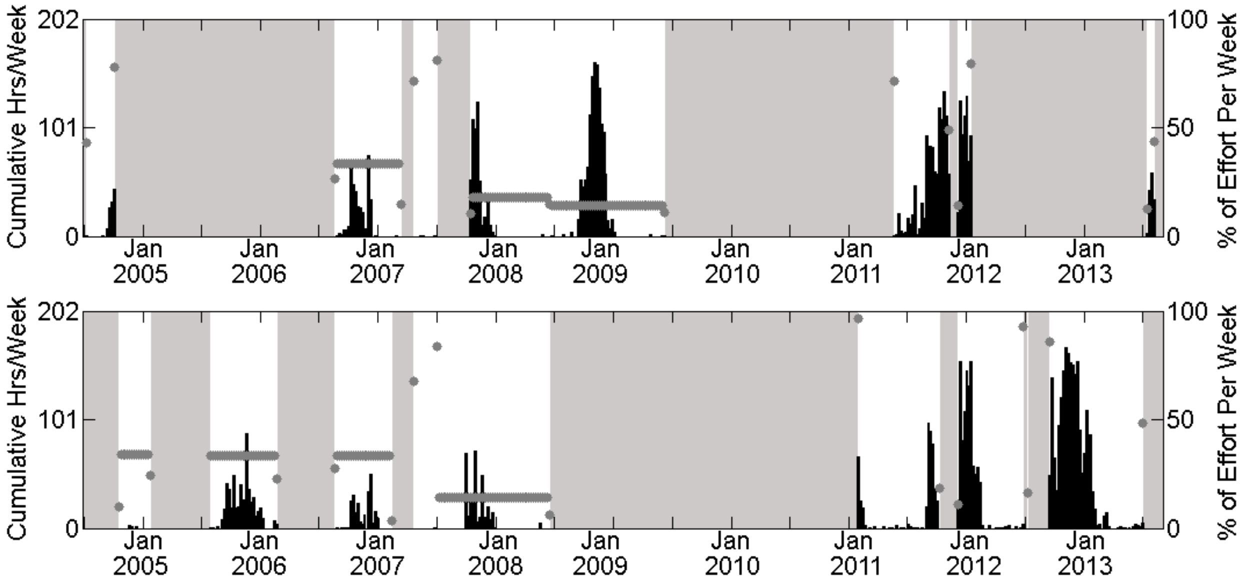


Figure 18. Weekly presence of humpback whales between 2004 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.

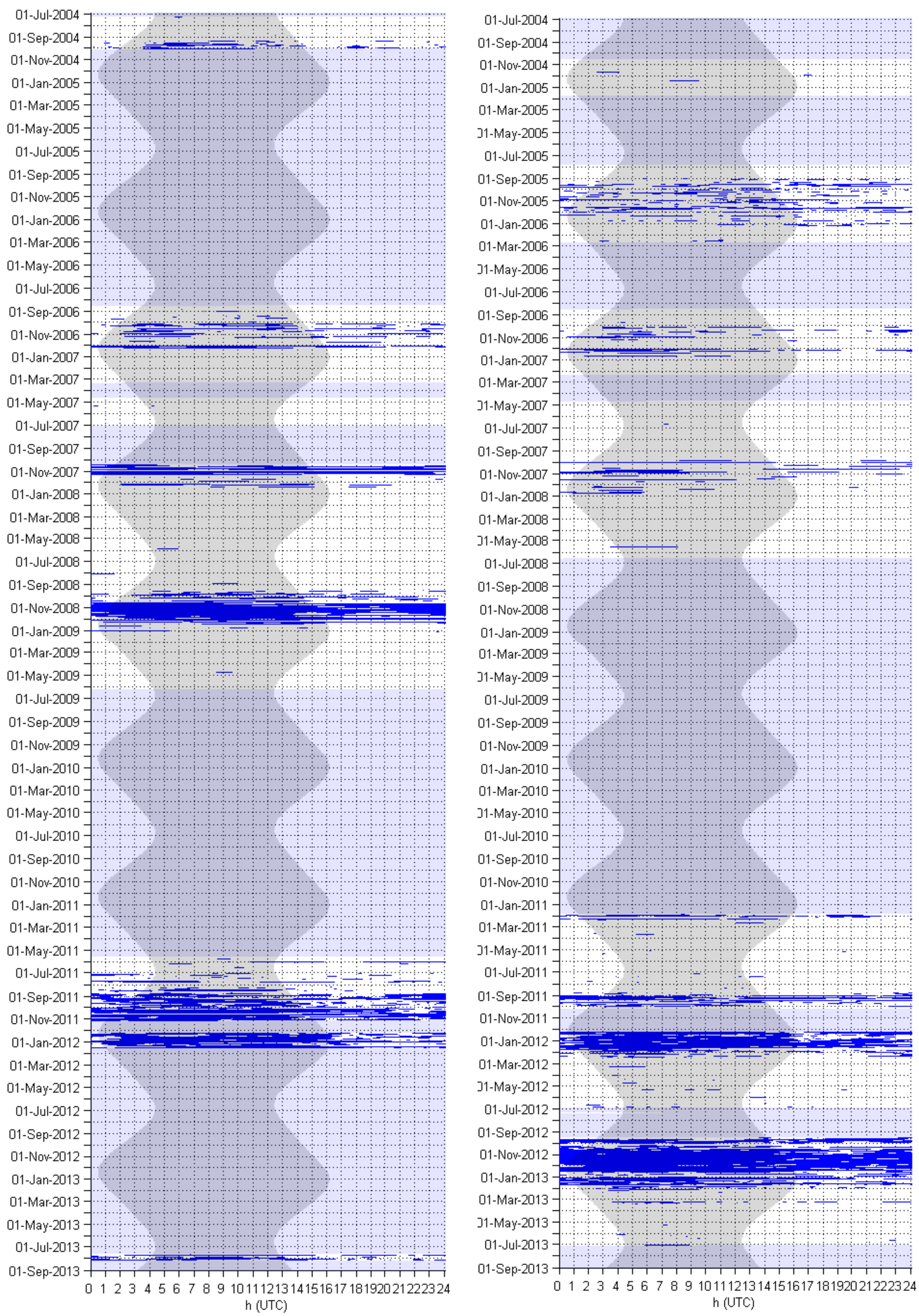


Figure 19. Humpback whale calls in one-minute bins between 2004 and 2013 at site CE (left) and QC (right). Effort markings are described in Figure 14.

Minke Whales

- Minke whale boings were detected at site QC. There were no detections at site CE.
- The majority of minke detections occurred on November 15, 2012, though there were a few detections on April 26 at site QC (Figure 20).
- There were too few detections to determine a diel pattern (Figure 21).

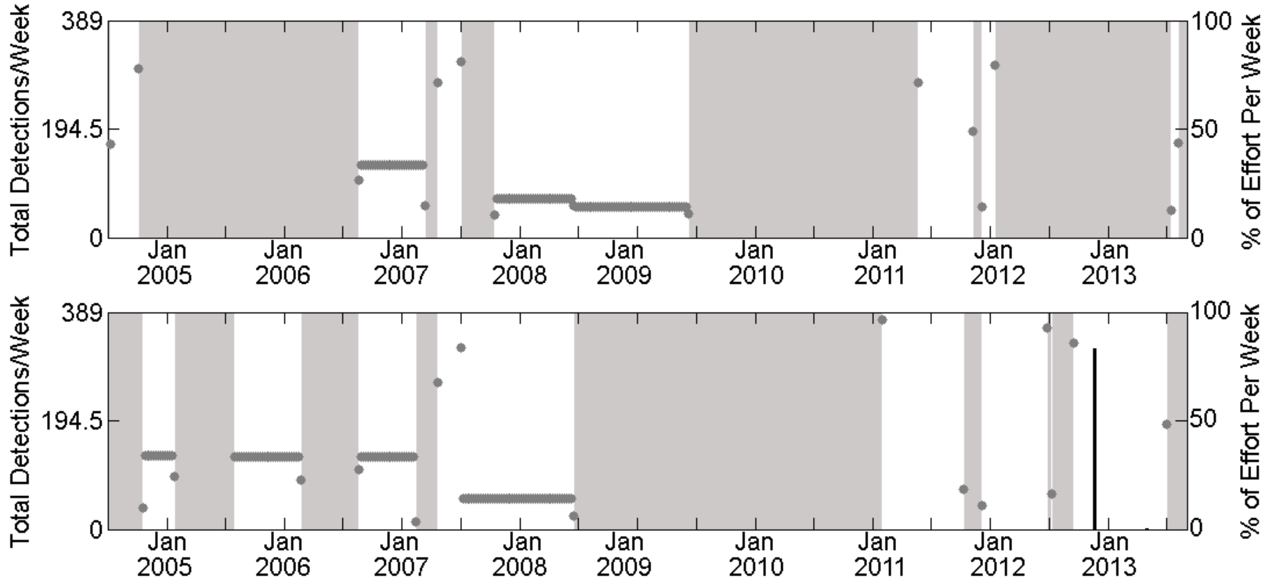


Figure 20. Weekly presence of minke whales between 2004 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.

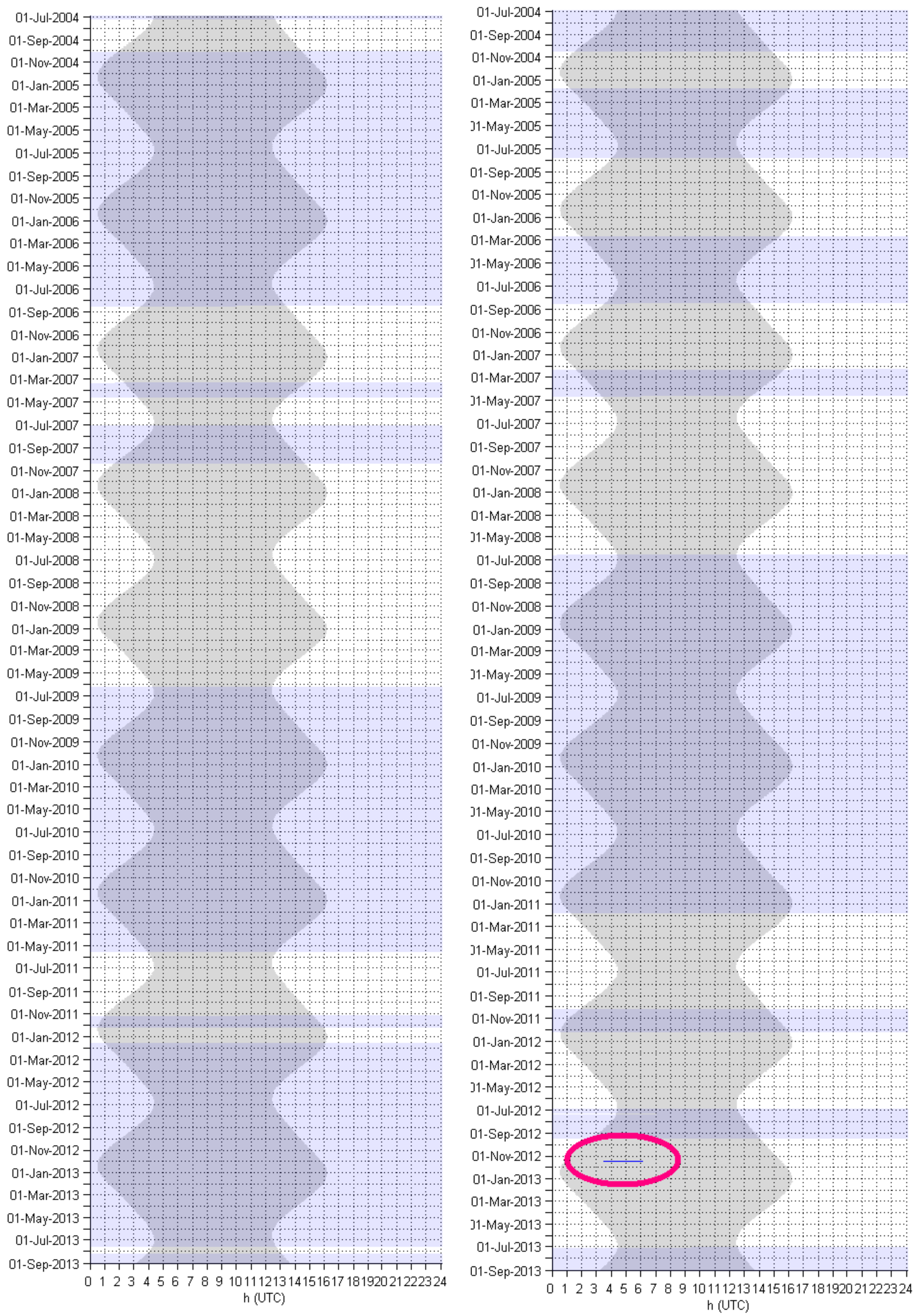


Figure 21. Minke whale calls in one-minute bins between 2004 and 2013 at site CE (left) and QC (right). Effort markings are described in Figure 14.

Odontocetes

Risso's Dolphins

- Risso's dolphin echolocation clicks were detected in low numbers throughout the recordings at site CE. Detections at site QC peaked in summer months (Figure 22).
- There was a shift in the number of detections of Risso's dolphin clicks at site CE with an increase in detections beginning June 2011 through the end of the monitoring period (Figure 22).
- There were too few detections at site CE to determine a diel pattern; however, there was a distinct diel pattern for Risso's dolphin clicks, with more echolocation activity at night at site QC. These detections are likely due to nighttime foraging (Figure 23).

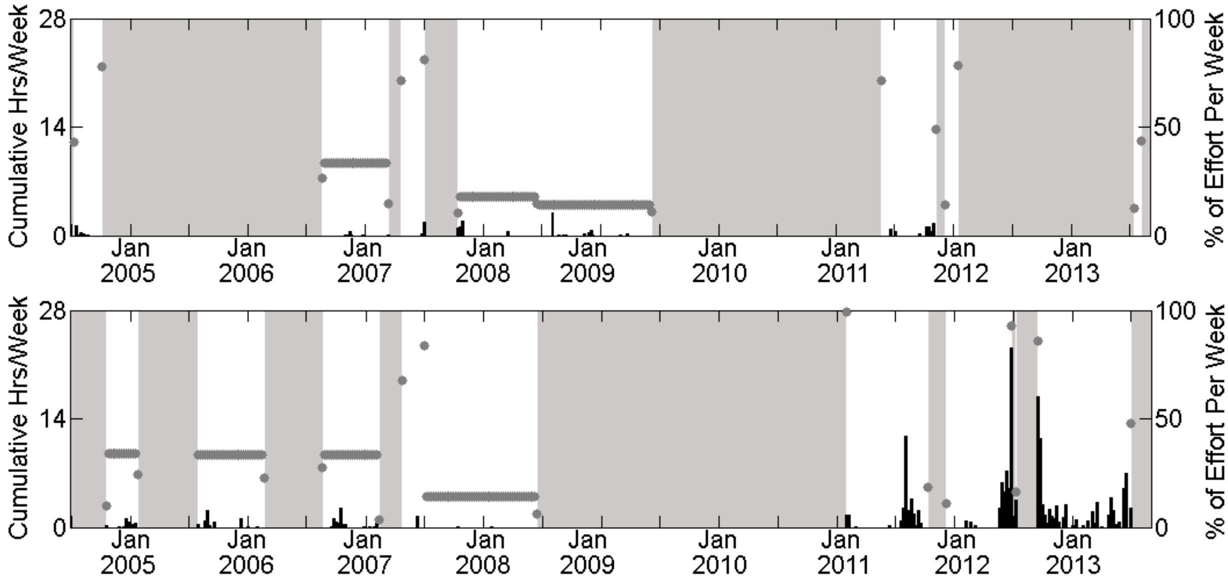
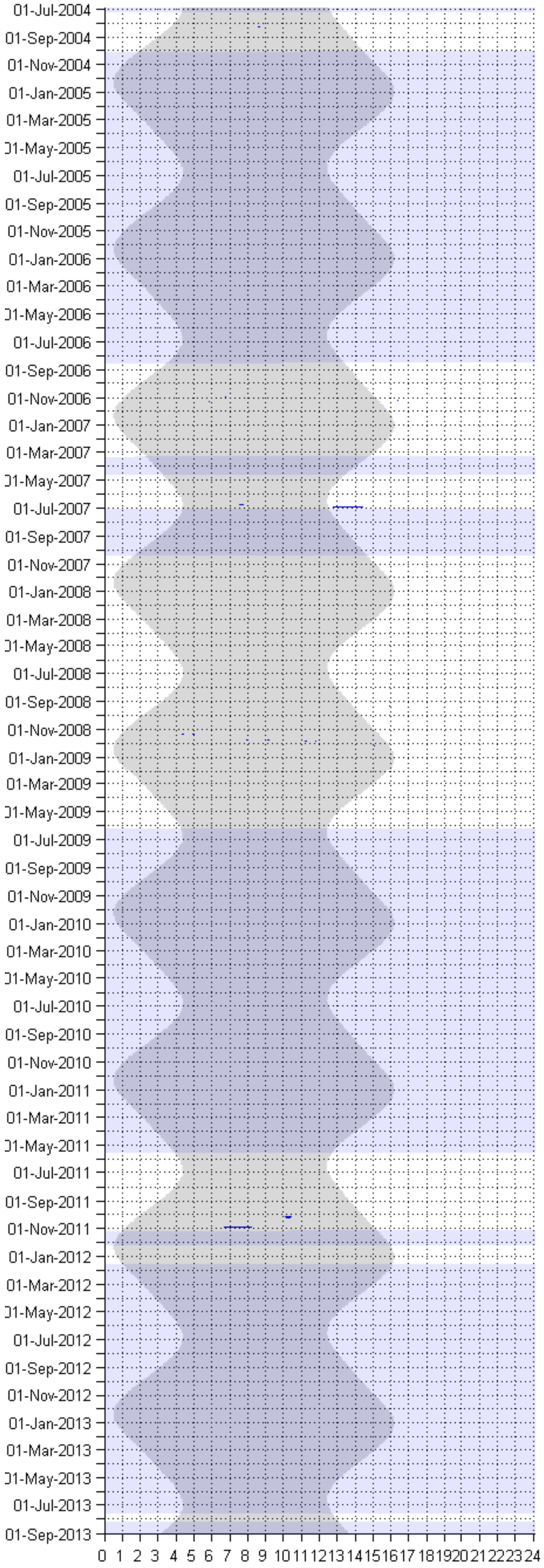


Figure 22. Weekly presence of Risso's dolphin echolocation clicks between 2004 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.



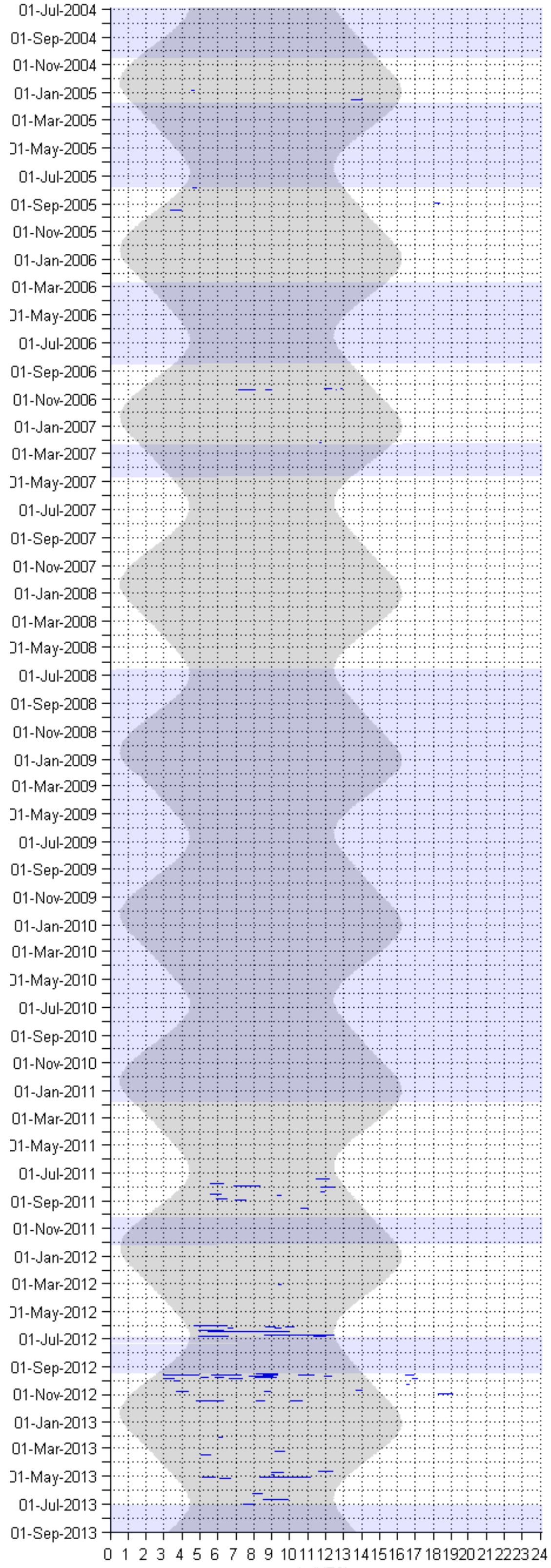


Figure 23. Risso's dolphin echolocation clicks between 2004 and 2013 in one-minute bins at site CE (left) and QC (right). Effort markings are described in Figure 14.

Pacific White-Sided Dolphins

- Pacific white-sided dolphin echolocation clicks were detected in low numbers at site CE. Detections at site QC peaked in summer months (Figure 24).
- There were more detections during the first half of the monitoring period at site QC, with peaks in detections occurring during summer months (Figure 24).
- There was a clear diel pattern for Pacific white-sided dolphin clicks at both sites, likely associated with nighttime foraging (Figure 25).

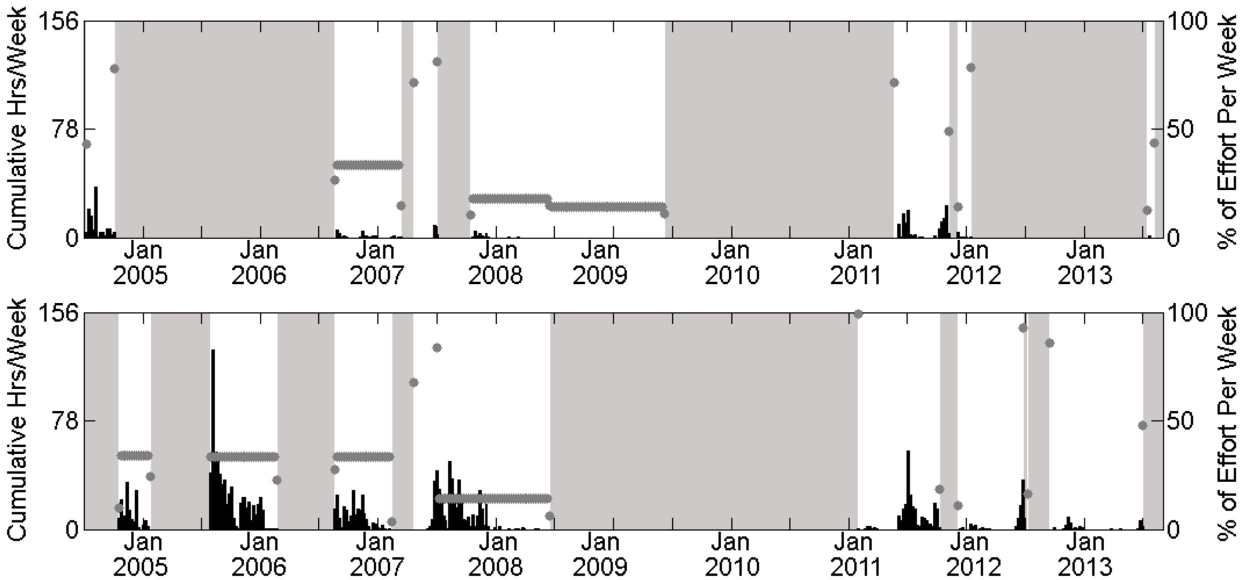


Figure 24. Weekly presence of Pacific white-sided dolphin echolocation clicks between 2004 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.

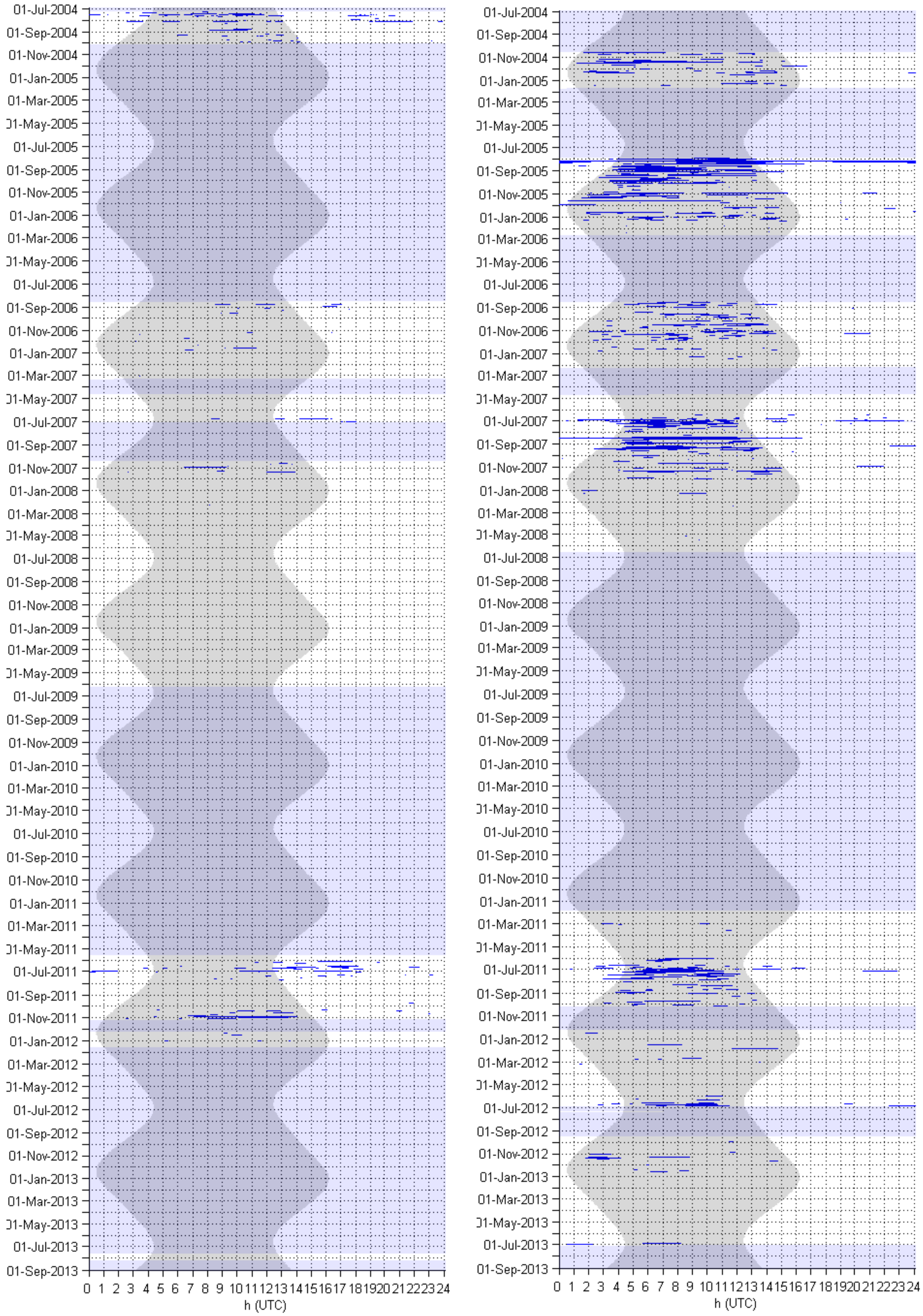


Figure 25. Pacific white-sided dolphin echolocation clicks between 2004 and 2013 in one-minute bins at site CE (left) and QC (right). Effort markings are described in Figure 14.

Sperm Whales

- Sperm whale echolocation clicks were detected in low numbers at site CE. Detections at site QC peaked in summer months (Figure 26).
- Sperm whale clicks were present throughout the monitoring period at site QC, though there were more click detections in the first half of the monitoring period than during the second half (Figure 26).
- There was no discernable diel pattern for sperm whale clicks at either site (Figure 27).

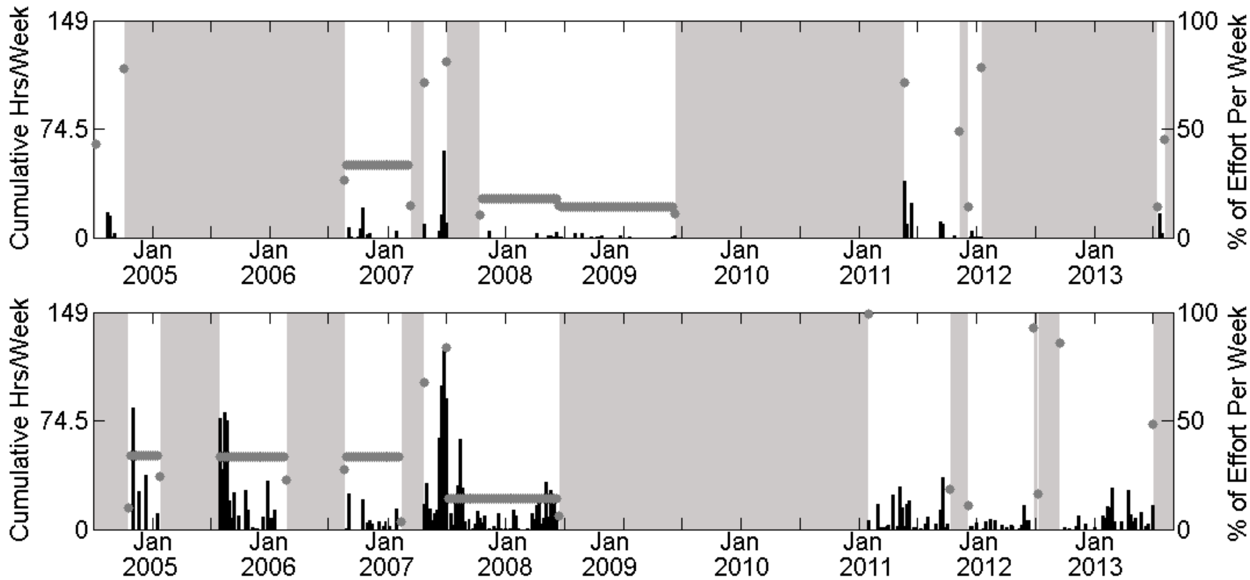


Figure 26. Weekly presence of sperm whale echolocation clicks between 2004 and 2013 at site CE (top) and QC (bottom). Effort markings are described in Figure 13.

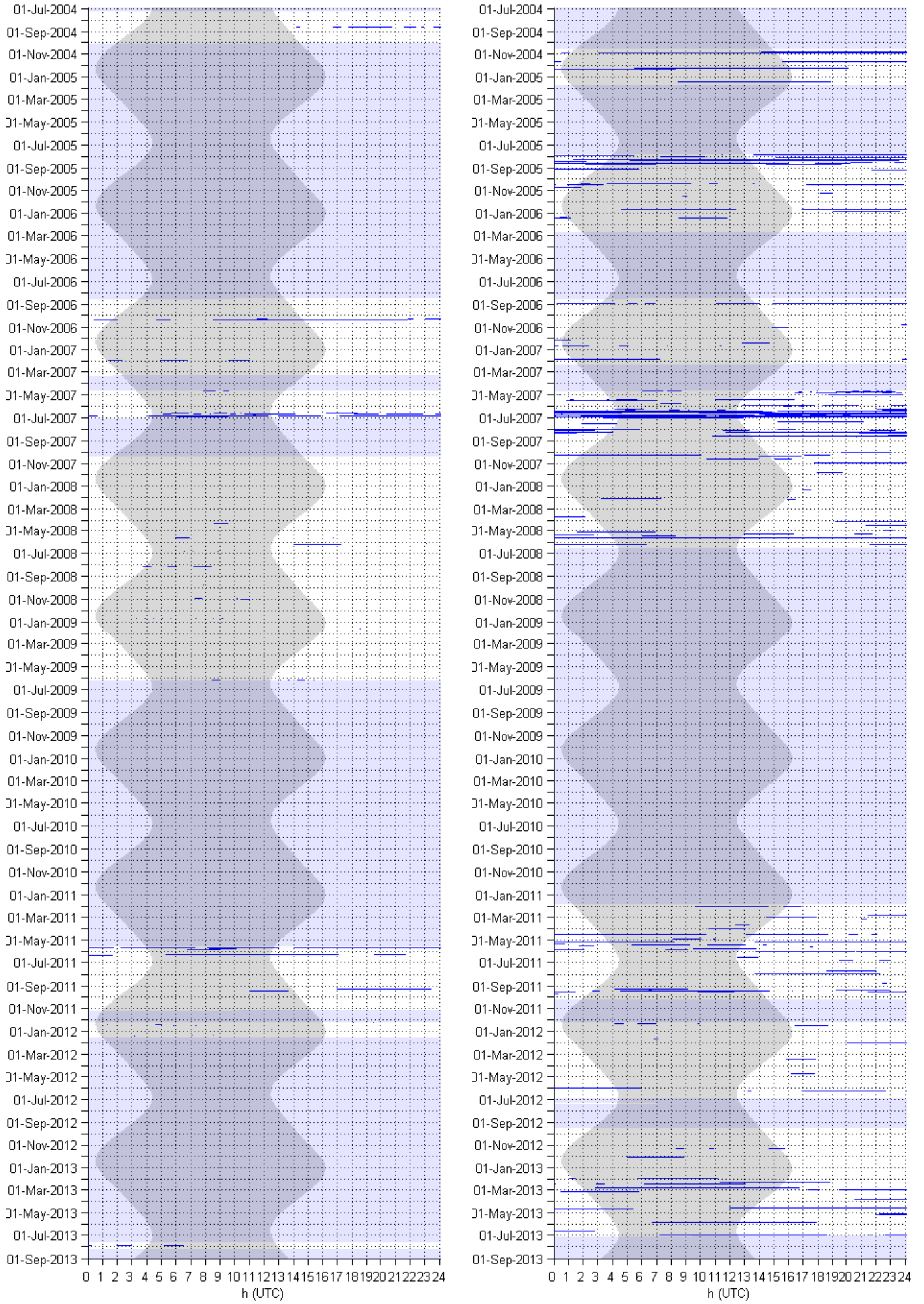


Figure 27. Sperm whale echolocation clicks between 2004 and 2013 in one-minute bins at site CE (left) and QC (right). Effort markings are described in Figure 14.

Beaked Whales

Stejneger's Beaked Whales

- Stejneger's beaked whales were the most commonly detected beaked whale.
- There were more detections in 2011-2013 than in 2007-2008 (Figure 28).
- There was no distinct seasonal pattern to the detections (Figure 28).
- There was no discernable diel pattern for Stejneger's beaked whale echolocation signals (Figure 29).

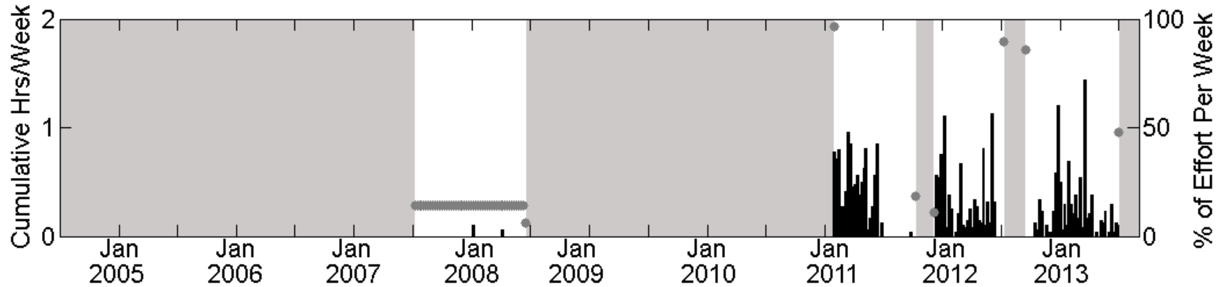


Figure 28. Weekly presence of Stejneger's beaked whale clicks between 2007 and 2013 at site QC. Effort markings are described in Figure 13.

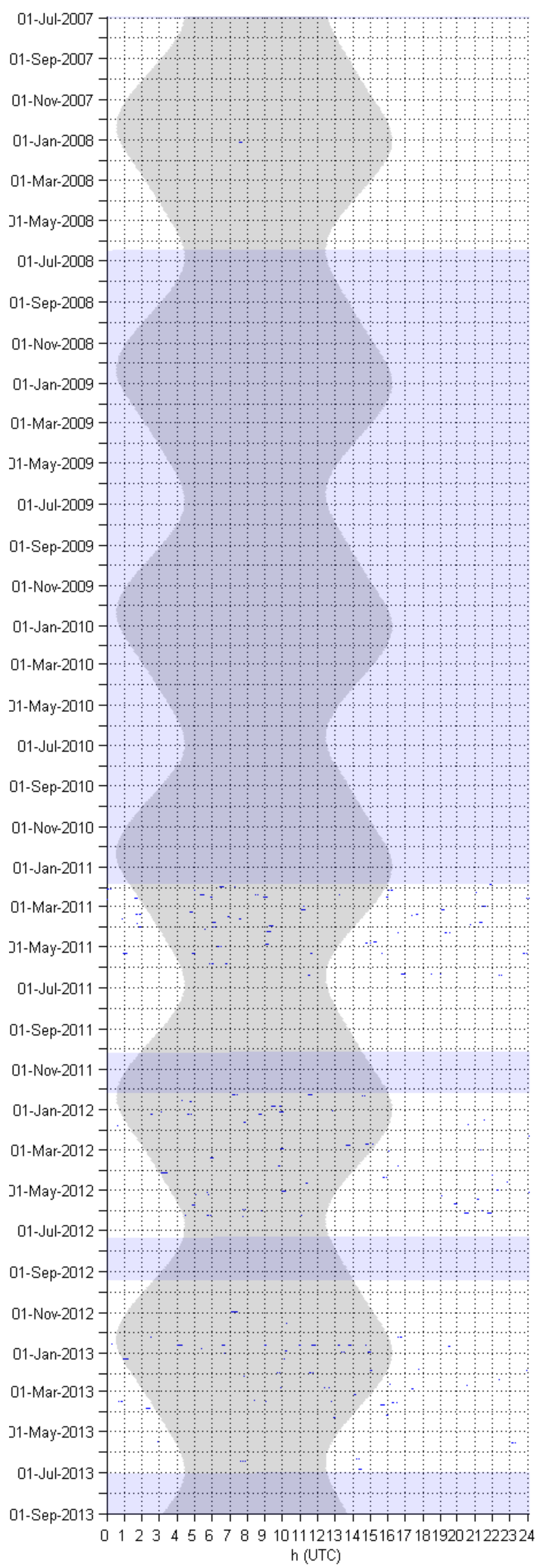


Figure 29. Stejneger's beaked whale echolocation clicks between 2007 and 2013 in one-minute bins at site QC. Effort markings are described in Figure 14.

Cuvier's Beaked Whales

- Cuvier's beaked whale detections in February 2012. There were no detections between 2007 and 2008 (Figure 30).
- There was no discernable diel pattern for Cuvier's beaked whale detections (Figure 31).

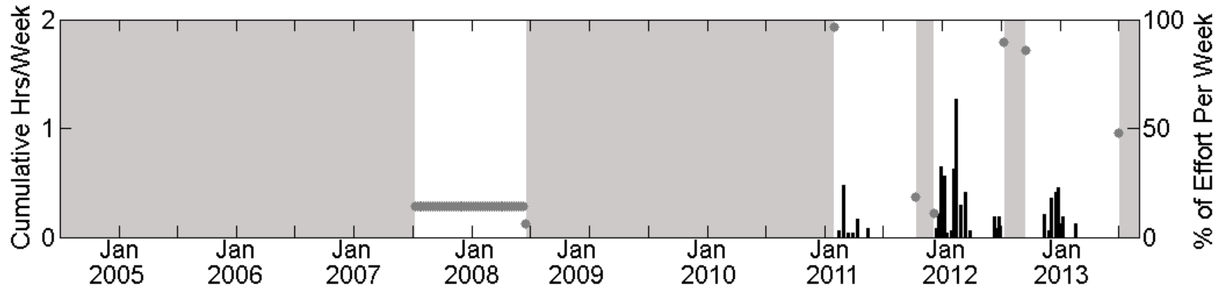


Figure 30. Weekly presence of Cuvier's beaked whale clicks between 2007 and 2013 at site QC. Effort markings are described in Figure 13.

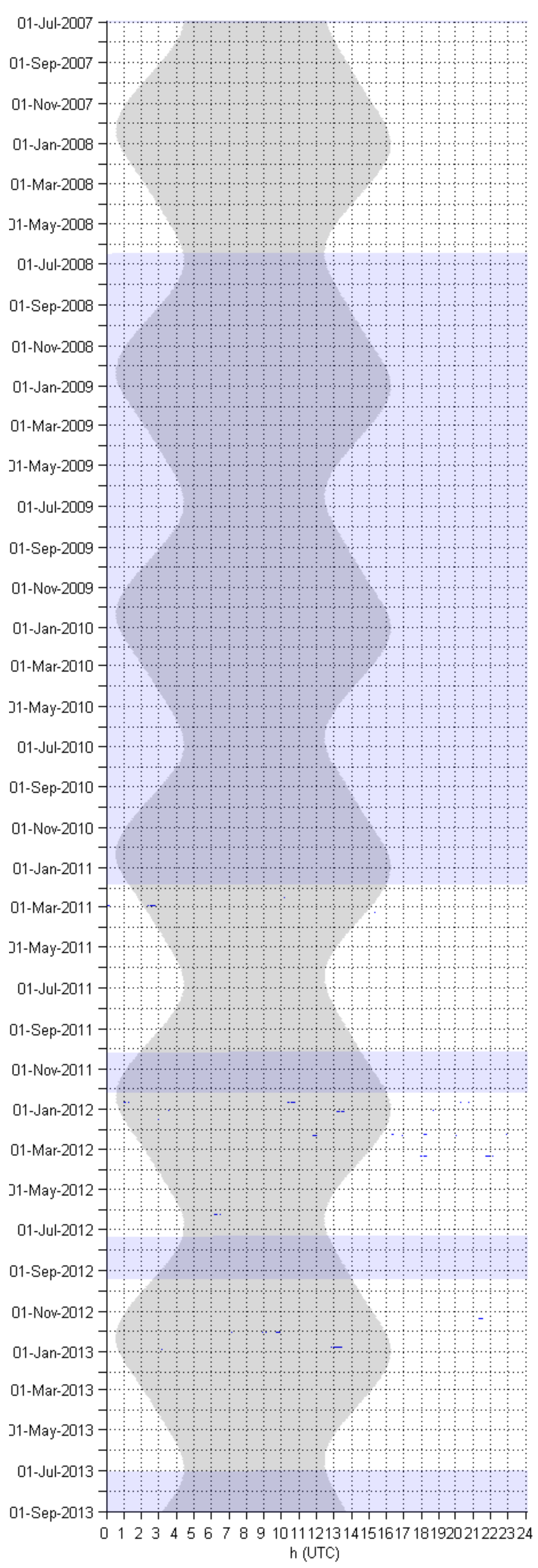


Figure 31. Cuvier's beaked whale echolocation clicks between 2007 and 2013 in one-minute bins at site QC. Effort markings are described in Figure 14.

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