Final Report

Cetacean Studies in the Gulf of Alaska Temporary Maritime Activities Area in July-August 2015: Passive Acoustic Monitoring of Marine Mammals Using Gliders

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14. ABSTRACT
A passive-acoustic glider survey was conducted in the Gulf of Alaska Temporary Maritime Activities Area (GoA-TMAA) between 11 July and 21 August 2015 (data collection period: 11 July through 11 August 2015). The goal of the project was to investigate the spatial distribution and temporal occurrence of odontocetes and mysticetes in the northern Gulf of Alaska. The survey focused primarily on the shelf break area between Middleton Island and Kodiak Island. The Gulf of Alaska is generally difficult to survey, and thus the knowledge about the abundance and distribution of cetaceans in this area is limited. Any additional effort improves the understanding and awareness of marine mammal occurrence in the GoA-TMAA.

The 2015 GoA-TMAA acoustic glider survey was very successful. The glider, referred to as SG203, conducted an acoustic survey that covered a distance of 744 kilometers over ground with the passive acoustic monitoring systems (effective frequency range 15 Hertz to 90 kilohertz) active and collected 680 hours of acoustic data over a 32-day period from 11 July through 11 August 2015. This survey further demonstrated that autonomous underwater vehicles are remarkably useful for acoustic monitoring in remote areas. These long-duration trials are invaluable for improving these glider systems and are crucial for further development efforts. A primary long-term technical goal is to extend the

deployment duration to allow for 2–3 months of continuous acoustic data collection.
A total of 315 cetacean encounters was recorded during 170 dives with the passive-acoustic monitoring system active. The data analysis revealed the presence of a wide variety of acoustically active cetaceans, including the infrasonic song notes produced by blue whales (Balaenoptera musculus) and the ultrasonic echolocation clicks of Pacific white-sided dolphins (Lagenorhynchus obliquidens).

Odontocete acoustic encounters were abundant. Most encounters were associated with the acoustic presence of sperm whales (Physeter macrocephalus) and killer whales (Orcinus orca). Other species detected included Pacific white-sided dolphins and a few unidentified odontocetes. Possible Stejneger's beaked whales were recorded on 12 occasions near the end of the survey.

Blue whale D calls as well as fin whale (Balaenoptera physalus) 40-Hz calls were the most abundant mysticete sound in the data set. The glider also recorded a variety of downsweeps throughout the survey, which potentially indicate the presence of sei whales (Balaenoptera borealis) in the study area. The glider did not record known vocalizations produced by humpback whales (Megaptera novaeangliae), North Pacific right whales (Eubalaena japonica), minke whales (Balaenoptera acutorostrata), or gray whales (Eschrichtius robustus).

There was also no acoustic evidence of naval sonar operation in the study area at the time of the survey.
Successful surveys like these demonstrate that mobile autonomous recording platforms can play an important role in future marine mammal monitoring efforts.

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Executive Summary

A passive-acoustic glider survey was conducted in the Gulf of Alaska Temporary Maritime Activities Area (GoA-TMAA) between 11 July and 21 August 2015 (data collection period: 11 July through 11 August 2015). The goal of the project was to investigate the spatial distribution and temporal occurrence of odontocetes and mysticetes in the northern Gulf of Alaska. The survey focused primarily on the shelf break area between Middleton Island and Kodiak Island. The Gulf of Alaska is generally difficult to survey, and thus the knowledge about the abundance and distribution of cetaceans in this area is limited. Any additional effort improves the understanding and awareness of marine mammal occurrence in the GoA-TMAA.

The 2015 GoA-TMAA acoustic glider survey was very successful. The glider, referred to as SG203, conducted an acoustic survey that covered a distance of 744 kilometers over ground with the passive acoustic monitoring systems (effective frequency range 15 Hertz to 90 kilohertz) active and collected 680 hours of acoustic data over a 32-day period from 11 July through 11 August 2015. This survey further demonstrated that autonomous underwater vehicles are remarkably useful for acoustic monitoring in remote areas. These long-duration trials are invaluable for improving these glider systems and are crucial for further development efforts. A primary long-term technical goal is to extend the deployment duration to allow for 2–3 months of continuous acoustic data collection.

A total of 315 cetacean encounters was recorded during 170 dives with the passive-acoustic monitoring system active. The data analysis revealed the presence of a wide variety of acoustically active cetaceans, including the infrasonic song notes produced by blue whales (*Balaenoptera musculus*) and the ultrasonic echolocation clicks of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*).

Odontocete acoustic encounters were abundant. Most encounters were associated with the acoustic presence of sperm whales (*Physeter macrocephalus*) and killer whales (*Orcinus orca*). Other species detected included Pacific white-sided dolphins and a few unidentified odontocetes. Possible Stejneger's beaked whales were recorded on 12 occasions near the end of the survey.

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Successful surveys like these demonstrate that mobile autonomous recording platforms can play an important role in future marine mammal monitoring efforts.

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Acronyms and Abbreviations

APL-UW	Applied Physics Laboratory, University of Washington
bit	basic unit of information
cm/s	centimeter(s) per second
FLAC	Free Lossless Audio Codec
FM	frequency modulated
GoA-TMAA	Gulf of Alaska Temporary Maritime Activities Area
HF	high frequency
HFM	high frequency modulated
Hz	hertz
ICI	inter-click interval
kHz	kilohertz
km	kilometer(s)
LTSA	long-term spectral average
m	meter(s)
MF	mid frequency
ms	millisecond(s)
MIRC	Mariana Islands Range Complex
PAM	passive acoustic monitoring
SD	standard deviation
U.S.	United States
UTC	Coordinated Universal Time

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1. Background and Objectives

As part of the regulatory compliance process associated with the Marine Mammal Protection Act and the Endangered Species Act, the United States (U.S.) Navy is responsible for meeting specific monitoring and reporting requirements for military training and testing activities. In support of these monitoring requirements, a cetacean survey using a passive-acoustic glider was conducted in the Gulf of Alaska Temporary Maritime Activities Area (GoA-TMAA) in July and August 2015. This report provides findings from this monitoring effort in order to further our understanding of the following monitoring question:

1.1 Monitoring Question

- What are the spatial distributions of beaked whales and Endangered Species Act-listed cetaceans (sperm, blue, fin, sei, humpback, and North Pacific right whales) in the GoA-TMAA?

The marine mammal monitoring reported here is part of a long-term monitoring effort under the U.S. Navy's Marine Species Monitoring Program, Contract No. N62470-10-D-3011, supported by HDR.

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2. Methods

2.1 General Glider Information

Underwater gliders use small changes in buoyancy to effect vertical motion and wings to convert the vertical motion to horizontal movement, thereby propelling the glider forward with very low power consumption. This allows gliders to perform long-duration surveys autonomously (Rudnick et al. 2004). During a mission, a glider is piloted remotely, via Iridium™ satellite connection, from a control center onshore (**Figure 1**).

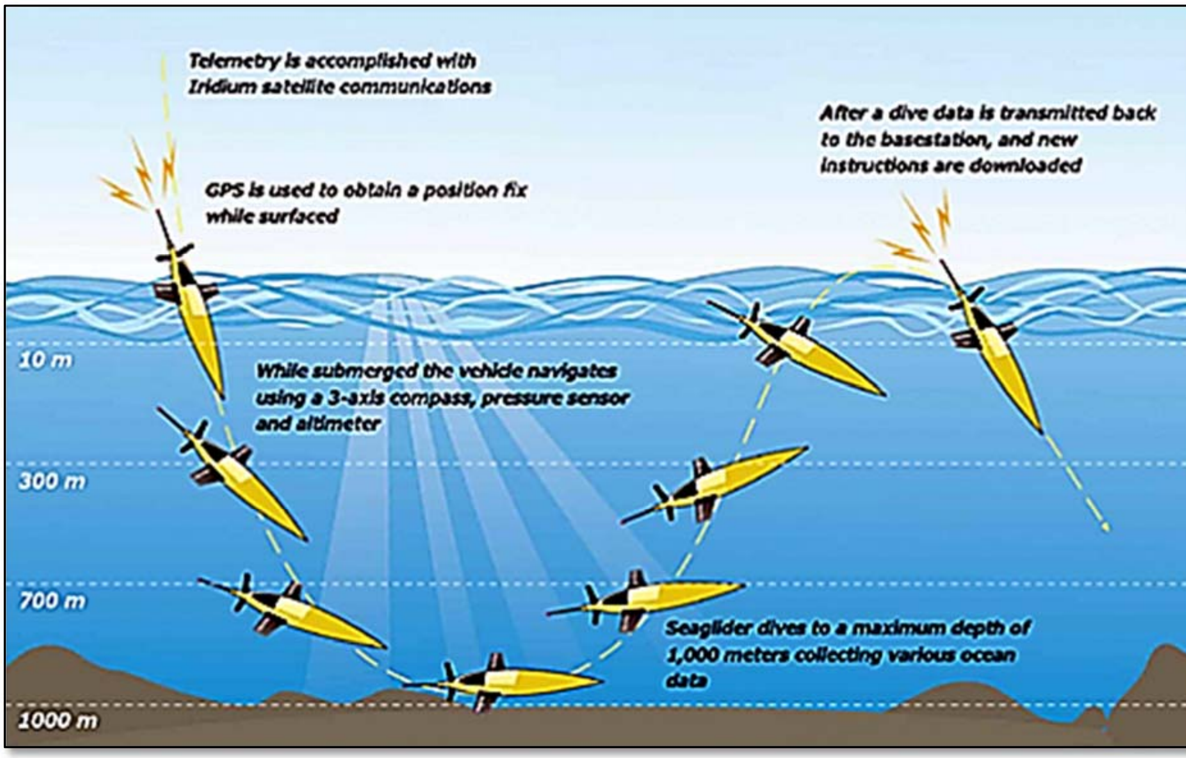

Figure 1: Mode of operation of a glider. Source: http://subseaworldnews.com

In 2007, the U.S. Navy's Office of Naval Research, Marine Mammals and Biology program started the Passive Acoustic Autonomous Monitoring of Marine Mammals program to develop near-real-time monitoring systems on autonomous underwater vehicles. The Marine Mammals and Biology program focused on passive acoustic systems for autonomous detection, classification, localization, and tracking of marine mammals on Navy exercise areas for periods in excess of 1 month. The passive-acoustic Seaglider™ used in this study is a result of this development effort. It was originally developed by the Applied Physics Laboratory, University of Washington (APL-UW) and is now commercially available from Kongsberg Inc. (Lynwood, Washington, USA). The PAM board (Revision B) has been classified as a Demonstration and Validation 6.4 system. Such 6.4 systems encompass integrated technologies ready to be evaluated in as realistic an operating environment as possible. The glider is capable of repeatedly diving to a depth of 1,000 meters (m) and back at a typical horizontal speed of 25 centimeters per second (cm/s). Dive durations are approximately 4 to 6 hours for 1,000-m dives.

The Seaglider™ (**Figure 2**) was equipped with a custom-designed and custom-built passive acoustic recording system (Rev. B PAM board, APL-UW, Seattle, Washington, USA). Acoustic signals were received by a single omni-directional hydrophone (type: HTI-99-HF, High Tech Inc., Gulfport, Mississippi, USA; sensitivity: -164 decibels referenced to 1 micropascal), amplified by 36 decibels, and recorded at 194-kilohertz (kHz) sample rate and 16-bit resolution. Aliasing is prevented by the use of an analog 90-kHz low-pass filter (five-pole Chebyshev filter). Acoustic data were compressed using the Free Lossless Audio Codec (FLAC) and stored on flash memory drives. The calibrated passive acoustic monitoring (PAM) system was optimized for continuous data in the 15 hertz (Hz) to 90 kHz frequency range, and thus was well suited for recording baleen whale and most toothed whale sounds. However, the bandwidth of the system did not cover the frequency range of sounds produced by pygmy and dwarf sperm whales (*Kogia* spp.) or porpoise species.

Figure 2: Passive-acoustic Seaglider™. The Seaglider™ is a commercial, off-the-shelf instrument sold by Kongsberg, Inc. (Lynwood, Washington, USA). The PAM system was developed and incorporated into the Seaglider™ by APL-UW (Seattle, Washington, USA).

The system featured an automatic 'blanking mechanism' that muted the PAM system during periods when the glider's noisy internal steering and buoyancy mechanisms were operated. During a typical 1,000-m dive, the associated data loss was between 5 and 10 percent. Because of high noise levels at or close to the surface, recordings were made only at depths of 25 to 1,000 m. The glider was programmed to transmit selected data packages via Iridium™ satellite link when surfacing between dives. These included position, standard conductivity, temperature, and depth profiles. The gliders typically stayed at the surface for less than 10 minutes.

This system has been validated during several surveys, including short (week-long) deployments at both the Atlantic Undersea Test and Evaluation Center and the Southern California Offshore Range (Klinck et al. 2012). The first long-duration (exceeding 1 month of quasi-continuous data collection) survey was conducted in the Mariana Islands Range Complex (MIRC) in fall 2014 under Contract N62470-10-D-3011 (Klinck et al. 2015a). Additional month-long deployments were conducted in the MIRC in 2015 (Klinck et al. 2016) and the HRC in 2014/15 (Klinck et al. 2015b) also under Contract N62470-10-D-3011. During the first glider deployment in MIRC, the PAM board firmware had an issue causing periodic acoustic data loss. This was resolved by having the pilot reboot the PAM system. This issue was later addressed by a script which automatically rebooted the PAM system after each dive. This significantly reduced the acoustic data loss caused by this issue. A permanent fix will require additional engineering and bench testing. The PAM board is a U.S. export-controlled item under both the Department of State's International Traffic in Arms Regulations and the Department of Commerce's Export Administration Regulations programs.

In the 2015 GoA-TMAA study, the glider was programmed to survey across diverse bathymetric features and cetacean habitats whenever possible (**Figure 3**). Waterspace management approval was received from the U.S. Navy prior to deployment of the glider. The glider's position and schedule were updated as the survey progressed. The instrument carried on-board digital bathymetric maps used for deciding how deep to dive in areas with water depths shallower than 1,000 m. The glider's depth-choice algorithm was designed to operate best when the instrument's course is orthogonal to the isobaths. Use of this map-reading method avoided the need to use active acoustics for altimetry, which would have hindered passive-acoustic recordings.

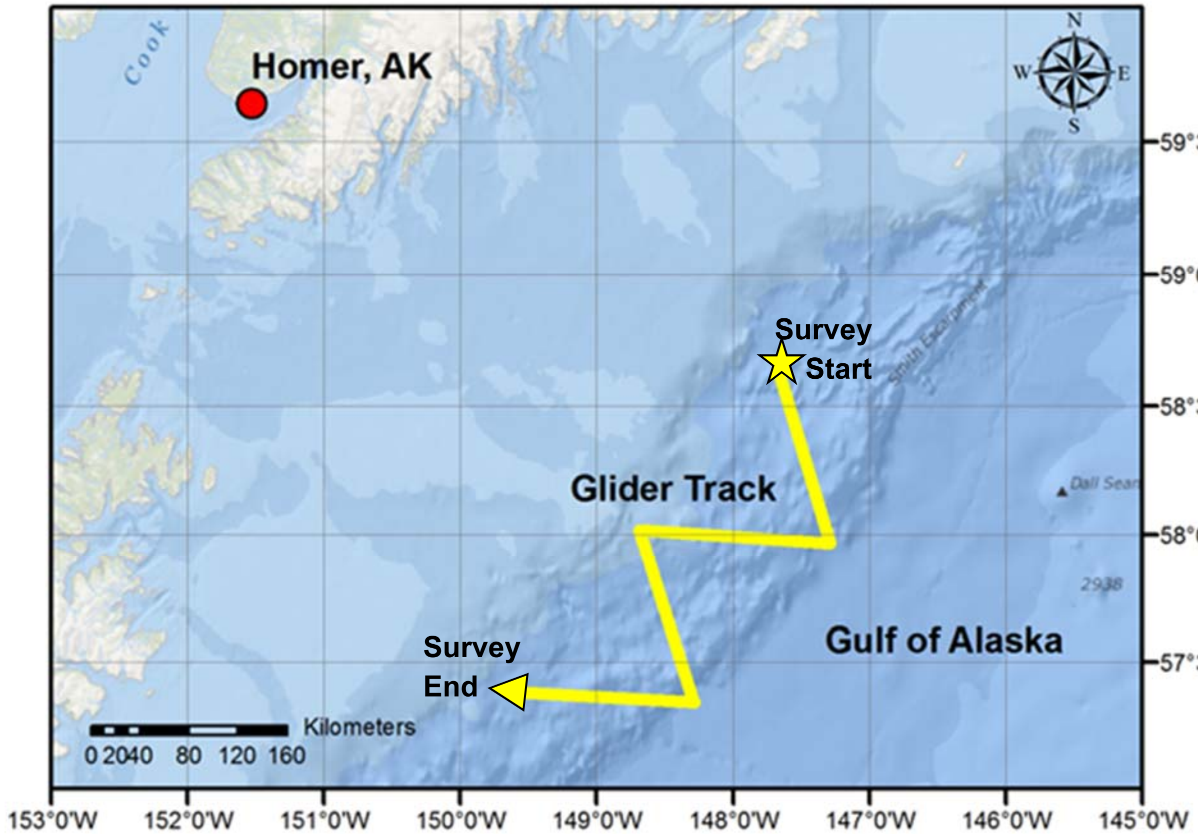

Figure 3: Proposed glider track (approximately 600 kilometers [km]) for the GoA-TMAA survey. Glider (yellow track) was programmed to survey the shelf break in a southwesterly direction.

2.2 Data Analysis

Because the data set was only 1 month in duration, the entire analysis was conducted manually by experienced analysts. Automated detectors and classifiers were not used for the analysis. This approach, while more labor intensive, reduced the likelihood of missed marine mammal acoustic encounters.

The FLAC files were decoded to standard .WAV audio file format, and three data sets with different sampling rates (194 kHz, 10 kHz, and 1 kHz) were generated for specific analyses. Analysis was primarily done on a per-dive basis, where acoustic detections were summarized for each dive and the percentage of time during a dive when sounds from a species of interest were detected. Marine mammal sounds were also tallied on an encounter basis. An acoustic encounter was defined as a period when target signals were present in the acoustic data sets, separated from other periods of signal detections by 30 or more minutes of silence.

2.2.1 Environmental Data

The glider collected conductivity, temperature, and depth profiles as well as information on depth-averaged currents throughout the duration of the survey (including periods when the PAM system was deactivated). APL-UW processed the raw environmental data using custom software routines and provided temperature, sound speed, and depth-averaged current plots for this report.

2.2.2 Odontocetes

Odontocete species that regularly occur in the GoA-TMAA area include Baird's (*Berardius bairdii*), Cuvier's (*Ziphius cavirostris*), and Stejneger's (*Mesoplodon stejnegeri)* beaked whales; sperm whales (*Physeter macrocephalus*); killer whales (*Orcinus orca*); Pacific white-sided dolphins (*Lagenorhynchus obliquidens*); harbor porpoise (*Phocoena phocoena)*; and Dall's porpoise (*Phocoenoides dalli*). Additionally, northern right whale dolphins (*Lissodelphis borealis*), Risso's dolphins (*Grampus griseus*), false killer whales (*Pseudorca crassidens),* and short-finned pilot whales (*Globicephala macrorhynchus*) have been known to occur in the region sporadically (DoN 2006).

The full bandwidth data (194 kHz sampling rate) were used to calculate long-term spectral average (LTSA) plots with a temporal resolution (Δt) of 5 seconds and a frequency resolution (Δf) of 100 Hz using the Triton Software Package (Scripps Whale Acoustics Lab, La Jolla, California, USA). Data slices of 15 minutes in duration were visually and aurally inspected by experienced analysts for odontocete sounds.

Odontocete sounds are typically placed into three categories: echolocation clicks, burst pulses, and whistles. Echolocation clicks are broadband, impulsive signals that have peak frequencies in the 5–150 kHz range and aid in foraging and navigation. Burst-pulse signals are click trains, or rapidly repeated clicks with a very short inter-click interval (ICI), which often sound like a buzz or creak. Burst-pulse signals are thought to have both social and echolocation functions. Whistles are frequency-modulated (FM) signals that cover a wide frequency range from a few hundred Hz to many kHz (depending on species), have a longer duration (up to several seconds), and are known to serve a variety of functions, especially in social contexts.

The analysts logged species information whenever possible, using previously described species-specific features that allow acoustic encounters to be identified to the species level, as described below:

- **Beaked whales:**
  - Baird's beaked whale echolocation clicks have the lowest peak frequency of all documented beaked whales, with spectral peaks at 15, 30, and 50 kHz (Baumann-Pickering et al. 2013, Dawson et al. 1998). Clicks have a relatively long duration of about 0.5 milliseconds (ms), and ICI's around 200 ms (Baumann-Pickering et al. 2013).
  - Cuvier's beaked whale clicks are uniquely identified by an FM click with a peak frequency of 40 kHz and ICIs of over 300 ms (Baumann-Pickering et al. 2013).
  - Stejneger's beaked whale clicks are higher in frequency (peak frequency 50 kHz) but also have the characteristic beaked whale FM and long duration (0.4 ms). However, they are also characterized by relatively short ICIs for beaked whales, at about 90 ms (Baumann-Pickering et al. 2013).

- **Sperm whale:** Echolocation clicks produced by sperm whales contain energy primarily in the 2–20 kHz frequency band, with peak energy at 10–15 kHz (Møhl et al., 2003). Clicks are observed during foraging dives and are characterized by a metronomic ICI of approximately 1 second (Møhl et al., 2003). Sperm whale click trains can be readily identified in the LTSA plots.
- **Killer whale:** Killer whale pulsed calls are the best described and well documented of their call types, and serve well to differentiate them from other species. Pulsed calls have energy between 1 and 6 kHz, with high-frequency components occasionally reaching over 30 kHz. Duration is typically 0.5 to 1.5 second (Ford, 1987). Analysts used aural and visual detection of pulsed calls for killer whale encounter identification. Additionally, a high frequency modulated (HFM) downsweep (peak frequency 20-36 kHz) has been attributed to killer whales in the North Pacific, and so analysts also looked for and attributed these signals to killer whales (Simonis et al., 2012).
- **Risso's dolphin:** Risso's dolphin echolocation clicks have a unique band pattern observable in bouts of clicks on an LTSA. Peak energy bands are located at 22, 26, 30, and 39 kHz, with distinct notches at 27 and 36 kHz (Soldevilla et al. 2008). This peak and notch pattern is not as apparent when looking at individual clicks, but the LTSA shows the characteristic appearance of many hundreds of clicks used to identify Risso's dolphins for this report.
- **Pacific white-sided dolphin:** Pacific white-sided dolphins also have a unique banding pattern that is easily measured in the LTSA of a click bout. They can be differentiated from Risso's dolphins because the spectral peaks are located at 22.2, 26.6, 33.7, and 37.3 kHz. Notches occur at 24.5 and 29.7 kHz (Soldevilla et al. 2008).
- **Dall's and harbor porpoise:** Both harbor and Dall's porpoise echolocation clicks have peak energy (115 to 150 kHz; Kyhn et al. 2013) above the upper frequency limit of the glider's PAM system.

High-frequency sounds that were recorded and detected in the LTSA, but could not be classified to one of the above species, were identified as unidentified odontocetes, and were further described by peak frequency.

2.2.3 Mysticetes

The Gulf of Alaska (GoA) is inhabited—at least seasonally—by blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whales (*B. borealis*), North Pacific right whales (*Eubalaena japonica*), gray whales (*Eschrichtius robustus*), minke whales (*B. acutorostrata*), and humpback whales (*Megaptera novaeangliae*). To analyze the collected data efficiently for these species, the broadband data were low-pass filtered and down-sampled and then divided into two datasets: one "low-frequency dataset" with a sampling rate of 1,000 Hz (15–500 Hz effective band) and a 10-kHz (15 Hz to 5 kHz) "mid-frequency" dataset. From these data, analysts produced LTSA plots with Δt of 1 second and Δf of 1 Hz (1-kHz data) and Δt of 2 seconds and Δf of 10 Hz (10-kHz data) via the Triton Software Package. Both LTSAs were coarsely screened visually and aurally for bioacoustic activity and general quality assurance. The actual logging of acoustic encounters was done in Raven Pro (Bioacoustics Research Program, Cornell University, Ithaca, New York, USA). Based on experience with previous glider datasets (e.g., Klinck et al. 2015a), analysts determined that it is most efficient to import the two datasets into Raven Pro, time align them, and examine them simultaneously for the species of interest (**Figure 4**). This provided sufficient detail in all frequency bands, but also enabled us to clearly identify sounds that had both very low-frequency mysticete components (i.e., 50 Hz) and higher frequency mysticete components (> 1,000 Hz), such as North Pacific minke whale boings. The low-frequency data were examined for western and central North Pacific blue whale song notes (Stafford et al. 1999, 2011), fin whale 20-Hz song notes (Thompson et al. 1992, Watkins 1981), and 40-Hz calls (Širović et al. 2013), the down-sweeping sounds from sei whales (Baumgartner et al. 2008, Rankin and Barlow 2007), right whale up-calls and gunshots (McDonald and Moore 2002) and gray whale M3 moans (Crane and Lashkari 1996). The mid-frequency data were primarily analyzed for humpback whale song and social sounds (Payne and McVay 1971, Stimpert and Au 2008), and minke whale boings (Rankin and Barlow 2005).

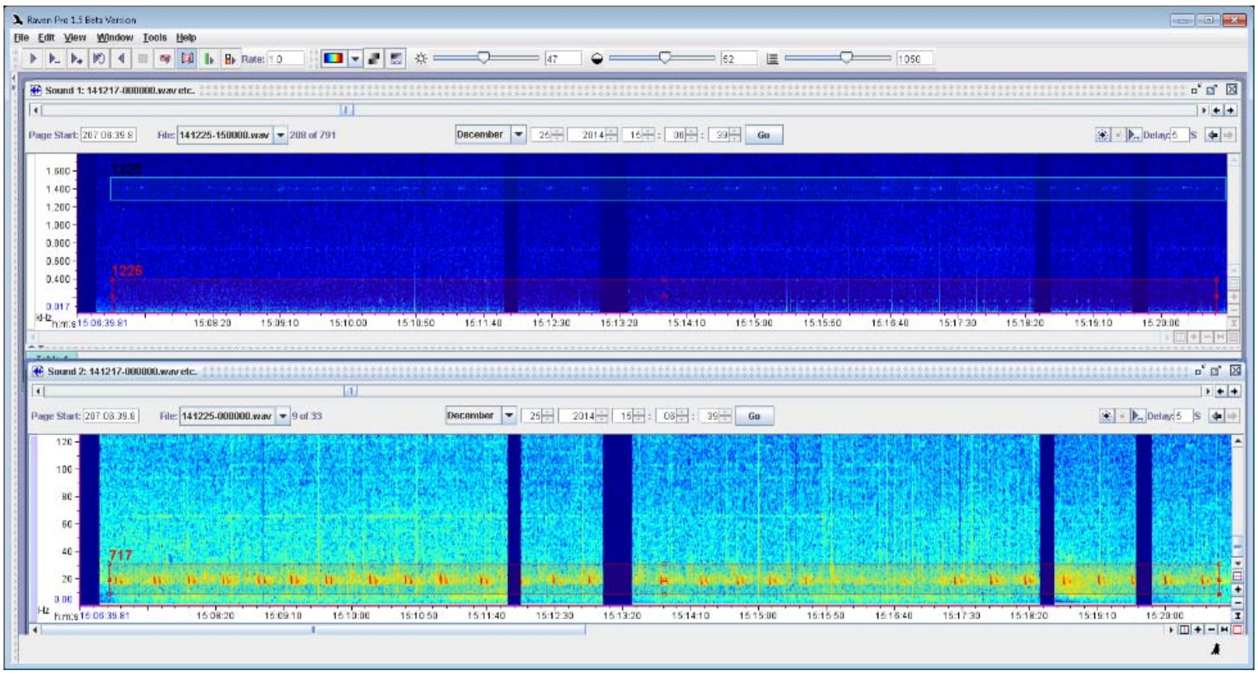

Figure 4: Example of time-aligned spectra (recorded during the Hawaii Range Complex glider survey) displayed in the software Raven Pro. The upper spectrogram shows the 10-kHz down-sampled data and was used to identify mid-frequency vocalizations from minke whales (light blue box) and humpback whales (red box). The lower spectrogram shows the 1-kHz data and was used to identify calls from fin whales (red box) and blue whales, and provided context when identifying the mid-frequency calls.

2.2.4 Navy Sonar

The mid-frequency LTSA plots were also screened visually and aurally for occurrences of all types of military active sonar, including active sonobuoys and low-frequency and mid-frequency sonar signals.

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3. Results

Seaglider™ SG203 was deployed on 11 July 2015, at approximately 02:15 Coordinated Universal Time (UTC), 200 km east-southeast of Homer, Alaska (N59° 06.97′, W147° 33.70′) using a small charter vessel. The Seaglider™ started to capture sound immediately after deployment, near-continuously in the 25 to 1,000-m depth range. SG203 surveyed the shelf break area in southwesterly direction towards Kodiak Island, Alaska. The acoustic survey was completed on 11 August 2015, 14:56 UTC (N57° 05.88′, W150° 48.86′). After a 10-day transit, the instrument was recovered at location N57° 12.28′, W151° 02.86′ on 21 August 2015, at approximately 14:40 UTC.

Table 1 and **Figure 5** provide a summary of the glider survey. A total of 800 gigabytes of acoustics data was recorded during the survey (11 July to 11 August 2015). The gliders also collected 36 megabytes of environmental/glider performance data. SG203 conducted 170 dives with the PAM system active. The median recording time per dive was 4.0 hours (standard deviation [SD]=0.8 hour). The glider recorded a total of 680 hours (approximately 28 days) of acoustic data over a 42-day period. All dates/times reported are in UTC.

Table 1: Summary of the glider survey.

Glider	# of dives	Distance over ground	Distance through water
SG203	250 (170)	975 (744) km	1,212 (890) km

Note: Values in parentheses indicate ‘PAM active’ statistics.
Key: km = kilometer(s)

Note that the glider did not record acoustic data during a few dives. The cause for this data loss was associated with PAM system “hang ups” (the PAM system stopped processing incoming acoustic data; likely associated with a firmware issue). This problem was observed and documented in the previous MIRC deployment (Klinck et al. 2015a); therefore, a script was written that automatically rebooted the PAM system after each dive. This significantly reduced acoustic data loss caused by this problem. A permanent fix will require additional engineering and bench testing.

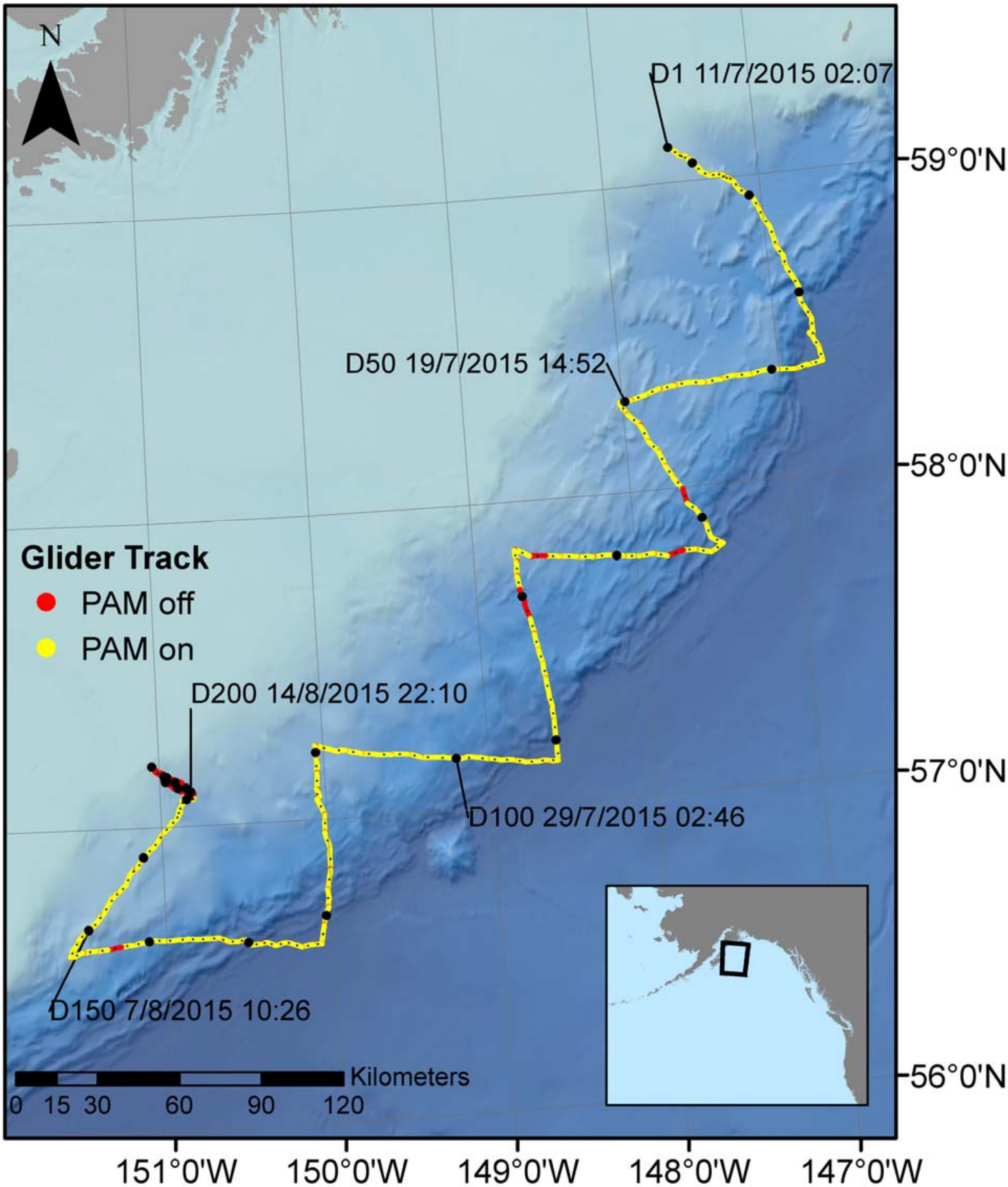

Figure 5: SG203 track line for the period 11 July to 11 August 2015. Each black dot (with every tenth one larger) on the track line indicates the midpoint location of a glider dive. Labels indicate dive number (e.g., D10 for dive no. 10) and date (format: dd/mm/yy UTC). Red sections indicate that the PAM system was switched off. The yellow segments indicate that the PAM system was active.

3.1 Environmental Data

The results of the environmental data analysis are summarized in **Figure 6** through **Figure 8**. White areas in the plots indicate no data and are a result of dives shallower than 1,000 m (e.g., bathymetry-limited dives). The sea surface temperature (**Figure 6**) varied little geographically and temporally and was approximately 13 degrees Celsius. The profiles indicated a temperature gradient of approximately 7 degrees Celsius in the 0 to 100-m depth range.

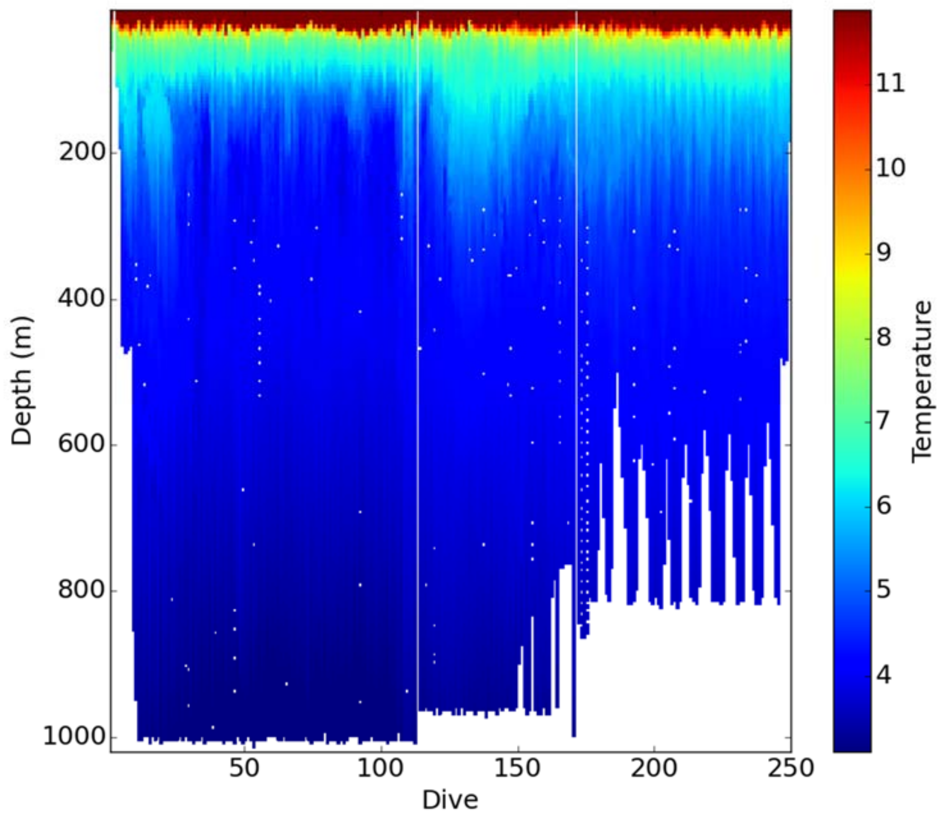

Figure 6: Temperature profiles recorded with SG203.

The sound-speed profile (**Figure 7**) showed that the depth of the sound channel varied in the survey area. For the majority of the survey, the sound channel axis was located at approximately 375 m. However, during dives 45 through 120 the sound channel axis was found to be higher up in the water column at around 225 m. A surface duct was present in the upper - 10 to 20-m depth range. The glider operated primarily in the sound channel and signal propagation conditions were therefore excellent for detecting biological sounds; however, estimating the absolute detection ranges for the various signals was not possible given the scope of this effort and the missing details on source levels, etc.

The depth-averaged ocean currents in the survey area were predominantly in a southwesterly direction (median direction for the entire survey was 211°; **Figure 8**). The median current speed during this survey was measured as 14.1 cm/s (SD 8.8 cm/s).

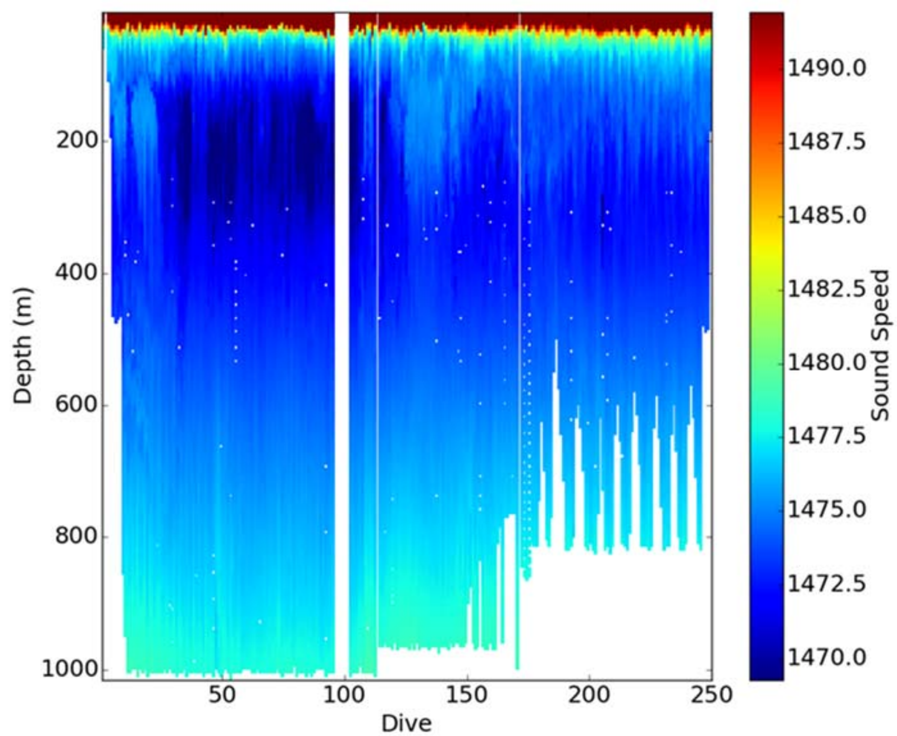

Figure 7: Sound-speed profiles recorded with SG203.

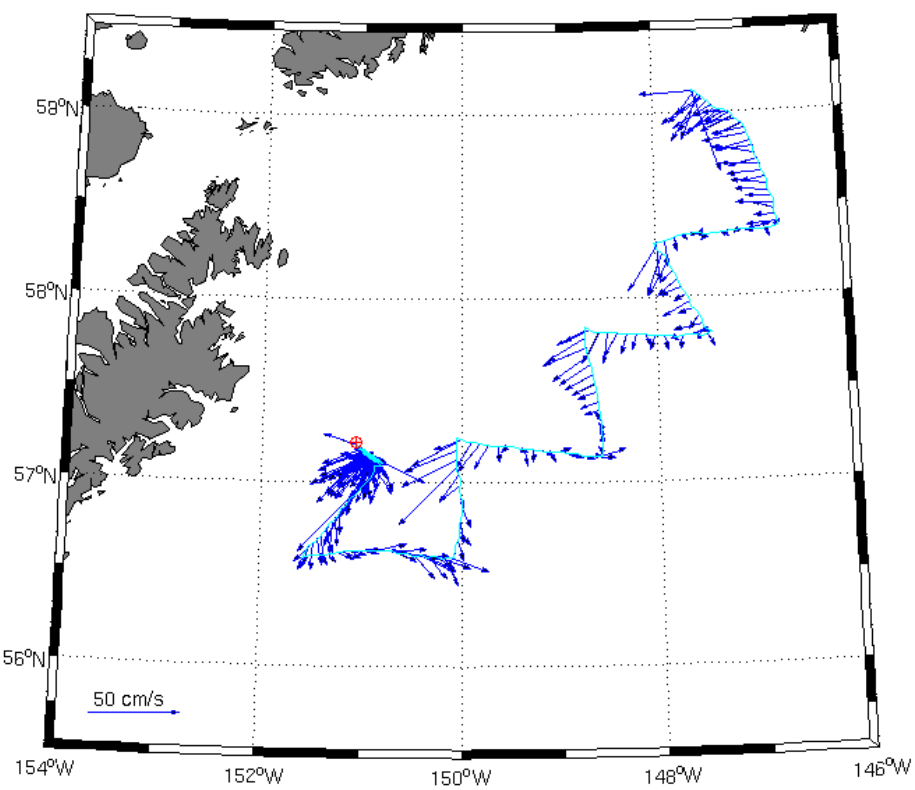

Figure 8: Depth-averaged currents measured with SG203.

3.2 Odontocetes

Details on all odontocete detections can be found in **Appendix A**.

Beaked whales

Beaked whale-like signals were detected in 12 different encounters, on 12 different dives. These signals had peak energy between 60 and 70 kHz, moderately long click durations (250 to 500 microseconds) and ICIs (130 to 600 ms, with an average of 280 ms), and some clicks had messy, but slight upsweeps characteristic of beaked whales (**Figure 9**). Although these clicks did not fit perfectly to vocalizations previously attributed to beaked whales in this region (Baumann-Pickering et al. 2013), after consulting with experts in beaked whale acoustics, we classified them as possible Stejneger's beaked whales (personal communication, Simone Baumann-Pickering).

Most of the possible Stejneger's Beaked Whale detections occurred near the end of the survey (**Figure 10**).

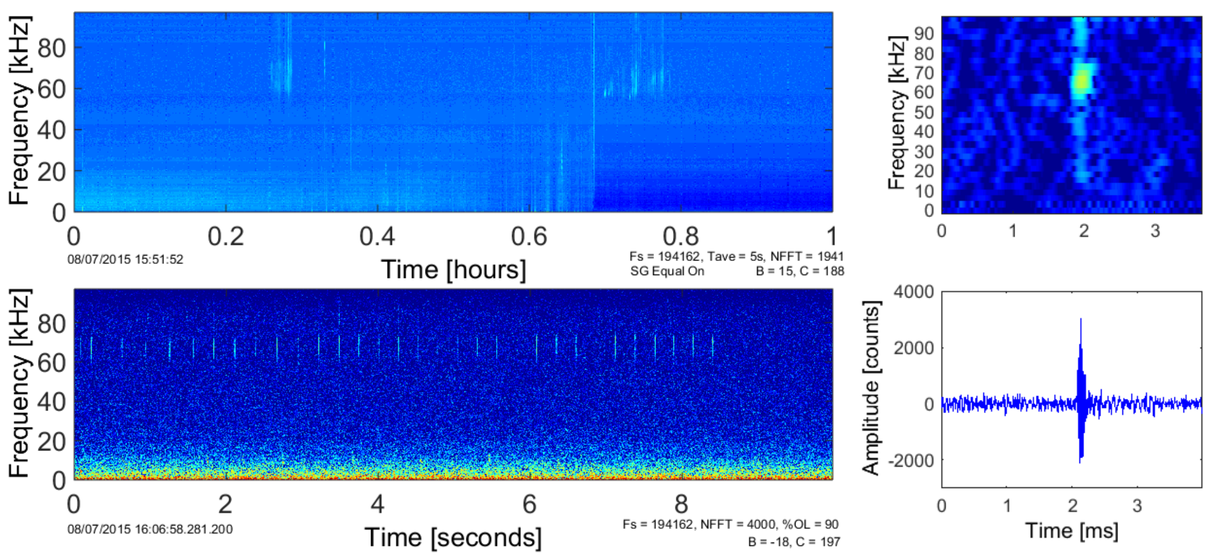

Figure 9. LTSA (top left) and spectrogram (bottom left, right) examples of the possible Stejneger's beaked whale clicks recorded by SG203 on 7 August 2015.

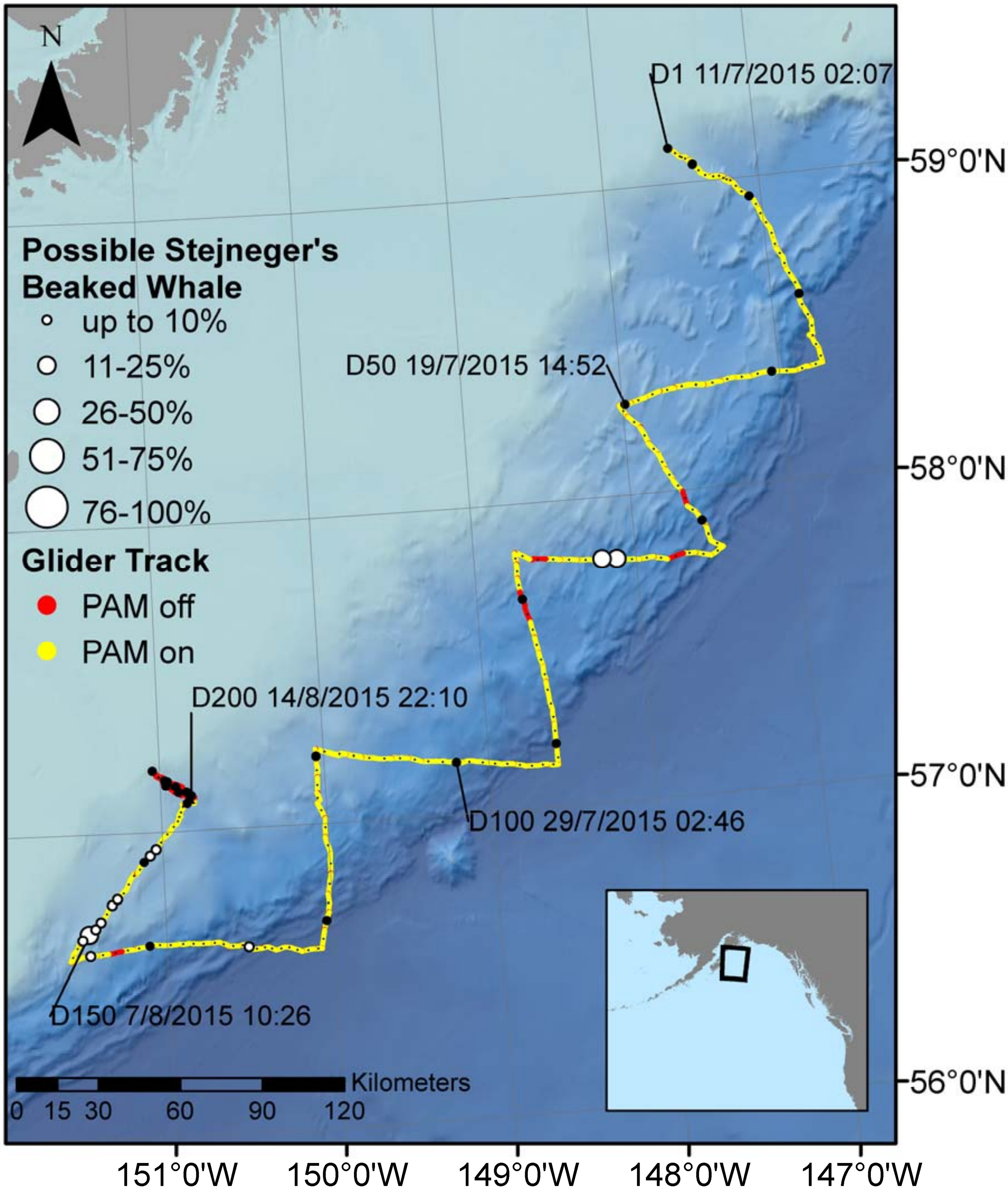

Figure 10. SG203 recorded possible Stejneger's beaked whale clicks. The circle size indicates percentage of recording time per dive with target signals.

Sperm whales

Sperm whales were the most commonly recorded of all marine mammal species, recorded on 147 dives, for a total of over 480 hours of sperm whale vocalizations. Both echolocation clicks and creaks were recorded (**Figure 11**). Echolocation clicks were recorded almost continuously, except for three short gaps (dives 40–43, 85–91, and 153–156; **Figure 12**). Many of the dives contained sperm whale vocalizations for 100 percent of the recording time.

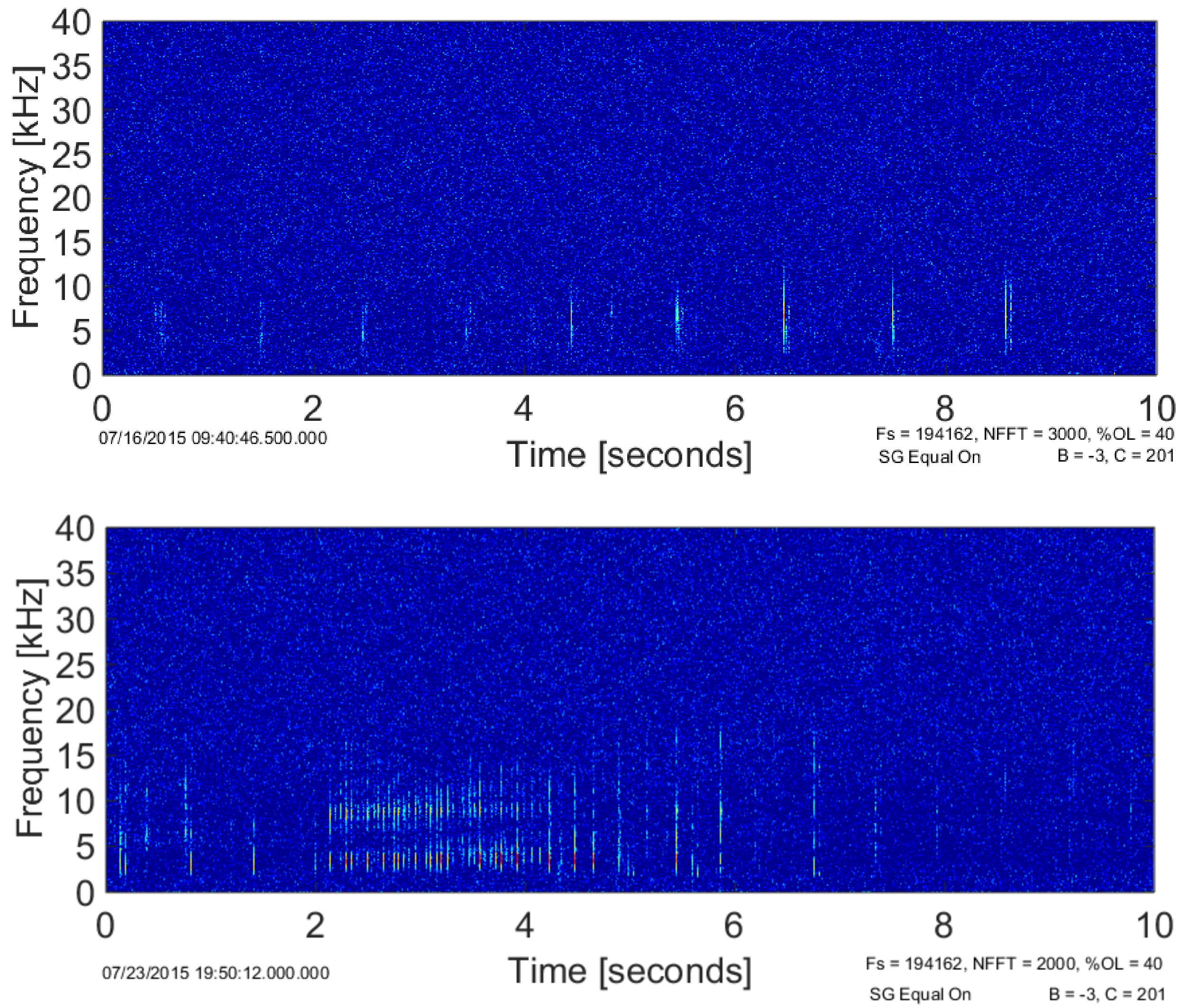

Figure 11. Sperm whale clicks (top panel) and creak (bottom panel), recorded by SG203 on 16 July and 23 July 2015, respectively.

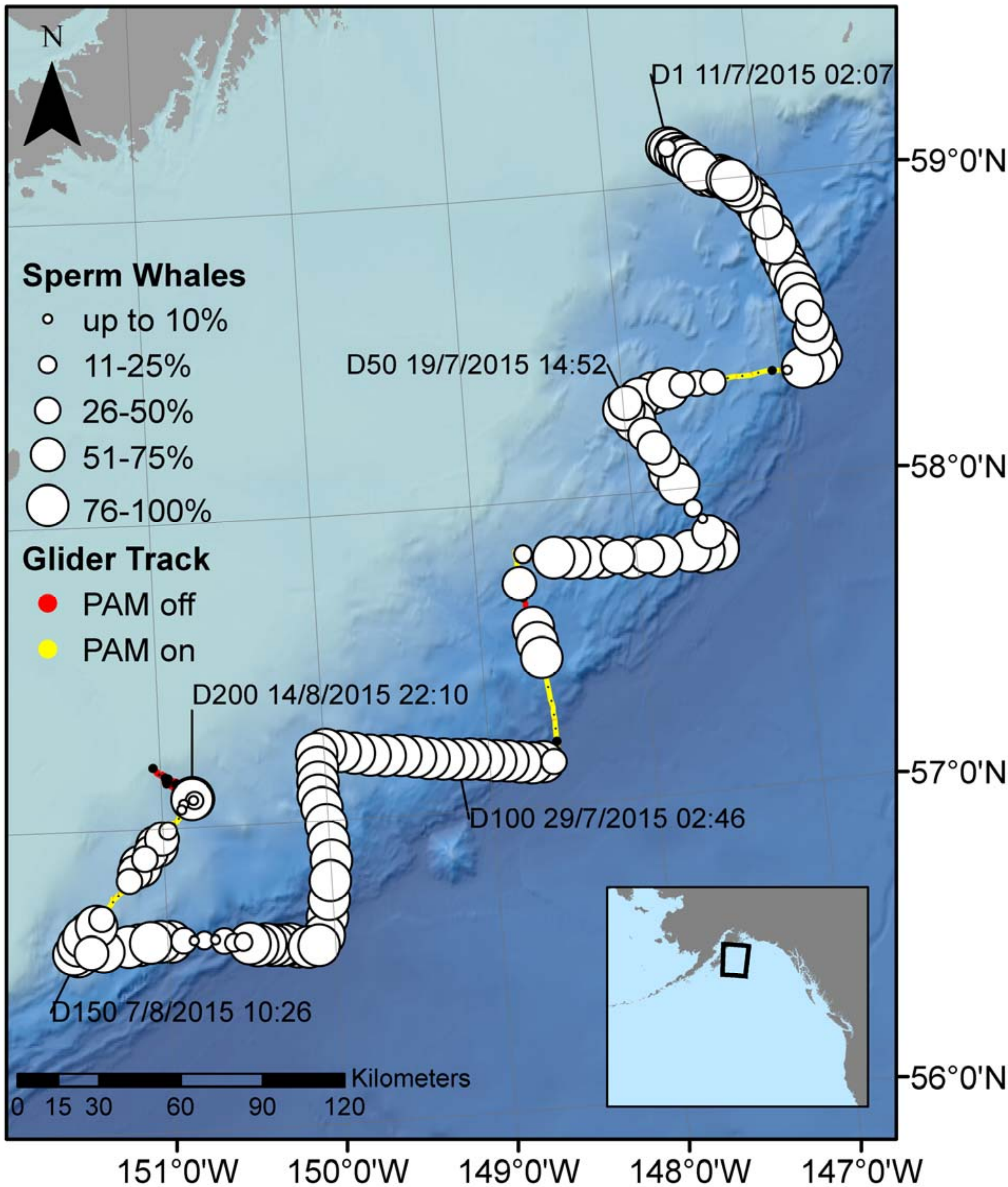

Figure 12. SG203 sperm whale clicks. The circle size indicates percentage of recording time per dive with target signals.

Killer whales

Killer whale whistles (including HFM whistles), burst pulses, and echolocation clicks were detected in both the high-frequency and mid-frequency data (**Figure 13**). Sounds detected in both analyses were merged into one killer whale category, resulting in 23 dives containing killer whale recordings. There was no discernable pattern of killer whale recordings along the survey track (**Figure 14**), as they were recorded when the glider was over both deep and shallow water.

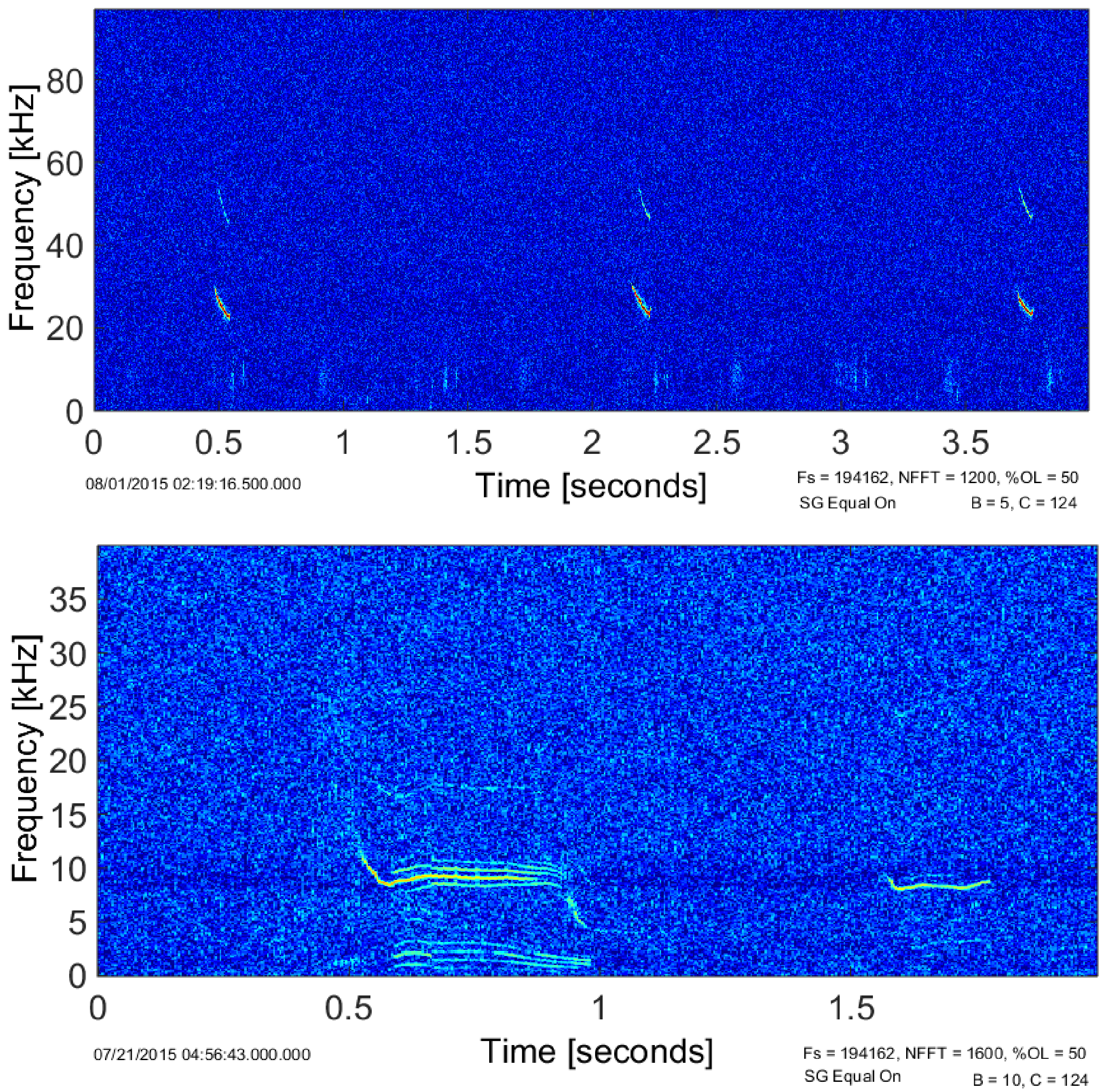

Figure 13. Example of killer whale HFM whistles (top panel) and pulsed calls (bottom panel), recorded by SG203 on 1 August 2015 and 21 July 2015, respectively.

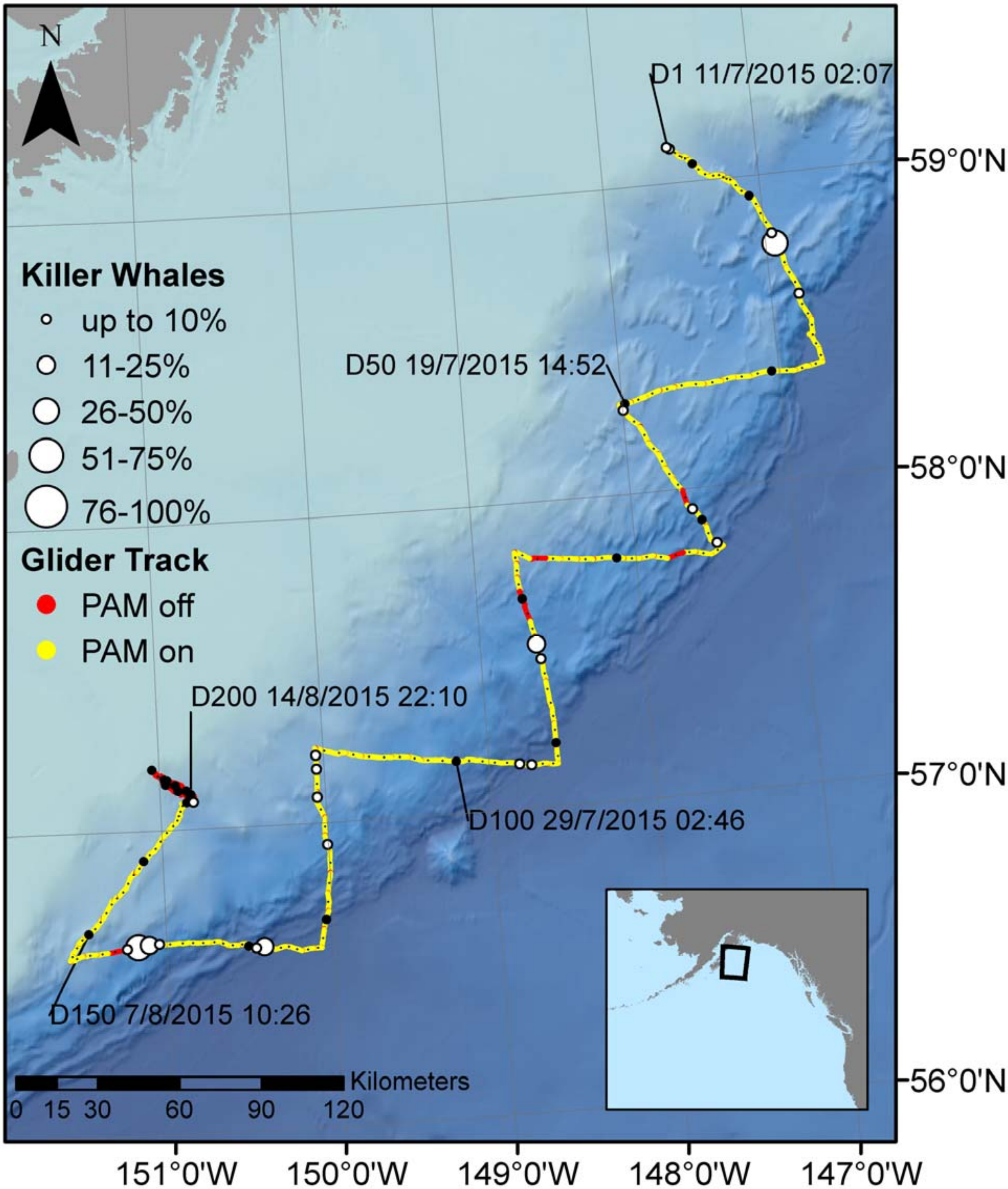

Figure 14. SG203 dives with killer whale sounds. The circle size indicates percentage of recording time per dive with target signals.

Risso's dolphins

No Risso's dolphins were recorded during this glider survey.

Pacific White-Sided Dolphins

A single, 5-minute series of Pacific white-sided dolphin sounds was recorded 31 July 2015, during dive 11 (**Figure 15**). This occurred when the glider was along the middle of the shelf break, over approximately 2,200 m of water (**Figure 16**).

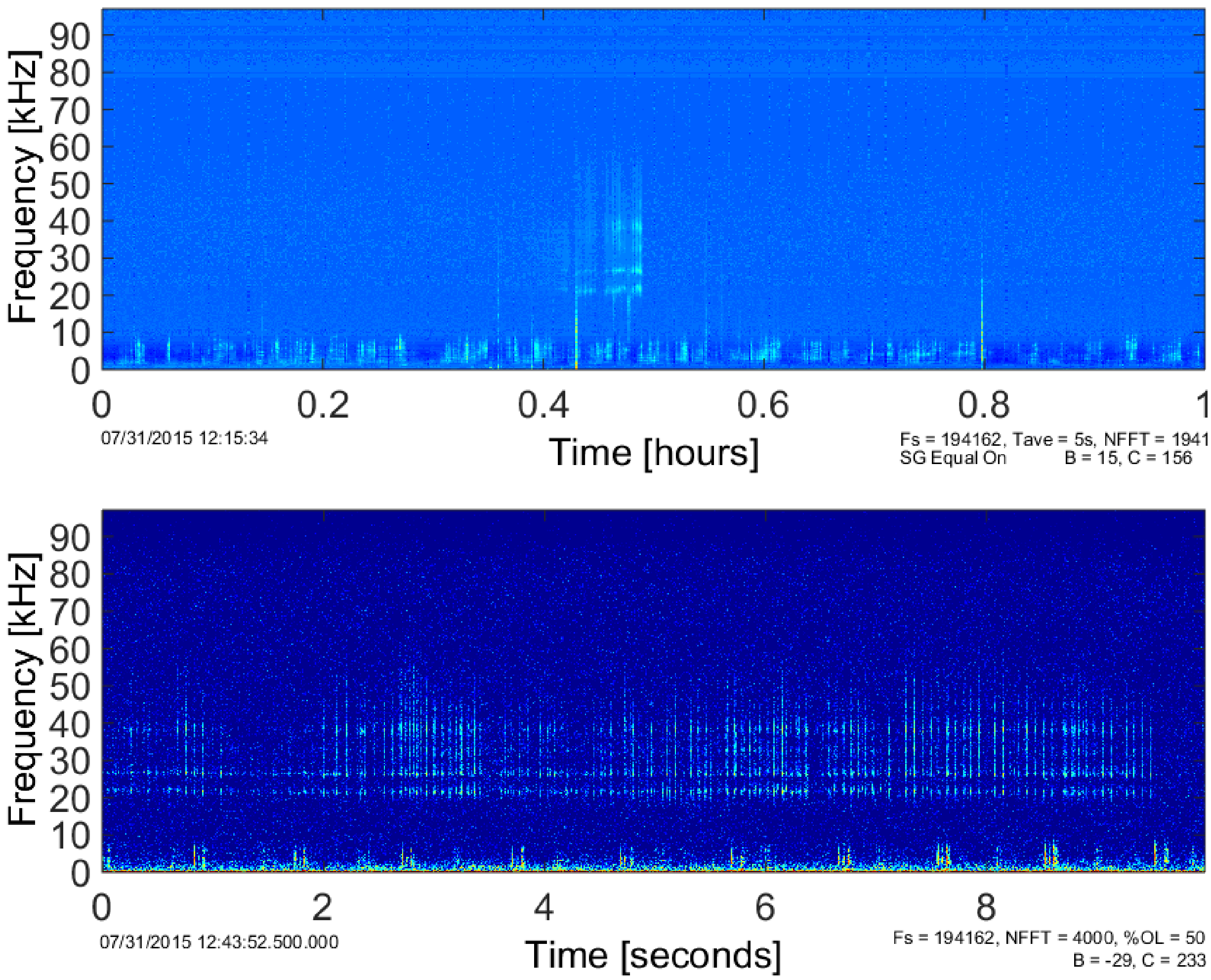

Figure 15. Example of Pacific white-sided dolphin clicks recorded by SG203 on 31 July 2015. The LTSA (top panel) as well as the spectrogram (bottom panel) both show the species-specific distinct banding pattern, with peak energy at 22 and 27 kHz. This series overlaps sperm whale clicks, which can be seen below 10 kHz in both the LTSA and spectrogram.

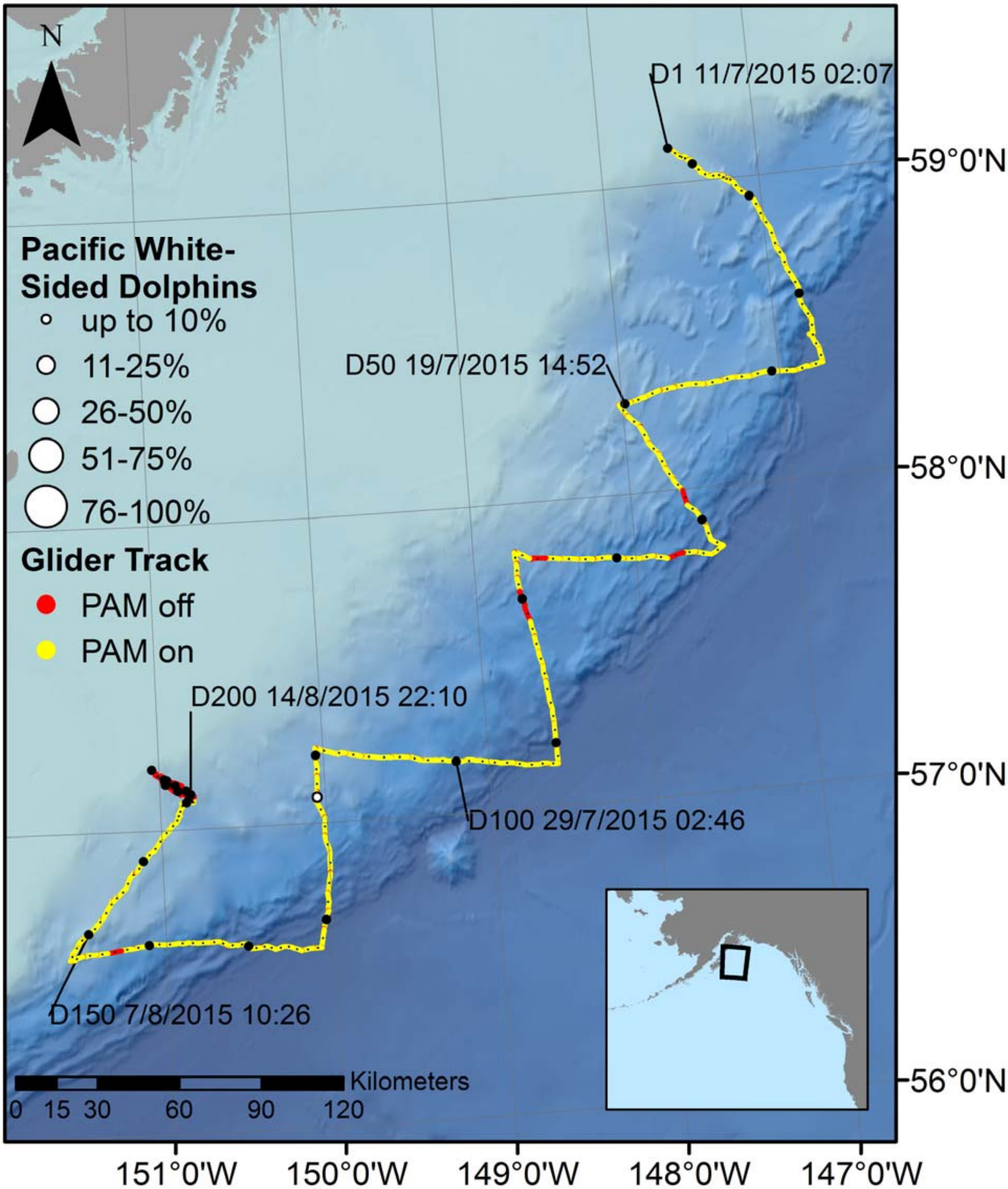

Figure 16. SG203 dives with Pacific white-sided dolphin clicks. The circle size indicates percentage of recording time per dive with target signals.

Unidentified odontocetes

SG203 recorded two series of what we categorized as an unidentified mid-frequency (MF) click. These clicks had peak energy between 20 and 28 kHz, with energy up to and over 60 kHz, and a short duration and ICI (**Figure 17**). They were recorded on dives 38 and 43 (**Figure 18**). The glider was near the edge of the shelf break or over very deep water for these two dives, in water depths of 2,700 to 4,700 m.

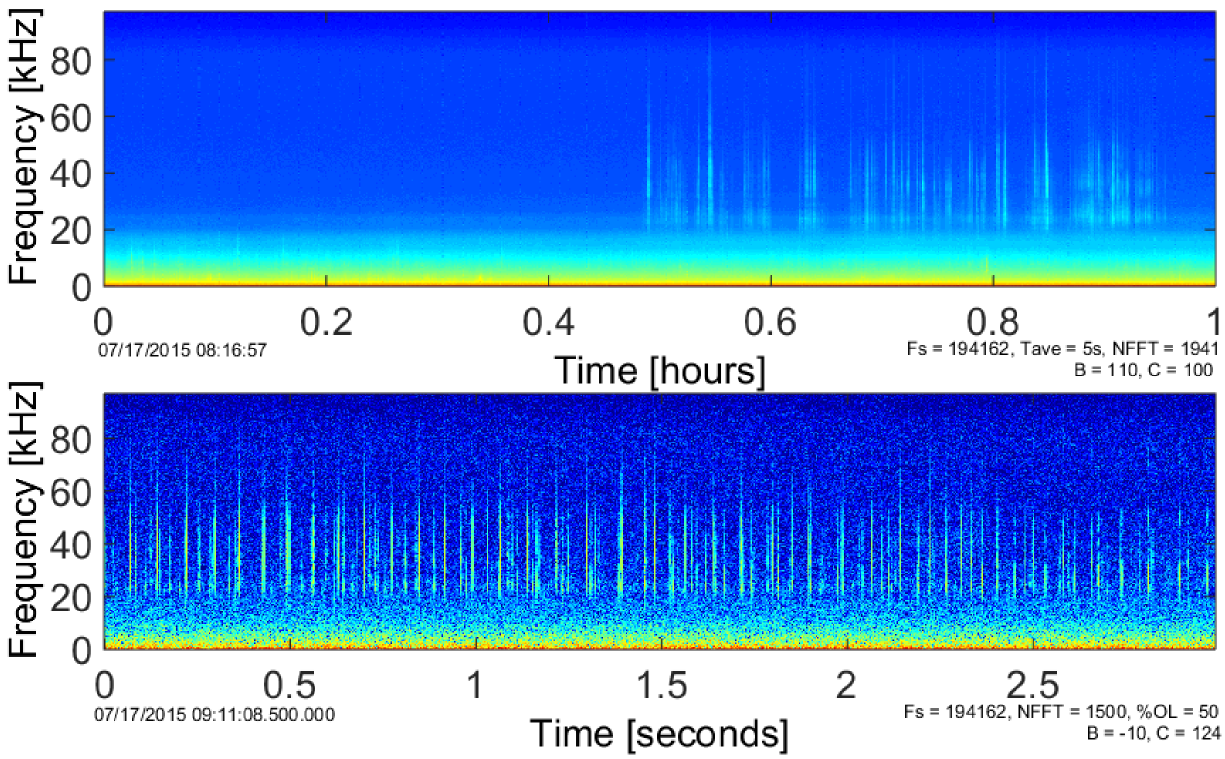

Figure 17. Example LTSA (top panel) and spectrogram (bottom panel) of unidentified odontocetes MF clicks recorded by SG203 on 17 July 2015.

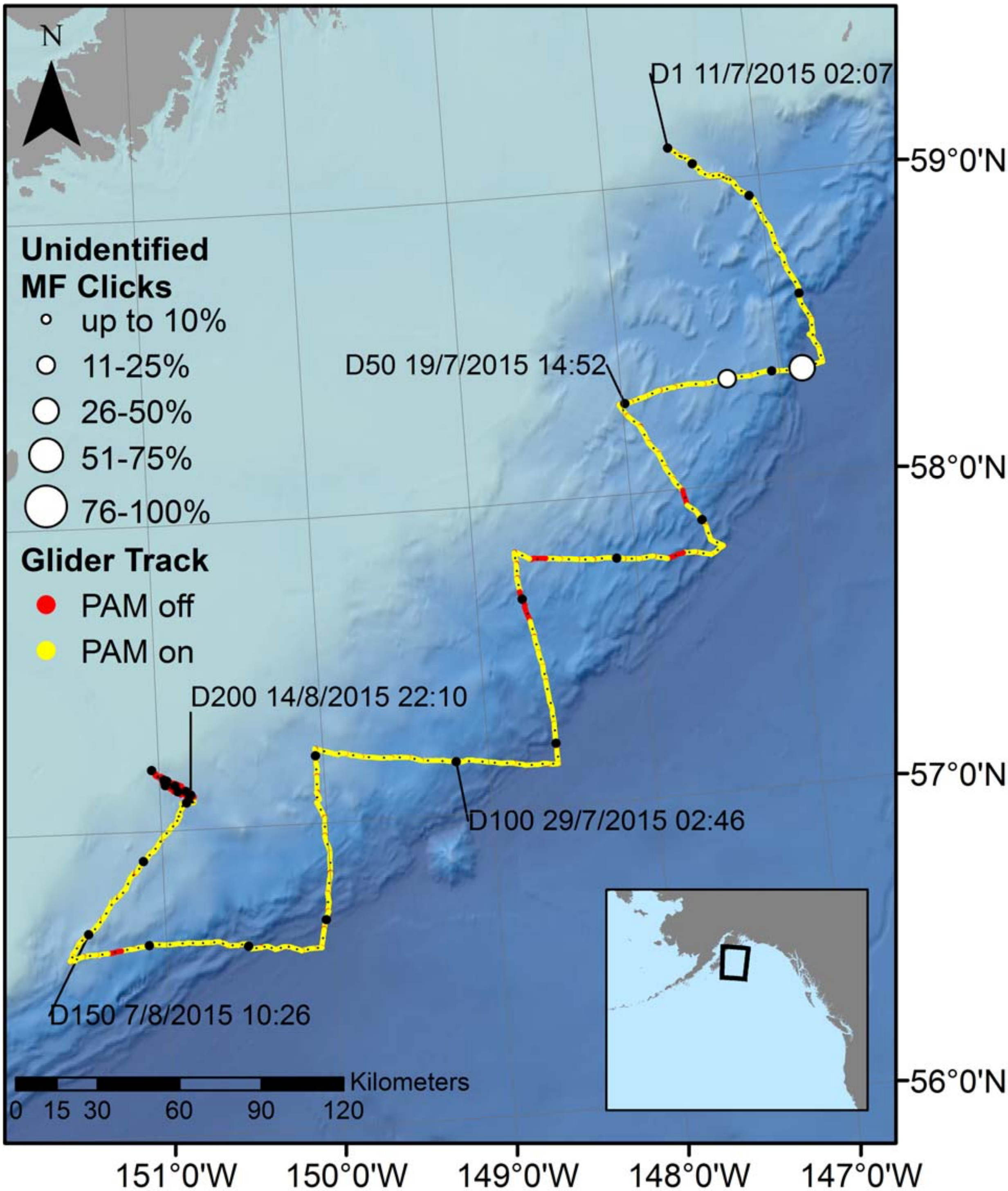

Figure 18. SG203 recorded unidentified MF clicks. The circle size indicates percentage of recording time per dive with target signals.

3.3 Mysticetes

Screening of the low- and mid-frequency data from SG203 revealed vocalizations from at least two species (blue and fin whales) of mysticetes. Analysts did not detect any calls from right, gray, humpback, minke, or gray whales. Additional details on all mysticete detections can be found in **Appendix A.**

Blue whales

The most commonly recorded low-frequency sound was a series of downsweeps that swept from around 60 Hz down to around 30 Hz over 2 to 5 seconds (**Figure 19**). These were recorded throughout the survey (**Figure 20**). Individual calls were highly variable, and sometimes were slightly convex in shape. Others collecting acoustic data in the area have identified these as blue whale D calls (Debich et al. 2014). The glider did not record any northeastern Pacific B calls nor any western Pacific tonal calls.

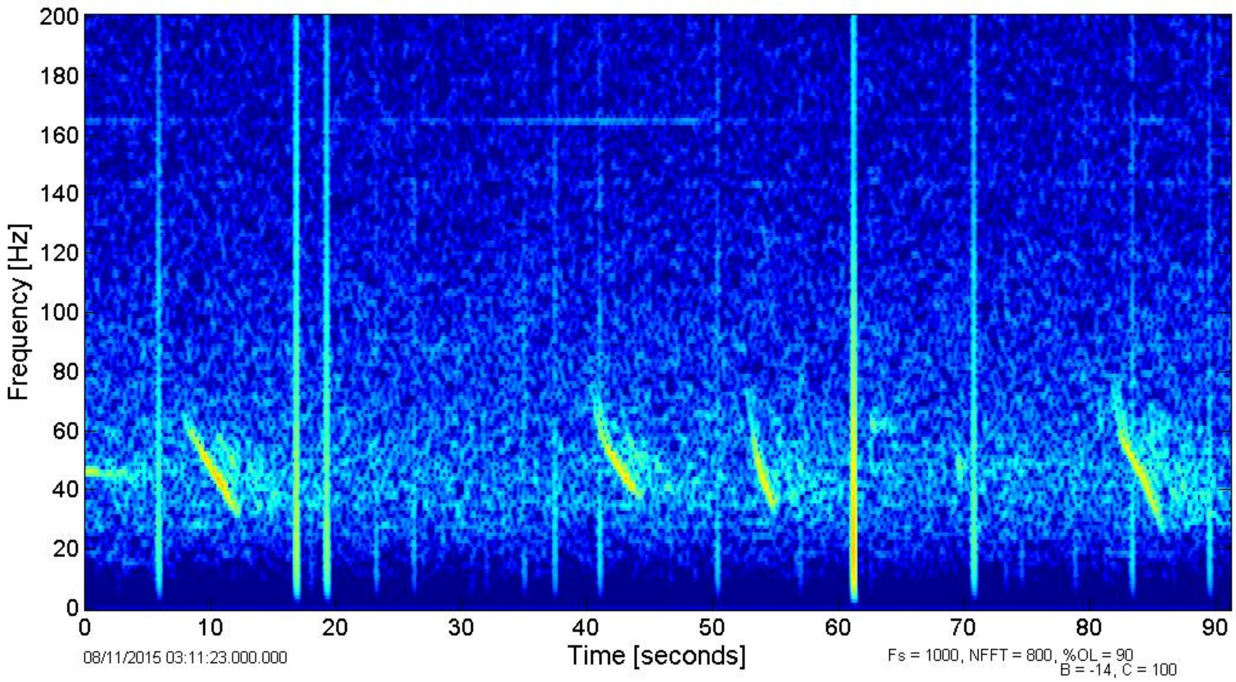

Figure 19. Example of blue whale D calls recorded by SG203 on 11 August 2015.

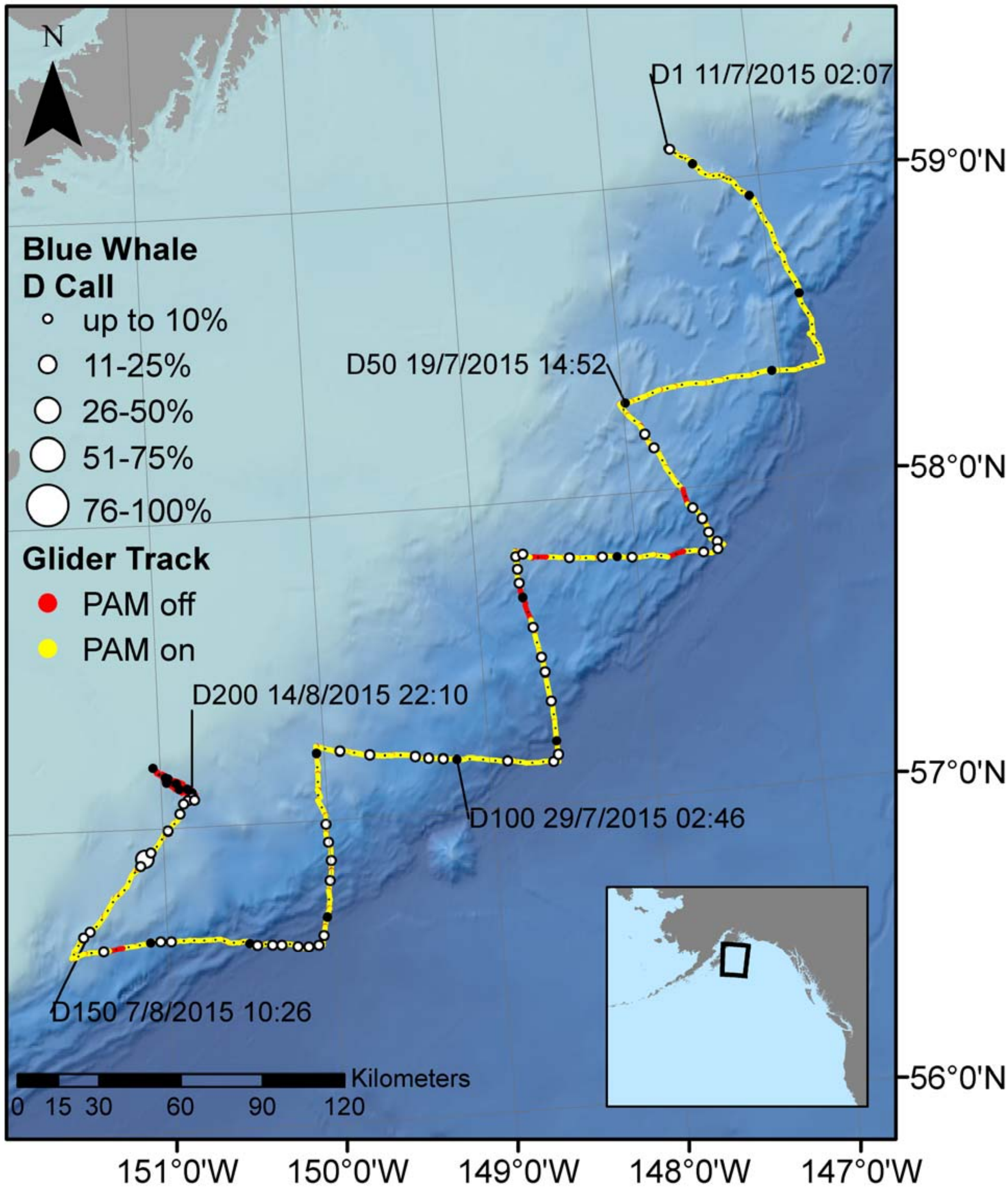

Figure 20. SG203 dives with recorded blue whale D calls. The circle size indicates percentage of recording time per dive with target signals.

Fin whales

The classic 20-Hz pulse calls produced by fin whales (**Figure 21**) were recorded only once (20 July 2015) on the shelf break (**Figure 22**). In addition, very short calls sweeping from 80 Hz down to 40 Hz over 1 second (**Figure 23**), identified by Širović et al. (2013) as 40-Hz fin whale calls, were recorded throughout the survey on both the shelf break and slope (**Figure 24).**

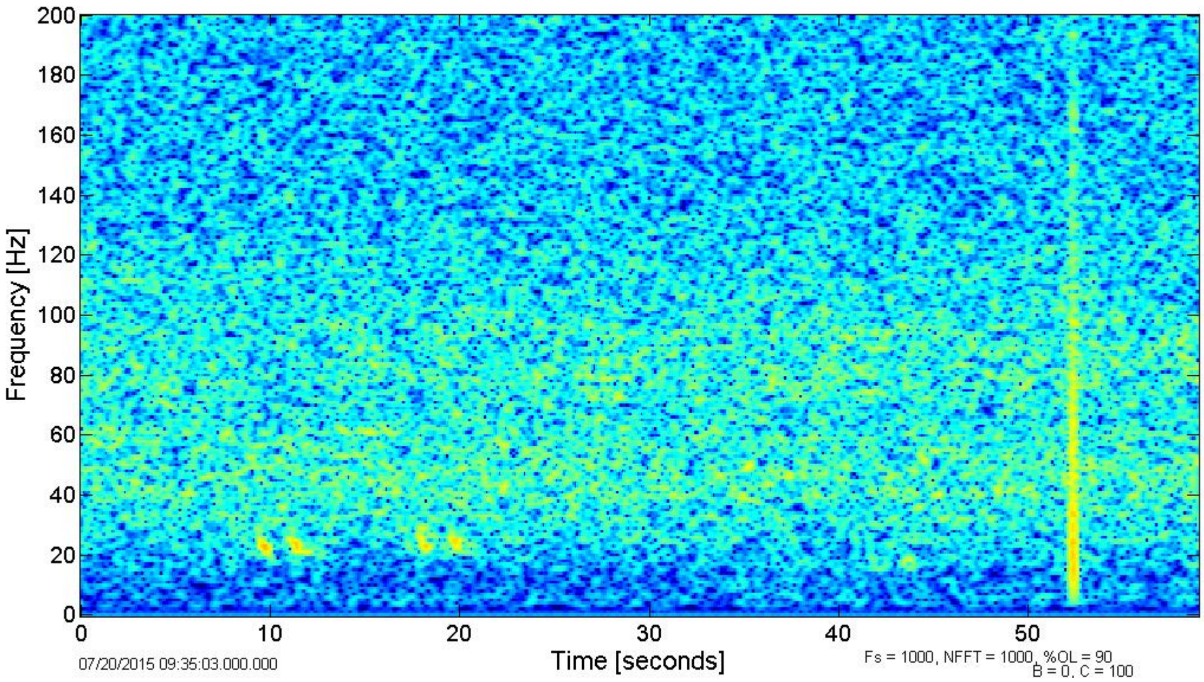

Figure 21: A series of low-frequency 20-Hz calls from a fin whale recorded by SG203 on 20 July 2015.

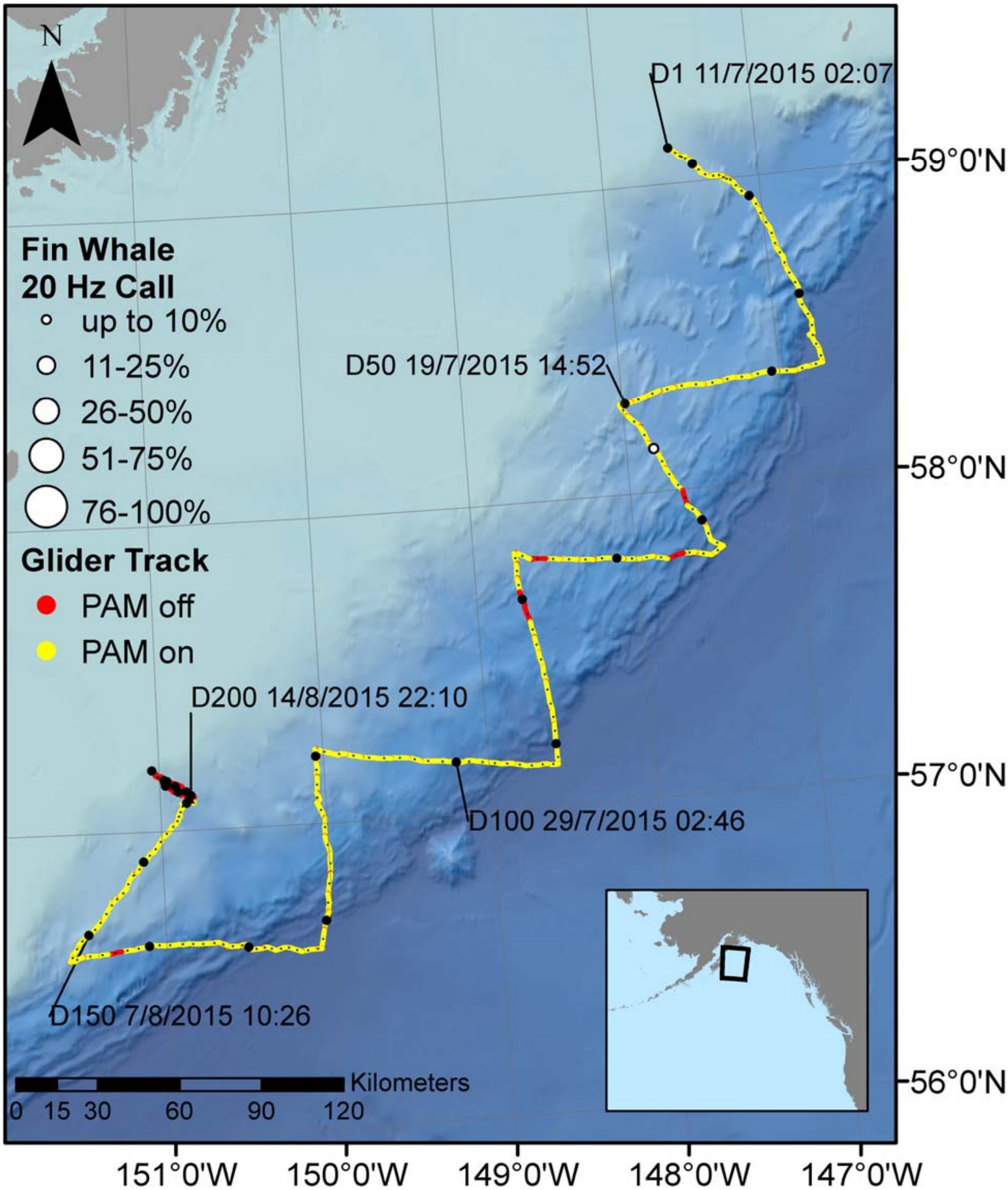

Figure 22: Location of SG203 dive where a single 10-second series of 20-Hz fin whale calls was recorded (white circle). The circle size indicates percentage of recording time per dive with target signals.

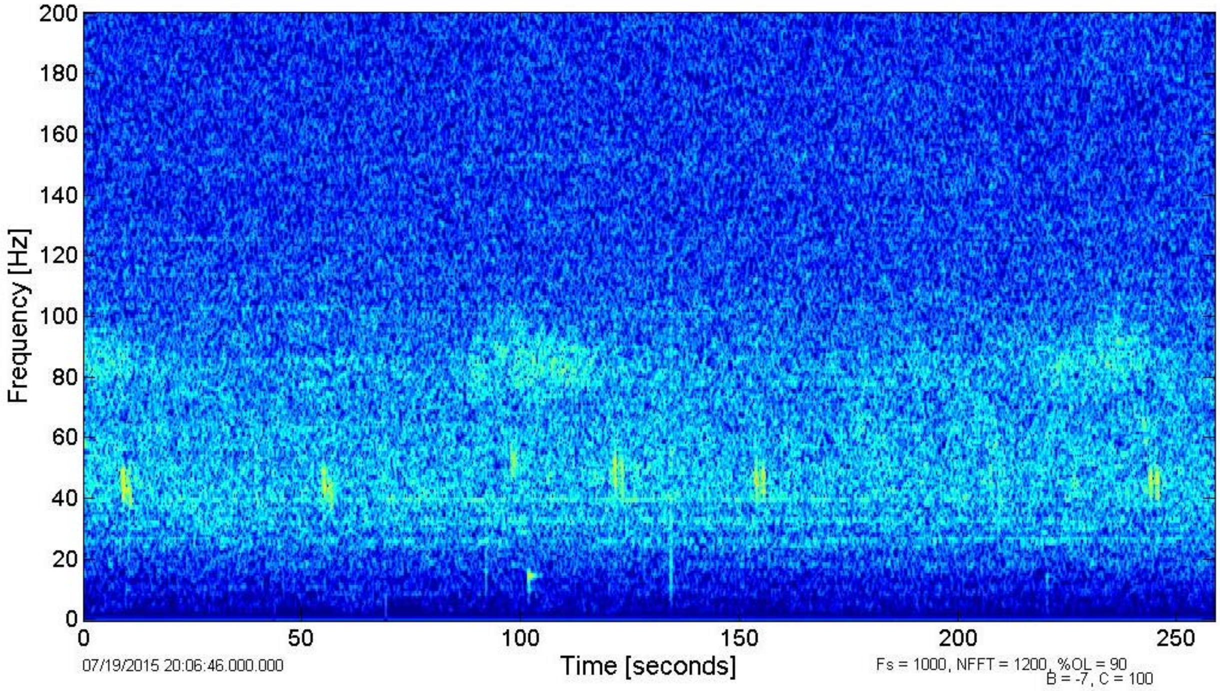

Figure 23: A series of low-frequency 40-Hz calls from a fin whale recorded by SG203 on 19 July 2015.

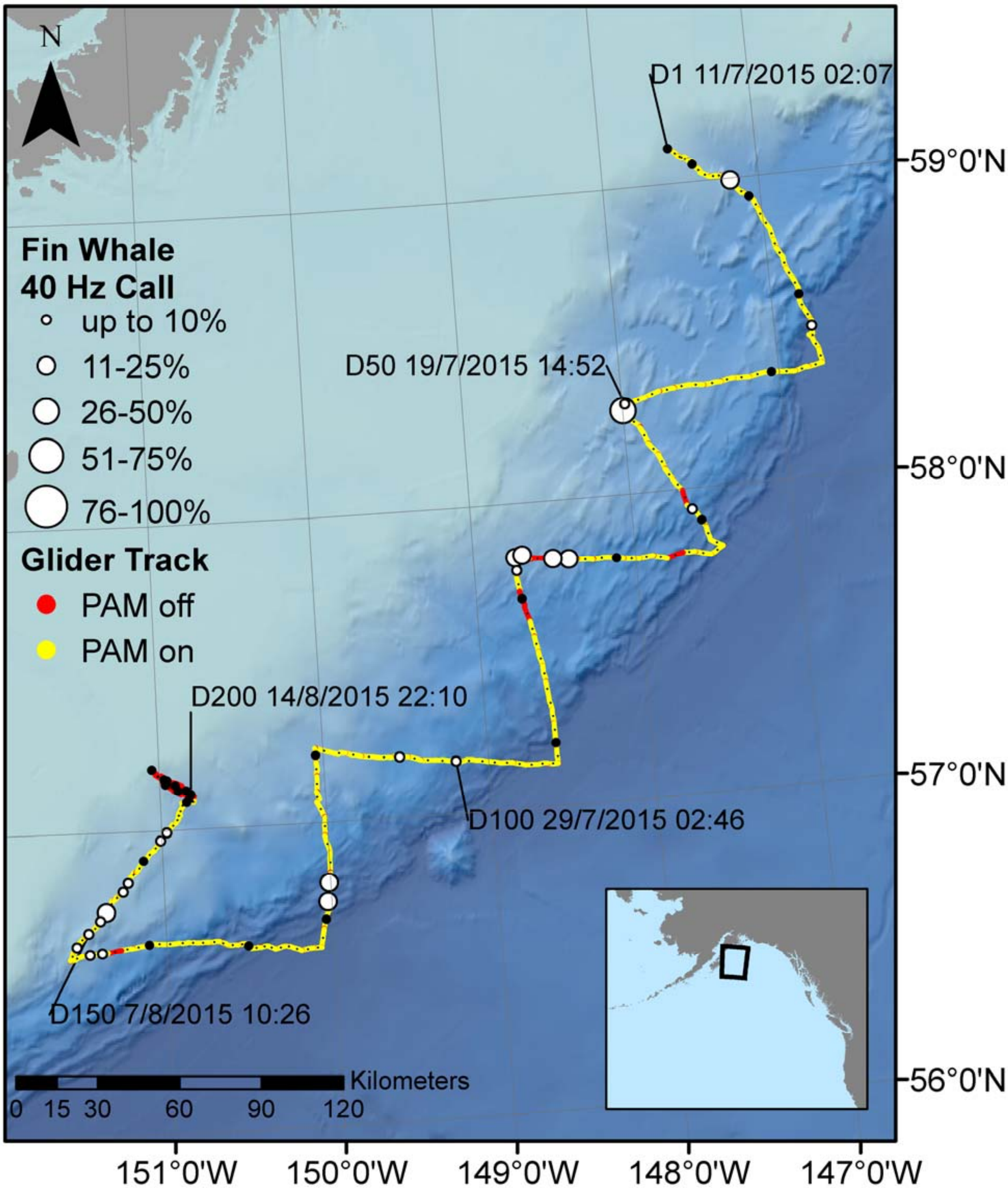

Figure 24: Location of dives where fin whale 40-Hz calls were recorded during summer 2015 SG203 survey. The circle size indicates percentage of recording time per dive with target signals.

Possible sei whales

In addition to the downsweeps reported above, the glider also recorded downsweeps that had characteristics similar to those reported to be from sei whales (see Rankin and Barlow 2007). Most of these calls began at around 100 Hz and swept down to 30 Hz over an approximate 4-second duration (**Figure 25**) and often had harmonics. These calls were recorded throughout the entire glider survey (**Figure 26**).

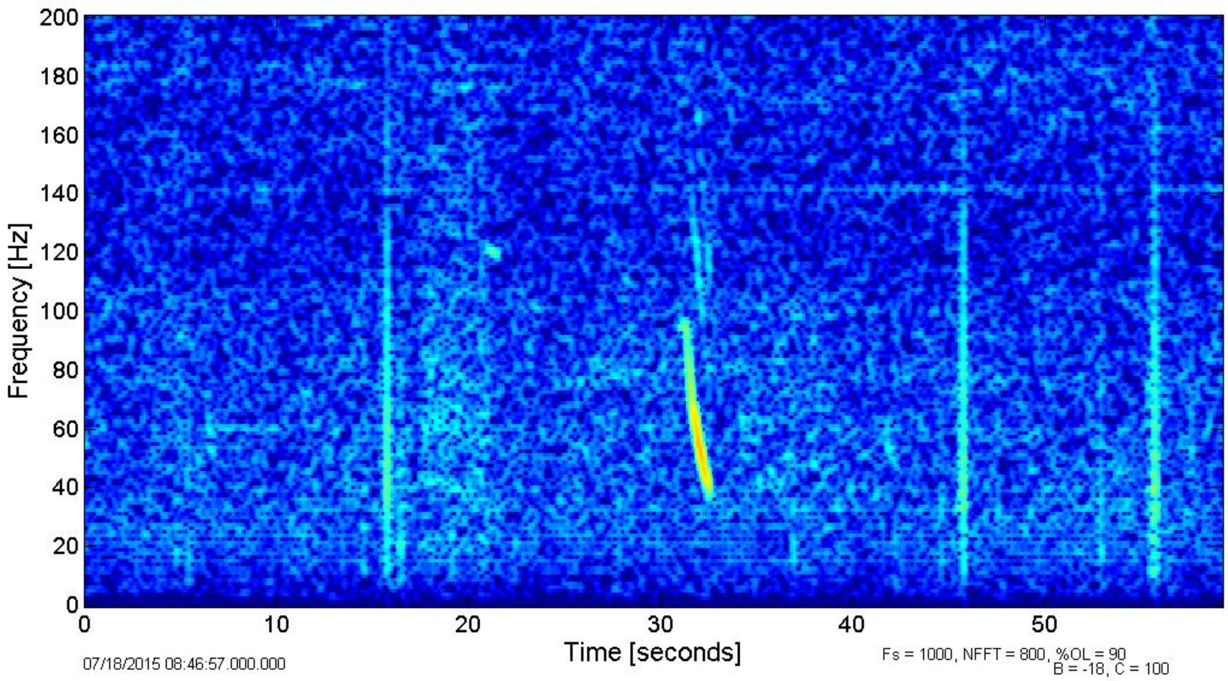

Figure 25. Example of possible sei whale downsweep recorded by SG203 on 18 July 2015.

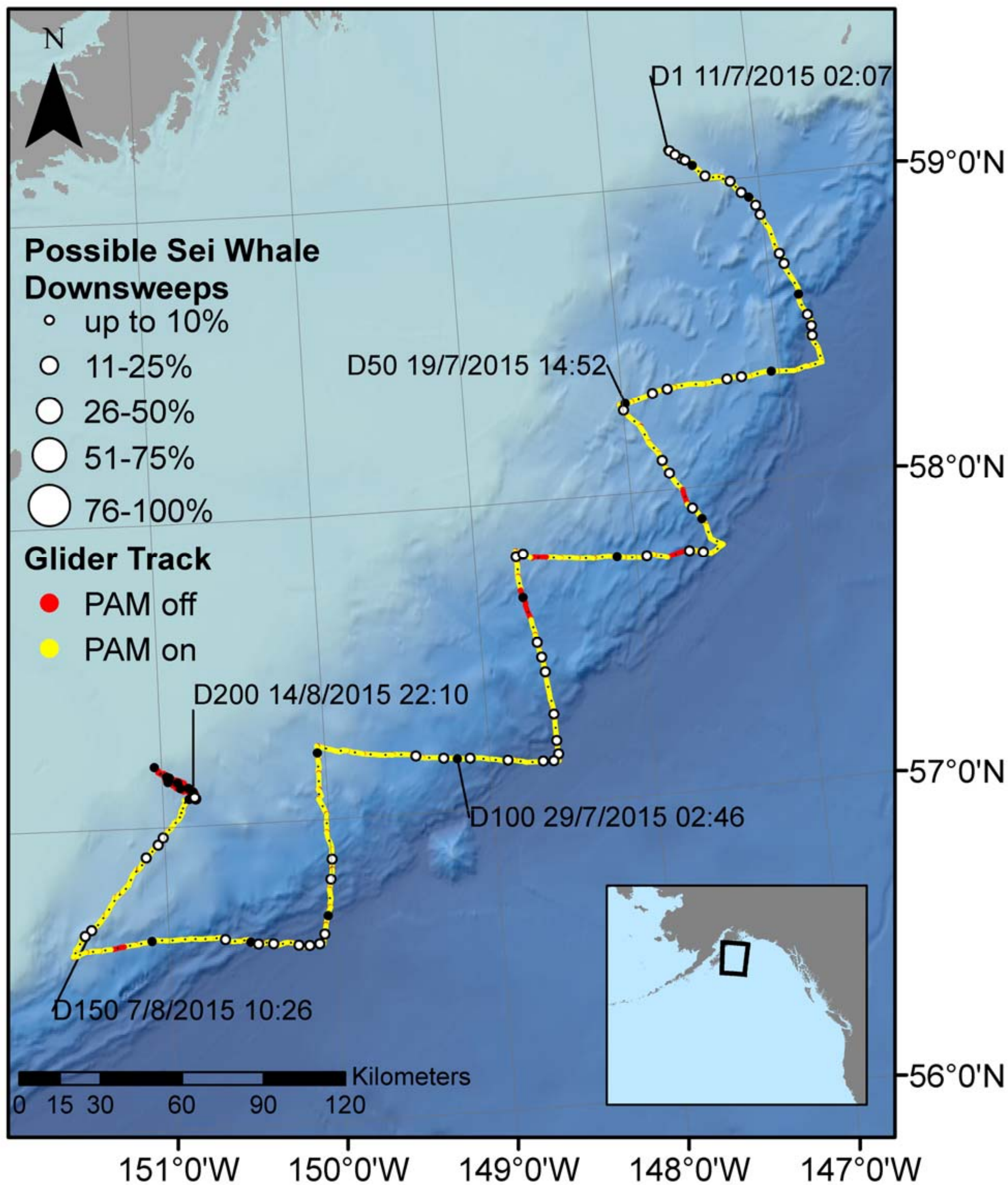

Figure 26. SG203 dives where downsweep (possible sei whale) calls were recorded. The circle size indicates percentage of recording time per dive with target signals.

Other unidentified downsweeping calls (possibly produced by a baleen whale)

Series of 6-10 short, approximately 2-second calls sweeping from approximately 160 Hz down to 140 Hz (**Figure 27**) were identified on multiple occasions in the beginning of the survey (11 to 14 July 2015). These calls were recorded while the glider was in relatively shallow shelf waters (**Figure 28**). It is unclear what species made these calls, but the frequency and timing of the calls indicated that they could be produced by a baleen whale.

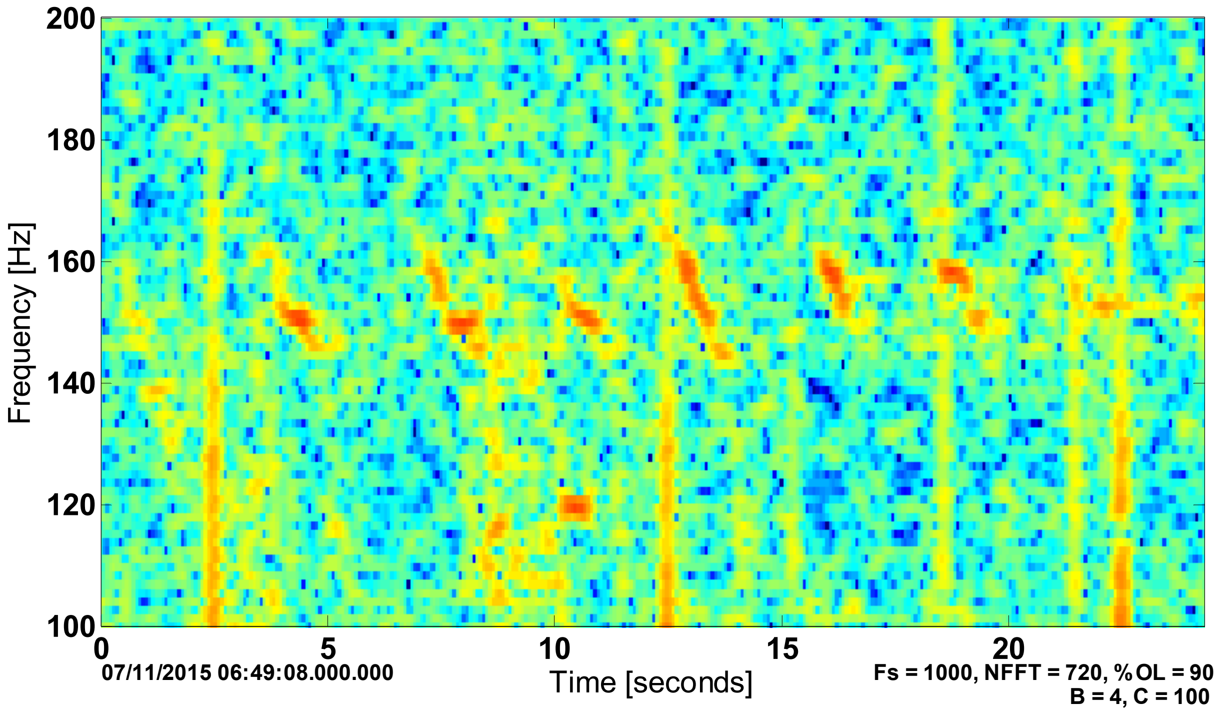

Figure 27. Spectrogram of unidentified mysticete downsweeps recorded by SG203 on 11 July 2015.

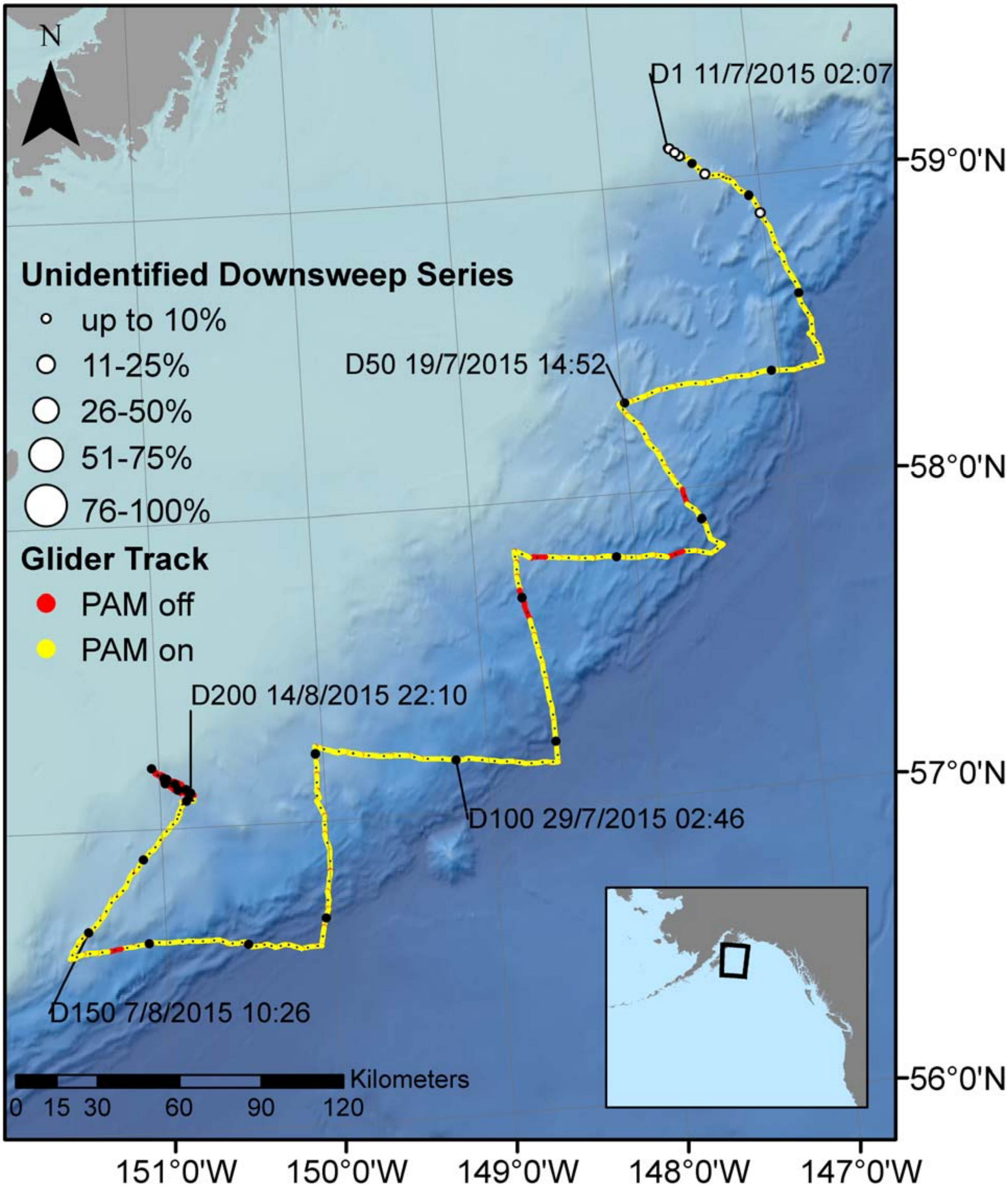

Figure 28: SG203 dives with recordings of unidentified downsweep series. The circle size indicates percentage of recording time per dive with target signals.

3.4 Navy Sonar

No naval sonar sounds were detected during this survey.

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4. Discussion

Glider Performance

The 2015 GoA-TMAA acoustic glider survey was very successful. SG203 covered a total distance of 744 km over the ground with the PAM system active. The Gulf of Alaska is difficult to survey, and thus knowledge about the abundance and distribution of cetaceans, especially in offshore areas, is still limited. This survey demonstrated that autonomous underwater vehicles are useful tools to conduct acoustic monitoring efforts in these remote areas.

Even though the 6.4 level PAM board (APL-UW, Rev. B) has been extensively tested on the bench and in short-duration trials, this was just the fourth acoustic Seaglider™ survey on the order of 1 month of quasi-continuous data collection (Klinck et al. 2015a). A total of 680 hours of acoustic data was collected over a 32-day period by the glider. These long-duration trials are invaluable for improving these systems and are crucial for further development efforts. A long-term technical goal is to further extend the deployment duration to allow for 2 to 3 months of continuous acoustic data collection.

Environmental Data

An additional benefit in using gliders for marine mammal surveys is the collection of environmental data. The measured depth-averaged currents during this survey indicated that a glider can be safely operated in this part of the GoA. The current information and temperature profiles are useful for future research on occurrence patterns of cetacean species in the GoA. The *in-situ* measured sound-speed profiles can be used to quantify sound propagation conditions in the study area in detail rather than using historical average data. These data will be used in an ongoing project funded by the U.S. Navy's Office of Naval Research to develop cetacean density estimation methods using acoustic data collected via slow-moving underwater vehicles such as gliders and floats (award # N00014-15-12142).

Monitoring Question

What are the spatial distributions of beaked whales and Endangered Species Act-listed cetaceans (sperm, blue, fin, sei, humpback, and North Pacific right whales) in the GoA-TMAA?

Beaked whales**.** Only possible Stejneger's beaked whales were recorded, during 12 glider dives over the 32 recording days. This was not entirely surprising, as previous studies have found decreases in beaked whale detections in the Gulf of Alaska in the summer months, with Stejneger's being the most commonly detected species in the summer (Baumann-Pickering et al. 2012, Debich et al. 2013, 2014). Further, previous acoustic studies primarily recorded beaked whales at sites or during transects far off the continental shelf, rather than sites that overlapped with the glider flight path along the shelf (Debich et al. 2013, 2014, Rone et al. 2014).

Sperm whales. Sperm whales were by far the most commonly recorded species of all cetaceans throughout the study period. Very few PAM-active dives did not contain continuous, loud sperm whale echolocation clicks, and there was no pattern of distribution along the survey track—sperm whales were detected on the outer shelf, near the shelf break, and off the shelf. This high number of sperm whale detections matches previous acoustic studies in the area, which reported high sperm whale presence throughout the summer months (Baumann-Pickering et al. 2012, Debich et al. 2013, 2014), particularly in the shelf area where the glider flew (Rone et al. 2014).

Other odontocetes. There was a high number of killer whale detections throughout the study area. This included both killer whale whistles and pulsed calls, as well as the recently described HFM whistles (Simonis et al. 2012). This again matches previous acoustic studies in the area, which found a peak in killer whale detections in the summer months (Baumann-Pickering et al. 2012, Debich et al. 2013, 2014).

Aside from possible Stejneger's beaked whales, killer whales and sperm whales, other odontocetes recorded included Pacific white-sided dolphins on one occasion, and a few series of unidentified odontocete clicks. The low number of Pacific white-sided dolphins corresponds with previous acoustic studies that only detected them in the fall months (Baumann-Pickering et al. 2012, Debich et al. 2013, 2014), and a visual and acoustic transect survey during the summer that had no sightings or acoustic detections (Rone et al. 2014).

The MF unidentified clicks could have been produced by any of the delphinids that cannot be classified to species level based solely on click parameters, such as false killer whales or short-finned pilot whales (Baumann-Pickering et al. 2015).

Blue Whales. SG203 did not record any blue whale northeastern Pacific B calls nor any western Pacific tonal calls during the survey. Rone et al. (2014) report recording very few blue whale calls during their June-July acoustic survey; those that were recorded were well offshore and south of our survey area. Other acoustic studies in the area (Debich et al. 2014, Stafford 2003, Watkins et al. 2000) did report recording blue whale calls during the summer months. However, the glider did record numerous series of blue whale D calls, which are thought to be associated with feeding (Oleson et al. 2007). D calls were recorded throughout the survey (late July–early August) both on the shelf and slope, which agrees with results from a similar survey in the Gulf of Alaska (Debich et al. 2014), where detections of D calls peaked during June–August.

Fin Whales. Very few fin whale 20-Hz calls were recorded by the glider. In a previous acoustic survey conducted during July, numerous 20-Hz fin whale calls were detected (Rone et al. 2014). However, in our glider survey numerous 40-Hz fin whale calls, which are likely associated with foraging (Širović et al. 2013), were recorded all along the survey track. This pattern is also similar to what was observed for blue whales, in that the primary call recorded for both of these species was that associated with feeding. The Gulf of Alaska is a known feeding ground for fin whales (DoN 2006) and thus the prevalence of 40 Hz calls was not surprising. In addition, the survey timing (July–August) may explain the lack of 20-Hz calls. In other studies, 40-Hz calls were recorded earlier in the season than 20-Hz calls (Debich et al. 2014 – Gulf of Alaska, Širović et al. 2013 – North Pacific).

***Potential sei whales*.** Sei whale calls have been recorded in the Gulf of Alaska both on and off the shelf (Rone et al. 2014). Sei whales have been reported to be in the area, though their presence and distribution is highly variable from year to year (DoN 2006). Typically, sei whales are distributed and feed along strong fronts (Horwood 1987, Perry et al. 1999). Sei whale downsweeps are difficult to distinguish from other downsweeps produced by fin whales and blue whales (Ou et al. 2015), and Rone et al. (2014) do not describe the calls they identify as sei whale acoustic encounters. Therefore, more information will be needed to confirm these are indeed sei whale downsweeps.

***Other unidentified series of downsweeps*.** The final category of potential baleen whale calls was a series of quick down-sweeping sounds that occurred in groups of 4 to 8 downsweeps. These have characteristics similar to humpback whale vocalizations but the glider recorded no other humpback sounds in either the 1-kHz or 5-kHz datasets, for this reason these calls weren't categorized as humpback sounds. They also bear some resemblance to blue whale D calls, but the timing and frequency of these series were distinct from other sounds that were categorized as D calls. More data are needed to confirm the source of these calls.

***Humpback, right, minke, and gray whales*.** SG203 did not record calls from humpback, right minke, or gray whales. This agrees with a previous acoustic study in the Gulf of Alaska (Rone et al. 2014). It may have been too early in the season to record humpback songs and minke whale boings, as these sounds are believed to be associated with wintertime breeding activity (Payne and McVay 1971, Rankin and Barlow 2005). The lack of gray whale sounds was not surprising as their vocalizations on the feeding grounds are isolated, indistinct moans and groans making them difficult to identify in acoustic data. In addition, others have recorded just a few hours of gray whale calls later in the year (September and October 2013; Debich et al. 2014). Finally, we have extensive experience with right whale vocalizations, and we are confident that we would have identified right whale upcalls or gunshots with our detailed analysis of the data if they had been present. Given the low numbers of this species (fewer than 20 animals; Wade et al. 2006), lack of these calls is also not surprising.

Conclusions

A successful glider trial like the GoA-TMAA 2015 survey demonstrates that mobile autonomous platforms can play an important role in marine mammal monitoring efforts, especially in inaccessible offshore areas. The Gulf of Alaska, which was targeted in this survey, is difficult to survey with vessels and aircraft because of notoriously difficult weather and ocean conditions, as well as the vast size of the area.

Advantages of glider surveys over traditional acoustic survey methods (towed or cabled arrays and moored recorders) include [a] increased spatial and temporal coverage, [b] improved detection range particularly for deep-diving species including beaked whales, [c] capability of recording both infrasonic and ultrasonic signals, and [d] reduced survey costs.

In addition, gliders can be equipped with a suite of additional environmental sensors. For example, active acoustic sensors would provide information on prey fields which would be helpful for more comprehensive ecosystem studies (e.g., how the occurrence of cetaceans relates to the availability of prey and oceanographic conditions).

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5. Literature Cited

Baumann-Pickering, S., McDonald, M. A., Simonis, A. E., Solsona Berga, A., Merkens, K. P. B., Oleson, E. M., Roch, M. A., Wiggins, S. M., Rankin, S., Yack, T. M., and Hildebrand, J. A. (**2013**). Species-specific beaked whale echolocation signals, *The Journal of the Acoustical Society of America*, **134**, 2293–2301. doi:10.1121/1.4817832

Baumann-Pickering, S., Simonis, A. E., Oleson, E. M., Baird, R. W., Roch, M. A., and Wiggins, S. M. (**2015**). False killer whale and short-finned pilot whale acoustic identification, *Endangered Species Research*, **28**, 97–108. doi:10.3354/esr00685

Baumann-Pickering, S., Širović, A., Hildebrand, J. A., Debich, A., Gottlieb, R. S., Johnson, S., Kerosky, S., Roche, L., Solsona Berga, A., Wakefield, L., and Wiggins, S. (**2012**). *Passive Acoustic Monitoring for Marine Mammals in the Gulf of Alaska Temporary Maritime Activities Area 2012-2013 MPL Technical Memorandum #538*,79 pages. Retrieved from http://cetus.ucsd.edu/Publications/Reports/DebichMPLTM546-2013.pdf

Baumgartner, M. F., Van Parijs, S. M., Wenzel, F. W., Tremblay, C. J., Carter Esch, H., and Warde, A. M. (**2008**). Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*), *The Journal of the Acoustical Society of America*, **124**, 1339–1349. doi:10.1121/1.2945155

Crane, N. L., and Lashkari, K. (**1996**). Sound production of gray whales, Eschrichtius robustus, along their migration route: a new approach to signal analysis, *The Journal of the Acoustical Society of America*, **100**, 1878–1886. doi:10.1121/1.416006

Dawson, S., Barlow, J., and Ljungblad, D. K. (**1998**). Sounds recorded from Baird’s beaked whale, *Berardius bairdii*, *Marine Mammal Science*, **14**, 335–344.

Debich, A. J., Baumann-Pickering, S., Širović, A., Hildebrand, J. A., Jasmine, S., Gottlieb, R. S., Jackson, A. N., Johnson, S. C., Roche, L., Jennifer, T., Thayre, B., Wakefield, L., and Wiggins, S. M. (**2013**). *Passive Acoustic Monitoring for Marine Mammals in the Gulf of Alaska Temporary Maritime Activities Area 2012-2013 MPL Technical Memorandum #546. Prepared for the U.S. Navy’s 2013 Gulf of Alaska annual monitoring report*,79 pages. Retrieved from http://cetus.ucsd.edu/Publications/Reports/DebichMPLTM546-2013.pdf

Debich, A. J., Pickering, S. B.-, Širović, A., Hildebrand, J. A., Alldredge, A. L., Gottlieb, R. S., Herbert, S. T., Johnson, S. C., Rice, A. C., Roche, L. K., Thayre, B. J., Trickey, J. S., Varga, L. M., and Wiggins, S. M. (**2014**). *Passive Acoustic Monitoring for Marine Mammals in the Gulf of Alaska Temporary Maritime Activities Area 2013-2014 MPL Technical Memorandum #549. Prepared for the U.S. Navy’s 2014 Gulf of Alaska annual monitoring report*,97 pages.

DoN (Department of the Navy) (**2006**). *Marine Resources Assessment for the Gulf of Alaska Operating Area. Pacific Division, Naval Facilities Engineering Command. Pearl Harbor, Hawaii. Contract #N62470-02-D-9997, CTO 0029. Prepared by Geo-Marine, Inc., Plano, Texas*,476 pages.

Ford, J. K. B. (**1987**). A catalogue of underwater calls produced by killer whales (*Orcinus orca*) in British Columbia, *Canadian Data Report of Fisheries and Aquatic Sciences,* 633 pages.

Gedamke, J., Costa, D. P., and Dunstan, A. (**2001**). Localization and visual verification of a complex minke whale vocalization, *The Journal of the Acoustical Society of America*, **109**, 3038–3047. doi:10.1121/1.1371763

Horwood, J. (**1987**). *The sei whale: Population biology, ecology, & management*, Croom Helm in association with Methuen, Inc, New York, NY.

Klinck, H., Mellinger, D. K., Klinck, K., Bogue, N. M., Luby, J. C., Jump, W. A., Shilling, G. B., Litchendorf, T., Wood, A. S., Schorr, G. S., and Baird, R. W. (**2012**). Near-real-rime acoustic monitoring of beaked whales and other cetaceans using a Seaglider™, *PLoS ONE*, **7**, e36128. doi:10.1371/journal.pone.0036128

Klinck, H., Nieukirk, S. L., Fregosi, S., Klinck, K., Mellinger, D. K., Lastuka, S., Schiling, G. B., and Luby, J. C. (**2015a**). *Cetacean Studies on the Mariana Islands Range Complex in September-November 2014: Passive Acoustic Monitoring of Marine Mammals Using Gliders. Final Report.* Prepared for Commander, U.S. Pacific Fleet, Environmental Readiness Division, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Pearl Harbor, Hawaii under Contract No. N62470-10-D-3011, Task Order KB25, issued to HDR Inc., Honolulu, Hawaii. Prepared by Oregon State University, Newport, OR and the Applied Physics Laboratory of the University of Washington, Seattle, WA. August 2015. 50 pages.

Klinck, H., Nieukirk, S. L., Fregosi, S., Klinck, K., Mellinger, D. K., Lastuka, S., Shilling, G. B., and Luby, J. C. (**2015b**). *Cetacean Studies in the Hawaii Range Complex in December 2014 – January 2015: Passive Acoustic Monitoring of Marine Mammals Using Gliders. Final Report.* Prepared for Commander, U.S. Pacific Fleet, Environmental Readiness Division, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Pearl Harbor, Hawaii under Contract No. N62470-10-D-3011, Task Order KB23, issued to HDR Inc., Honolulu, Hawaii. Prepared by Oregon State University, Newport, OR and the Applied Physics Laboratory of the University of Washington, Seattle, WA. October 2015. 58 pages.

Klinck, H., Nieukirk, S. L., Fregosi, S., Klinck, K., Mellinger, D. K., Lastuka, S., Shilling, G. B., and Luby, J. C. (**2016**). *Cetacean Studies in the Mariana Islands Range Complex in March-April 2016: Passive Acoustic Monitoring of Marine Mammals Using Gliders. Final Report.* Prepared for Commander, U.S. Pacific Fleet, Environmental Readiness Division, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Pearl Harbor, Hawaii under Contract No. N62470-10-D-3011, Task Order KB23, issued to HDR Inc., Honolulu, Hawaii. Prepared by Oregon State University, Newport, OR and the Applied Physics Laboratory of the University of Washington, Seattle, WA. March 2016. 52 pages.

Kyhn, L. A., Tougaard, J., Beedholm, K., Jensen, F. H., Ashe, E., Williams, R., and Madsen, P. T. (**2013**). Clicking in a killer whale habitat: Narrow-band, high-frequency biosonar clicks of harbour porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*), *PLoS ONE*, **8**, e63763. doi:10.1371/journal.pone.0063763

Møhl, B., Wahlberg, M., Madsen, P. T., Heerfordt, A., and Lund, A. (**2003**). The monopulsed nature of sperm whale clicks, *The Journal of the Acoustical Society of America*, **114**, 1143–1154. doi:10.1121/1.1586258

Oleson, E. M., Wiggins, S. M., and Hildebrand, J. A. (**2007**). Temporal separation of blue whale call types on a southern California feeding ground, *Animal Behaviour*, **74**, 881–894. doi:10.1016/j.anbehav.2007.01.022

Ou, H., Au, W. W. L., Van Parijs, S., Oleson, E. M., and Rankin, S. (**2015**). Discrimination of frequency-modulated Baleen whale downsweep calls with overlapping frequencies, *The Journal of the Acoustical Society of America*, **137**, 3024–3032. doi:10.1121/1.4919304

Payne, R. S., and McVay, S. (**1971**). Songs of humpback whales, *Science*, **173**, 585–597. doi:10.1126/science.173.3997.585

Perry, S. L., DeMaster, D. P., and Silber, G. K. (**1999**). The great whales: History and status of six species listed as endangered under the US Endangered Species Act of 1973, *Marine Fisheries Review*, **61**, 44–51.

Rankin, S., and Barlow, J. (**2005**). Source of the North Pacific "boing" sound attributed to minke whales, *The Journal of the Acoustical Society of America*, **118**, 3346–3351. doi:10.1121/1.2046747

Rankin, S., and Barlow, J. (**2007**). Vocalizations of the sei whale, *Balaenoptera borealis*, off the Hawaiian Islands, *Bioacoustics*, **16**, 137–145. doi:10.1080/09524622.2007.9753572

Rone, B. K., Douglas, A. B., Yack, T. M., Zerbini, A. N., Norris, T. N., Fergeson, E., and Calambokidis, J. (**2014**). *Report for the Gulf of Alaska Line-Transect Survey (GOALS) II: Marine Mammal Occurence in the Temporary Maritime Activities Area (TMAA) Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Honolulu, Hawaii under Contract No. N62470-10-D-3011, Task Order 022, issued to HDR Inc., San Diego, CA.April 2014*,82 pages.

Rudnick, D. L., Davis, R. E., Eriksen, C. C., Fratantoni, D. M., and Perry, M. J. (**2004**). Underwater Gliders for Ocean Research, *Marine Technology Society Journal*,. doi:10.4031/002533204787522703

Simonis, A. E., Baumann-Pickering, S., Oleson, E., Melcón, M. L., Gassmann, M., Wiggins, S. M., and Hildebrand, J. a (**2012**). High-frequency modulated signals of killer whales (*Orcinus orca*) in the North Pacific, *The Journal of the Acoustical Society of America*, **131**, EL295–301. doi:10.1121/1.3690963

Širović, A., Williams, L. N., Kerosky, S. M., Wiggins, S. M., and Hildebrand, J. A. (**2013**). Temporal separation of two fin whale call types across the eastern North Pacific, *Marine Biology*, **160**, 47–57. doi:10.1007/s00227-012-2061-z

Soldevilla, M. S., Henderson, E. E., Campbell, G. S., Wiggins, S. M., Hildebrand, J. A., and Roch, M. A. (**2008**). Classification of Risso's and Pacific white-sided dolphins using spectral properties of echolocation clicks, *The Journal of the Acoustical Society of America*, **124**, 609–624. doi:10.1121/1.2932059

Stafford, K. M. (**2003**). Two types of blue whale calls recorded in the Gulf of Alaska, *Marine Mammal Science*, **19**, 682–693. doi:10.1111/j.1748-7692.2003.tb01124.x

Stafford, K. M., Chapp, E., Bohnenstiel, D. R., and Tolstoy, M. (**2011**). Seasonal detection of three types of "pygmy" blue whale calls in the Indian Ocean, *Marine Mammal Science*, **27**, 828–840. doi:10.1111/j.1748-7692.2010.00437.x

Stafford, K. M., Nieukirk, S. L., and Fox, C. G. (**1999**). Low-frequency whale sounds recorded on hydrophones moored in the eastern tropical Pacific, *The Journal of the Acoustical Society of America*, **106**, 3687–3698. doi:10.1121/1.428220

Stimpert, A. K., and Au, W. W. L. (**2008**). Humpback whale (*Megaptera noveangliae*) social sounds in Hawai'i, *Bioacoustics*, **17**, 48–50. doi:10.1080/09524622.2008.9753760

Thompson, P. O., Findley, L. T., and Vidal, O. (**1992**). 20-Hz pulses and other vocalizations of fin whales, *Balaenoptera physalus*, in the Gulf of California, Mexico, *The Journal of the Acoustical Society of America*, **92**, 3051–3057.

Wade, P., Heide-Jorgensen, M. P., Shelden, K., Barlow, J., Carretta, J., Durban, J. W., Leduc, R., Munger, L., Rankin, S., Sauter, A., and Stinchcomb, C. (**2006**). Acoustic detection and satellite-tracking leads to discovery of rare concentration of endangered North Pacific right whales, *Biology Letters*, **2**, 417–419.

Watkins, W. A. (**1981**). Activites and underwater sounds of fin whales, *The Scientific Reporst of the Whales Research Institute*, **33**, 83–117.

Watkins, W. A., Daher, M. A., Reppucci, G. M., George, J. E., Martin, N. A., Dimarzio, N. A., and Gannon, D. P. (**2000**). Seasonality and distribution of whale calls in the North Pacific, *Oceanography*, **13**, 62–67.

A

Details of All Acoustic Encounters Recorded by Glider SG203

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Appendix A. Details of All Acoustic Encounters Recorded by Glider SG203

This appendix includes a collection of tables where encounter information is listed for each species acoustically identified in the glider data collected during the GoA-TMAA 2015 survey. An encounter was defined as a period when target signals were present in the acoustic data and separated from other periods of signal detections by 30 or more minutes of silence. Note, however, that in other parts of this report, analysts summarized the acoustic data by glider dives, not encounters. Encounter data have been provided to enable direct comparison with line-transect studies conducted in the area.

A.1 Odontocetes

Possible Stejneger's beaked whales

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	70	23/07/2015 10:37:13	23/07/2015 12:39:28	PSBW	57.7959	148.1176
2	130	03/08/2015 16:39:32	03/08/2015 16:41:24	PSBW	56.6100	150.5112
3	145	06/08/2015 10:51:44	06/08/2015 10:56:19	PSBW	56.6017	151.4594
4	149	07/08/2015 06:56:38	07/08/2015 06:56:57	PSBW	56.6531	151.5027
5	150	07/08/2015 08:55:01	07/08/2015 09:21:52	PSBW	56.6716	151.4616
6	151	07/08/2015 16:07:01	07/08/2015 16:08:33	PSBW	56.6891	151.4220
7	152	07/08/2015 16:58:26	07/08/2015 17:03:39	PSBW	56.7113	151.3886
8	154	08/08/2015 02:21:56	08/08/2015 02:22:35	PSBW	56.7665	151.3178
9	154	08/08/2015 04:51:21	08/08/2015 04:52:59	PSBW	56.7665	151.3178
10	155	08/08/2015 06:49:04	08/08/2015 06:50:15	PSBW	56.7862	151.2841
11	161	09/08/2015 09:03:44	09/08/2015 09:05:42	PSBW	56.9245	151.0774
12	162	09/08/2015 16:07:31	09/08/2015 16:08:54	PSBW	56.9442	151.0405

*PSBW = Possible Stejneger's beaked whales

Sperm whale encounters

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	9	11/07/2015 03:33:21	12/07/2015 03:39:57	Pm	59.0778	147.4560
2	14	12/07/2015 04:10:11	13/07/2015 04:19:06	Pm	59.0123	147.2506
3	17	13/07/2015 05:14:51	13/07/2015 06:50:47	Pm	58.9940	147.1817
4	17	13/07/2015 07:33:35	13/07/2015 09:42:14	Pm	58.9940	147.1817
5	18	13/07/2015 10:26:11	13/07/2015 14:20:47	Pm	58.9741	147.1511
6	21	13/07/2015 14:59:17	14/07/2015 12:44:59	Pm	58.9072	147.0346
7	24	14/07/2015 14:09:27	14/07/2015 18:50:56	Pm	58.8065	146.9557
8	28	14/07/2015 19:47:23	16/07/2015 04:05:29	Pm	58.6719	146.8713
9	32	16/07/2015 05:04:05	16/07/2015 05:06:13	Pm	58.5310	146.7823
10	33	16/07/2015 06:44:17	16/07/2015 07:39:35	Pm	58.4923	146.7652
11	33	16/07/2015 09:08:40	16/07/2015 10:37:41	Pm	58.4923	146.7652
12	36	16/07/2015 11:52:35	17/07/2015 09:59:24	Pm	58.3904	146.7294
13	39	17/07/2015 10:56:47	17/07/2015 11:20:21	Pm	58.3531	146.9527
14	44	18/07/2015 10:53:40	18/07/2015 10:54:31	Pm	58.3385	147.4233
15	44	18/07/2015 12:26:51	18/07/2015 15:25:50	Pm	58.3385	147.4233
16	45	18/07/2015 17:40:19	18/07/2015 18:13:25	Pm	58.3388	147.5275
17	46	18/07/2015 18:58:40	18/07/2015 19:57:11	Pm	58.3383	147.6182
18	48	18/07/2015 23:40:50	19/07/2015 15:57:03	Pm	58.3209	147.8057
19	51	19/07/2015 17:32:34	19/07/2015 18:45:08	Pm	58.2752	147.9963
20	51	19/07/2015 19:18:16	19/07/2015 21:03:44	Pm	58.2752	147.9963
21	52	19/07/2015 22:14:02	20/07/2015 01:23:37	Pm	58.2358	147.9353

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
22	53	20/07/2015 02:38:35	20/07/2015 03:29:18	Pm	58.1890	147.8782
23	53	20/07/2015 04:52:10	20/07/2015 07:48:49	Pm	58.1890	147.8782
24	54	20/07/2015 08:43:34	20/07/2015 08:59:04	Pm	58.1421	147.8287
25	54	20/07/2015 09:41:47	20/07/2015 10:20:10	Pm	58.1421	147.8287
26	55	20/07/2015 11:14:16	20/07/2015 12:00:14	Pm	58.0989	147.7846
27	55	20/07/2015 12:45:34	20/07/2015 13:17:42	Pm	58.0989	147.7846
28	56	20/07/2015 13:50:12	20/07/2015 23:22:12	Pm	58.0549	147.7467
29	59	21/07/2015 05:08:11	21/07/2015 06:01:17	Pm	57.9324	147.6240
30	60	21/07/2015 13:01:37	21/07/2015 13:10:47	Pm	57.8952	147.5714
31	61	21/07/2015 14:03:43	21/07/2015 15:02:05	Pm	57.8494	147.5393
32	64	21/07/2015 16:09:45	22/07/2015 20:54:02	Pm	57.7854	147.5827
33	68	22/07/2015 23:10:33	23/07/2015 01:38:14	Pm	57.7901	147.9335
34	69	23/07/2015 03:07:02	23/07/2015 08:20:37	Pm	57.7894	148.0253
35	70	23/07/2015 09:48:35	23/07/2015 09:48:47	Pm	57.7959	148.1176
36	73	23/07/2015 10:24:37	24/07/2015 11:35:01	Pm	57.8058	148.4133
37	79	25/07/2015 00:50:23	25/07/2015 01:32:27	Pm	57.7348	148.7345
38	82	25/07/2015 02:16:14	26/07/2015 03:02:30	Pm	57.5877	148.6712
39	92	27/07/2015 12:43:07	27/07/2015 12:52:02	Pm	57.1413	148.6115
40	105	27/07/2015 14:06:01	01/08/2015 14:44:01	Pm	57.2017	149.6317
41	121	01/08/2015 15:27:46	02/08/2015 07:47:19	Pm	56.6229	150.0649
42	126	02/08/2015 08:35:32	03/08/2015 18:22:26	Pm	56.5991	150.3198
43	130	03/08/2015 19:10:48	03/08/2015 20:56:36	Pm	56.6100	150.5112

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
44	131	03/08/2015 21:39:18	03/08/2015 21:39:55	Pm	56.6173	150.5490
45	132	04/08/2015 01:54:59	04/08/2015 03:03:01	Pm	56.6157	150.6060
46	132	04/08/2015 03:42:22	04/08/2015 03:42:28	Pm	56.6157	150.6060
47	132	04/08/2015 04:23:36	04/08/2015 04:23:44	Pm	56.6157	150.6060
48	133	04/08/2015 06:03:00	04/08/2015 07:31:19	Pm	56.6232	150.6616
50	134	04/08/2015 12:39:55	04/08/2015 12:40:43	Pm	56.6292	150.7148
51	135	04/08/2015 14:14:16	04/08/2015 14:15:02	Pm	56.6283	150.7815
52	135	04/08/2015 15:20:41	04/08/2015 15:21:10	Pm	56.6283	150.7815
53	135	04/08/2015 15:51:34	04/08/2015 15:52:49	Pm	56.6283	150.7815
54	135	04/08/2015 16:53:21	04/08/2015 17:52:33	Pm	56.6283	150.7815
55	136	04/08/2015 19:22:02	04/08/2015 19:22:24	Pm	56.6298	150.8412
56	139	05/08/2015 01:28:45	05/08/2015 15:11:18	Pm	56.6295	151.0421
57	141	05/08/2015 16:30:14	06/08/2015 00:41:57	Pm	56.6216	151.1687
58	144	06/08/2015 06:23:46	06/08/2015 11:38:42	Pm	56.6046	151.3855
59	147	06/08/2015 13:00:22	07/08/2015 07:58:52	Pm	56.5995	151.5644
60	150	07/08/2015 08:37:54	07/08/2015 15:44:39	Pm	56.6716	151.4616
61	151	07/08/2015 16:16:20	07/08/2015 16:16:48	Pm	56.6891	151.4220
62	152	07/08/2015 17:15:53	07/08/2015 19:18:29	Pm	56.7113	151.3886
63	152	07/08/2015 20:11:07	07/08/2015 20:11:42	Pm	56.7113	151.3886
64	157	08/08/2015 16:45:30	08/08/2015 18:52:47	Pm	56.8333	151.2134
65	159	08/08/2015 19:53:28	09/08/2015 03:09:01	Pm	56.8810	151.1438
66	160	09/08/2015 04:15:11	09/08/2015 04:43:15	Pm	56.9041	151.1155

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
67	160	09/08/2015 06:40:43	09/08/2015 06:41:07	Pm	56.9041	151.1155
68	161	09/08/2015 07:30:20	09/08/2015 11:23:31	Pm	56.9245	151.0774
69	162	09/08/2015 13:18:01	09/08/2015 18:02:23	Pm	56.9442	151.0405
70	163	09/08/2015 19:15:53	09/08/2015 21:24:34	Pm	56.9674	151.0083
71	168	10/08/2015 13:22:40	10/08/2015 13:33:24	Pm	57.0617	150.8798
72	169	10/08/2015 14:38:49	10/08/2015 14:55:08	Pm	57.0792	150.8669
73	171	10/08/2015 22:56:41	10/08/2015 22:57:01	Pm	57.0911	150.8068

*Pm = *Physeter macrocephalus* (sperm whale)

Killer whale encounters

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	4	11/07/2015 04:43:27	11/07/2015 05:21:36	Oo	59.1200	147.5695
2	25	14/07/2015 18:03:43	14/07/2015 20:45:00	Oo	58.7717	146.9411
3	30	15/07/2015 18:25:24	15/07/2015 18:35:45	Oo	58.6012	146.8237
4	51	19/07/2015 18:32:04	19/07/2015 18:46:22	Oo	58.2752	147.9963
5	59	21/07/2015 04:55:48	21/07/2015 04:57:41	Oo	57.9324	147.6240
6	62	21/07/2015 20:32:14	21/07/2015 20:39:14	Oo	57.8159	147.4933
7	83	25/07/2015 20:01:16	25/07/2015 22:05:29	Oo	57.5356	148.6544
8	84	25/07/2015 23:12:00	25/07/2015 23:13:16	Oo	57.4866	148.6347
9	94	28/07/2015 00:36:38	28/07/2015 00:41:29	Oo	57.1431	148.7424
10	95	28/07/2015 03:35:44	28/07/2015 03:36:48	Oo	57.1486	148.8144
11	110	31/07/2015 01:03:12	31/07/2015 01:13:45	Oo	57.2224	150.0450
12	111	31/07/2015 02:33:34	31/07/2015 02:59:35	Oo	57.1774	150.0447

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
13	111	31/07/2015 03:38:41	31/07/2015 03:57:02	Oo	57.1774	150.0447
14	113	31/07/2015 13:08:24	31/07/2015 13:12:49	Oo	57.0853	150.0493
15	116	01/08/2015 02:11:15	01/08/2015 02:19:27	Oo	56.9297	150.0055
16	128	03/08/2015 09:52:44	03/08/2015 12:02:29	Oo	56.6056	150.4162
17	140	05/08/2015 11:03:39	05/08/2015 12:53:29	Oo	56.6277	151.1022
18	140	05/08/2015 14:06:15	05/08/2015 18:11:16	Oo	56.6277	151.1022
19	141	05/08/2015 18:50:57	05/08/2015 19:05:52	Oo	56.6216	151.1687
20	141	05/08/2015 20:09:48	05/08/2015 20:13:20	Oo	56.6216	151.1687
21	142	05/08/2015 20:57:59	05/08/2015 21:56:44	Oo	56.6167	151.2350
22	142	05/08/2015 22:33:20	05/08/2015 23:19:48	Oo	56.6167	151.2350
23	172	11/08/2015 00:29:44	11/08/2015 00:36:44	Oo	57.0909	150.8001

*Oo = *Orcinus Orca* (Killer whale)

Pacific white-sided dolphin encounters

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	113	31/07/2015 12:39:14	31/07/2015 12:44:08	Lo	57.0853	150.0493

*LO = *Lagenorhynchus obliquidens* (Pacific white-sided dolphin)

Unidentified mid-frequency click encounters

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	38	17/07/2015 08:45:18	17/07/2015 09:52:42	UMFC	58.3561	146.8547
2	43	18/07/2015 08:28:07	18/07/2015 08:55:13	UMFC	58.3456	147.3287

*UMFC = Unidentified mid-frequency click

A.2 MYSTICETES

Blue whale encounters

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	5	11/07/2015 06:42:28	11/07/2015 06:42:52	Bm	59.1143	147.5508
2	53	20/07/2015 02:20:31	20/07/2015 02:20:35	Bm	58.1890	147.8782
3	53	20/07/2015 03:56:35	20/07/2015 05:10:39	Bm	58.1890	147.8782
4	53	20/07/2015 05:46:53	20/07/2015 05:59:00	Bm	58.1890	147.8782
5	54	20/07/2015 06:49:11	20/07/2015 06:55:56	Bm	58.1421	147.8287
6	54	20/07/2015 08:17:13	20/07/2015 08:54:37	Bm	58.1421	147.8287
7	59	21/07/2015 07:06:13	21/07/2015 07:06:16	Bm	57.9324	147.6240
8	60	21/07/2015 09:22:10	21/07/2015 09:34:10	Bm	57.8952	147.5714
9	61	21/07/2015 14:27:43	21/07/2015 14:27:48	Bm	57.8494	147.5393
10	62	21/07/2015 20:10:28	21/07/2015 20:16:46	Bm	57.8159	147.4933
11	63	22/07/2015 02:22:52	22/07/2015 02:24:23	Bm	57.7916	147.4942
12	64	22/07/2015 06:08:27	22/07/2015 06:49:37	Bm	57.7854	147.5827
13	69	23/07/2015 06:03:16	23/07/2015 06:04:24	Bm	57.7894	148.0253
14	71	23/07/2015 13:20:03	23/07/2015 13:20:58	Bm	57.7990	148.2096
15	73	23/07/2015 21:49:05	23/07/2015 22:12:54	Bm	57.8058	148.4133
16	73	24/07/2015 00:28:39	24/07/2015 00:28:44	Bm	57.8058	148.4133
17	76	24/07/2015 11:03:08	24/07/2015 11:07:24	Bm	57.8297	148.6982
18	76	24/07/2015 13:26:52	24/07/2015 13:30:56	Bm	57.8297	148.6982
19	76	24/07/2015 14:50:07	24/07/2015 14:51:03	Bm	57.8297	148.6982
20	77	24/07/2015 16:29:40	24/07/2015 16:50:07	Bm	57.8234	148.7416

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
21	77	24/07/2015 17:49:30	24/07/2015 18:00:08	Bm	57.8234	148.7416
22	77	24/07/2015 18:41:40	24/07/2015 18:51:18	Bm	57.8234	148.7416
23	78	24/07/2015 22:11:07	24/07/2015 22:50:16	Bm	57.7813	148.7390
24	78	24/07/2015 23:27:40	24/07/2015 23:37:06	Bm	57.7813	148.7390
25	79	25/07/2015 00:41:02	25/07/2015 00:58:51	Bm	57.7348	148.7345
26	79	25/07/2015 01:36:01	25/07/2015 02:16:05	Bm	57.7348	148.7345
27	79	25/07/2015 03:04:38	25/07/2015 03:47:03	Bm	57.7348	148.7345
28	79	25/07/2015 04:18:08	25/07/2015 04:19:55	Bm	57.7348	148.7345
29	82	25/07/2015 16:28:59	25/07/2015 16:29:59	Bm	57.5877	148.6712
30	84	25/07/2015 23:11:13	26/07/2015 00:00:44	Bm	57.4866	148.6347
31	84	26/07/2015 02:38:28	26/07/2015 02:53:04	Bm	57.4866	148.6347
32	85	26/07/2015 04:10:21	26/07/2015 04:12:46	Bm	57.4375	148.6197
33	85	26/07/2015 05:16:17	26/07/2015 06:50:24	Bm	57.4375	148.6197
34	87	26/07/2015 14:03:49	26/07/2015 14:05:36	Bm	57.3403	148.5972
35	87	26/07/2015 14:38:31	26/07/2015 14:42:39	Bm	57.3403	148.5972
36	87	26/07/2015 15:25:48	26/07/2015 15:37:31	Bm	57.3403	148.5972
37	91	27/07/2015 07:41:45	27/07/2015 07:44:54	Bm	57.1637	148.5798
38	92	27/07/2015 12:44:04	27/07/2015 12:47:49	Bm	57.1413	148.6115
39	96	28/07/2015 06:41:20	28/07/2015 06:41:55	Bm	57.1551	148.8887
40	101	29/07/2015 05:32:13	29/07/2015 05:32:24	Bm	57.1779	149.2792
41	101	29/07/2015 06:37:53	29/07/2015 06:57:09	Bm	57.1779	149.2792
42	102	29/07/2015 14:18:24	29/07/2015 14:18:53	Bm	57.1829	149.3659

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
43	103	29/07/2015 14:55:19	29/07/2015 14:55:34	Bm	57.1914	149.4466
44	103	29/07/2015 15:44:23	29/07/2015 15:44:41	Bm	57.1914	149.4466
45	106	30/07/2015 07:14:56	30/07/2015 07:18:23	Bm	57.2062	149.7220
46	108	30/07/2015 16:15:37	30/07/2015 16:16:01	Bm	57.2244	149.9017
47	115	31/07/2015 22:03:23	31/07/2015 22:24:28	Bm	56.9882	150.0127
48	116	01/08/2015 03:31:24	01/08/2015 03:54:11	Bm	56.9297	150.0055
50	117	01/08/2015 06:20:52	01/08/2015 06:21:02	Bm	56.8689	149.9954
51	118	01/08/2015 14:05:04	01/08/2015 14:14:55	Bm	56.8023	150.0085
52	121	02/08/2015 02:02:19	02/08/2015 02:03:53	Bm	56.6229	150.0649
53	122	02/08/2015 07:46:54	02/08/2015 08:03:11	Bm	56.5920	150.0986
54	123	02/08/2015 10:45:27	02/08/2015 10:46:30	Bm	56.5890	150.1583
55	124	02/08/2015 13:46:26	02/08/2015 13:46:38	Bm	56.5917	150.2240
56	124	02/08/2015 14:23:59	02/08/2015 14:26:09	Bm	56.5917	150.2240
57	126	02/08/2015 22:22:42	02/08/2015 22:27:30	Bm	56.5991	150.3198
58	127	03/08/2015 03:44:29	03/08/2015 03:45:06	Bm	56.6005	150.3749
59	127	03/08/2015 05:00:30	03/08/2015 06:10:56	Bm	56.6005	150.3749
60	129	03/08/2015 13:37:12	03/08/2015 13:38:50	Bm	56.6025	150.4644
61	138	05/08/2015 06:16:15	05/08/2015 06:27:25	Bm	56.6286	150.9781
62	139	05/08/2015 07:34:31	05/08/2015 07:37:36	Bm	56.6295	151.0421
63	139	05/08/2015 09:49:45	05/08/2015 09:51:01	Bm	56.6295	151.0421
64	139	05/08/2015 10:54:27	05/08/2015 10:58:25	Bm	56.6295	151.0421
65	144	06/08/2015 07:01:53	06/08/2015 07:16:19	Bm	56.6046	151.3855

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
66	149	07/08/2015 07:34:15	07/08/2015 07:38:23	Bm	56.6531	151.5027
67	150	07/08/2015 08:42:04	07/08/2015 09:15:39	Bm	56.6716	151.4616
68	150	07/08/2015 10:36:28	07/08/2015 10:37:27	Bm	56.6716	151.4616
69	159	09/08/2015 02:49:05	09/08/2015 03:17:42	Bm	56.8810	151.1438
70	160	09/08/2015 03:52:58	09/08/2015 04:56:06	Bm	56.9041	151.1155
71	160	09/08/2015 05:53:04	09/08/2015 06:22:17	Bm	56.9041	151.1155
72	161	09/08/2015 08:33:18	09/08/2015 08:39:45	Bm	56.9245	151.0774
73	161	09/08/2015 10:34:02	09/08/2015 10:37:21	Bm	56.9245	151.0774
74	164	09/08/2015 21:41:38	09/08/2015 21:42:39	Bm	56.9931	150.9685
75	164	09/08/2015 23:03:11	09/08/2015 23:05:36	Bm	56.9931	150.9685
76	167	10/08/2015 07:53:40	10/08/2015 07:55:01	Bm	57.0473	150.8913
77	169	10/08/2015 15:02:39	10/08/2015 15:03:13	Bm	57.0792	150.8669
78	170	10/08/2015 20:01:18	10/08/2015 20:05:11	Bm	57.0895	150.8396
79	171	11/08/2015 00:26:09	11/08/2015 00:26:36	Bm	57.0911	150.8068
80	172	11/08/2015 03:12:09	11/08/2015 03:13:00	Bm	57.0909	150.8001
81	173	11/08/2015 05:36:02	11/08/2015 05:41:10	Bm	57.0957	150.8062
82	174	11/08/2015 06:56:53	11/08/2015 07:01:46	Bm	57.0993	150.8131

*Bm = *Balaenoptera musculus* (blue whale)

Fin whale encounters

Enc. [no.]	Call type	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
1	40 Hz	17	13/07/2015 07:26:17	13/07/2015 08:06:26	Bp	58.9940	147.1817
2	40 Hz	33	16/07/2015 07:37:10	16/07/2015 07:37:36	Bp	58.4923	146.7652
3	40 Hz	50	19/07/2015 13:45:36	19/07/2015 13:47:06	Bp	58.2964	147.9826
4	40 Hz	51	19/07/2015 17:57:37	19/07/2015 18:51:17	Bp	58.2752	147.9963
5	40 Hz	51	19/07/2015 19:29:57	19/07/2015 21:21:43	Bp	58.2752	147.9963
6	20 Hz	54	20/07/2015 09:35:09	20/07/2015 09:35:27	Bp	58.1421	147.8287
7	40 Hz	59	21/07/2015 06:35:30	21/07/2015 06:57:58	Bp	57.9324	147.6240
8	40 Hz	73	24/07/2015 00:23:28	24/07/2015 00:53:43	Bp	57.8058	148.4133
9	40 Hz	74	24/07/2015 01:54:13	24/07/2015 02:19:23	Bp	57.8108	148.5097
10	40 Hz	74	24/07/2015 04:09:06	24/07/2015 04:17:00	Bp	57.8108	148.5097
11	40 Hz	76	24/07/2015 11:01:25	24/07/2015 11:02:25	Bp	57.8297	148.6982
12	40 Hz	77	24/07/2015 13:55:33	24/07/2015 16:43:59	Bp	57.8234	148.7416
13	40 Hz	78	24/07/2015 20:53:55	24/07/2015 20:56:36	Bp	57.7813	148.7390
14	40 Hz	100	29/07/2015 01:40:03	29/07/2015 01:40:31	Bp	57.1726	149.1971
15	40 Hz	100	29/07/2015 04:18:04	29/07/2015 04:18:32	Bp	57.1726	149.1971
16	40 Hz	104	29/07/2015 21:42:15	29/07/2015 21:44:22	Bp	57.1994	149.5357
17	40 Hz	118	01/08/2015 12:10:16	01/08/2015 12:39:41	Bp	56.8023	150.0085
18	40 Hz	118	01/08/2015 14:17:42	01/08/2015 14:59:58	Bp	56.8023	150.0085
19	40 Hz	119	01/08/2015 16:00:37	01/08/2015 17:00:06	Bp	56.7400	150.0221
20	40 Hz	144	06/08/2015 08:46:12	06/08/2015 08:50:19	Bp	56.6046	151.3855
21	40 Hz	144	06/08/2015 09:22:49	06/08/2015 09:28:39	Bp	56.6046	151.3855

Enc. [no.]	Call type	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
22	40 Hz	145	06/08/2015 10:44:01	06/08/2015 10:45:58	Bp	56.6017	151.4594
23	40 Hz	148	07/08/2015 01:09:21	07/08/2015 01:42:40	Bp	56.6286	151.5356
24	40 Hz	150	07/08/2015 09:18:08	07/08/2015 09:29:17	Bp	56.6716	151.4616
25	40 Hz	150	07/08/2015 11:04:14	07/08/2015 11:22:54	Bp	56.6716	151.4616
26	40 Hz	152	07/08/2015 17:15:16	07/08/2015 17:54:27	Bp	56.7113	151.3886
27	40 Hz	152	07/08/2015 18:39:49	07/08/2015 18:51:54	Bp	56.7113	151.3886
28	40 Hz	153	07/08/2015 22:02:41	07/08/2015 22:10:56	Bp	56.7387	151.3515
29	40 Hz	153	07/08/2015 23:05:23	08/08/2015 00:11:47	Bp	56.7387	151.3515
30	40 Hz	153	08/08/2015 00:49:40	08/08/2015 01:30:08	Bp	56.7387	151.3515
31	40 Hz	156	08/08/2015 10:03:44	08/08/2015 10:04:29	Bp	56.8048	151.2462
32	40 Hz	156	08/08/2015 13:43:36	08/08/2015 14:09:33	Bp	56.8048	151.2462
33	40 Hz	163	09/08/2015 19:45:40	09/08/2015 19:48:08	Bp	56.9674	151.0083
34	40 Hz	164	09/08/2015 21:36:33	09/08/2015 21:40:33	Bp	56.9931	150.9685
35	40 Hz	164	09/08/2015 23:08:12	09/08/2015 23:10:01	Bp	56.9931	150.9685

*Bp = *Balaenoptera physalus* (fin whale)

Possible sei whale encounters

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
1	5	11/07/2015 06:06:30	11/07/2015 07:06:33	Bb	59.1143	147.5508
2	6	11/07/2015 09:21:17	11/07/2015 09:23:26	Bb	59.0996	147.5164
3	8	11/07/2015 12:50:31	11/07/2015 12:50:42	Bb	59.0833	147.4765
4	8	11/07/2015 13:24:41	11/07/2015 13:26:17	Bb	59.0833	147.4765
5	9	11/07/2015 15:39:00	11/07/2015 15:41:03	Bb	59.0778	147.4560

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
6	12	12/07/2015 06:12:56	12/07/2015 06:28:44	Bb	59.0197	147.3386
7	17	13/07/2015 05:34:59	13/07/2015 05:38:30	Bb	58.9940	147.1817
8	17	13/07/2015 06:38:11	13/07/2015 06:39:11	Bb	58.9940	147.1817
9	19	13/07/2015 18:16:17	13/07/2015 18:38:30	Bb	58.9537	147.1183
10	21	14/07/2015 01:48:21	14/07/2015 02:06:19	Bb	58.9072	147.0346
11	21	14/07/2015 02:39:02	14/07/2015 02:52:00	Bb	58.9072	147.0346
12	21	14/07/2015 04:05:34	14/07/2015 04:05:38	Bb	58.9072	147.0346
13	22	14/07/2015 05:50:57	14/07/2015 06:53:55	Bb	58.8753	147.0122
14	26	15/07/2015 01:14:21	15/07/2015 01:14:26	Bb	58.7402	146.9179
15	27	15/07/2015 05:06:51	15/07/2015 05:26:36	Bb	58.7061	146.8934
16	27	15/07/2015 06:03:04	15/07/2015 06:19:37	Bb	58.7061	146.8934
17	32	16/07/2015 03:43:54	16/07/2015 03:43:59	Bb	58.5310	146.7823
18	33	16/07/2015 07:23:24	16/07/2015 07:32:07	Bb	58.4923	146.7652
19	34	16/07/2015 15:05:31	16/07/2015 15:05:36	Bb	58.4606	146.7670
20	42	18/07/2015 01:03:08	18/07/2015 01:36:33	Bb	58.3479	147.2379
21	43	18/07/2015 06:58:48	18/07/2015 07:29:40	Bb	58.3456	147.3287
22	43	18/07/2015 08:14:54	18/07/2015 08:47:31	Bb	58.3456	147.3287
23	47	19/07/2015 00:36:45	19/07/2015 00:37:45	Bb	58.3312	147.7098
24	48	19/07/2015 06:07:35	19/07/2015 07:18:23	Bb	58.3209	147.8057
25	51	19/07/2015 17:55:45	19/07/2015 18:38:26	Bb	58.2752	147.9963
26	55	20/07/2015 13:25:14	20/07/2015 13:29:15	Bb	58.0989	147.7846
27	56	20/07/2015 18:10:12	20/07/2015 18:10:16	Bb	58.0549	147.7467

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
28	59	21/07/2015 05:16:42	21/07/2015 06:34:25	Bb	57.9324	147.6240
29	64	22/07/2015 05:40:38	22/07/2015 05:40:40	Bb	57.7854	147.5827
30	64	22/07/2015 06:33:26	22/07/2015 06:43:09	Bb	57.7854	147.5827
31	65	22/07/2015 12:23:50	22/07/2015 12:23:53	Bb	57.7933	147.6683
32	68	23/07/2015 00:11:34	23/07/2015 00:11:39	Bb	57.7901	147.9335
33	76	24/07/2015 14:12:49	24/07/2015 14:13:11	Bb	57.8297	148.6982
34	77	24/07/2015 17:49:07	24/07/2015 17:49:19	Bb	57.8234	148.7416
35	77	24/07/2015 18:38:54	24/07/2015 18:59:28	Bb	57.8234	148.7416
36	83	25/07/2015 20:56:19	25/07/2015 21:10:39	Bb	57.5356	148.6544
37	84	25/07/2015 23:06:04	25/07/2015 23:07:34	Bb	57.4866	148.6347
38	84	26/07/2015 00:31:32	26/07/2015 00:31:45	Bb	57.4866	148.6347
39	84	26/07/2015 02:17:33	26/07/2015 02:49:52	Bb	57.4866	148.6347
40	85	26/07/2015 03:49:06	26/07/2015 04:22:11	Bb	57.4375	148.6197
41	85	26/07/2015 05:06:13	26/07/2015 05:06:58	Bb	57.4375	148.6197
42	88	26/07/2015 17:09:39	26/07/2015 17:10:45	Bb	57.2956	148.5871
43	88	26/07/2015 18:19:02	26/07/2015 18:19:49	Bb	57.2956	148.5871
44	88	26/07/2015 20:44:13	26/07/2015 20:44:20	Bb	57.2956	148.5871
45	90	27/07/2015 03:49:46	27/07/2015 03:58:09	Bb	57.2078	148.5845
46	90	27/07/2015 05:42:37	27/07/2015 05:42:41	Bb	57.2078	148.5845
47	91	27/07/2015 07:05:59	27/07/2015 07:37:31	Bb	57.1637	148.5798
48	91	27/07/2015 08:09:43	27/07/2015 08:13:06	Bb	57.1637	148.5798
50	91	27/07/2015 08:50:14	27/07/2015 08:50:20	Bb	57.1637	148.5798

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
51	91	27/07/2015 10:18:23	27/07/2015 10:19:34	Bb	57.1637	148.5798
52	92	27/07/2015 13:38:21	27/07/2015 13:38:28	Bb	57.1413	148.6115
53	93	27/07/2015 16:31:51	27/07/2015 16:32:11	Bb	57.1435	148.6761
54	96	28/07/2015 06:04:54	28/07/2015 06:07:47	Bb	57.1551	148.8887
55	96	28/07/2015 07:00:26	28/07/2015 07:00:31	Bb	57.1551	148.8887
56	96	28/07/2015 07:33:08	28/07/2015 07:33:11	Bb	57.1551	148.8887
57	99	29/07/2015 00:13:16	29/07/2015 00:13:29	Bb	57.1709	149.1181
58	101	29/07/2015 07:18:56	29/07/2015 07:19:37	Bb	57.1779	149.2792
59	103	29/07/2015 16:25:09	29/07/2015 16:25:15	Bb	57.1914	149.4466
60	117	01/08/2015 06:21:19	01/08/2015 06:21:24	Bb	56.8689	149.9954
61	118	01/08/2015 12:47:20	01/08/2015 12:47:36	Bb	56.8023	150.0085
62	121	02/08/2015 02:06:24	02/08/2015 02:47:16	Bb	56.6229	150.0649
63	122	02/08/2015 04:58:59	02/08/2015 05:16:56	Bb	56.5920	150.0986
64	122	02/08/2015 05:48:31	02/08/2015 05:57:47	Bb	56.5920	150.0986
65	122	02/08/2015 07:00:28	02/08/2015 07:59:03	Bb	56.5920	150.0986
66	123	02/08/2015 08:43:14	02/08/2015 09:45:32	Bb	56.5890	150.1583
67	123	02/08/2015 10:50:57	02/08/2015 11:20:39	Bb	56.5890	150.1583
68	124	02/08/2015 13:49:54	02/08/2015 14:22:24	Bb	56.5917	150.2240
69	127	03/08/2015 02:56:56	03/08/2015 02:56:59	Bb	56.6005	150.3749
70	127	03/08/2015 04:15:44	03/08/2015 04:16:58	Bb	56.6005	150.3749
71	127	03/08/2015 05:57:33	03/08/2015 05:59:31	Bb	56.6005	150.3749
72	129	03/08/2015 13:25:34	03/08/2015 13:25:37	Bb	56.6025	150.4644

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees E]
73	133	04/08/2015 06:34:08	04/08/2015 06:34:11	Bb	56.6232	150.6616
74	133	04/08/2015 09:02:13	04/08/2015 09:05:49	Bb	56.6232	150.6616
75	149	07/08/2015 06:24:02	07/08/2015 06:28:11	Bb	56.6531	151.5027
76	150	07/08/2015 10:01:11	07/08/2015 10:34:16	Bb	56.6716	151.4616
77	160	09/08/2015 06:10:27	09/08/2015 06:10:32	Bb	56.9041	151.1155
78	162	09/08/2015 13:07:22	09/08/2015 13:07:26	Bb	56.9442	151.0405
79	162	09/08/2015 16:21:04	09/08/2015 16:21:44	Bb	56.9442	151.0405
80	163	09/08/2015 17:50:09	09/08/2015 17:50:18	Bb	56.9674	151.0083
81	172	11/08/2015 00:29:04	11/08/2015 00:31:29	Bb	57.0909	150.8001
82	172	11/08/2015 02:54:46	11/08/2015 03:02:46	Bb	57.0909	150.8001

*Bb = Balaenoptera borealis (sei whale)

Unidentified downsweep series

Enc. [no.]	Dive [no.]	Start date [UTC] [dd/mm/yyyy hh:mm:ss]	End date [UTC] [dd/mm/yyyy hh:mm:ss]	Species ID/Label*	Latitude [degrees N]	Longitude [degrees W]
1	5	11/07/2015 06:37:45	11/07/2015 07:04:25	UDS	59.1143	147.5508
2	6	11/07/2015 07:38:30	11/07/2015 07:38:54	UDS	59.0996	147.5164
3	7	11/07/2015 10:58:52	11/07/2015 10:59:24	UDS	59.0869	147.4896
4	12	12/07/2015 05:22:15	12/07/2015 05:34:41	UDS	59.0197	147.3386
5	22	14/07/2015 07:59:04	14/07/2015 08:10:52	UDS	58.8753	147.0122

*UDS = Unidentified downsweep series