PROTECTED SPECIES MITIGATION AND MONITORING REPORT

Marine Geophysical 2D Seismic Survey, Puerto Rico (Cruise ID No. MGL2314, MGL2315, and MGL2316)

Puerto Rico Survey, RV *Marcus G Langseth* (Callsign: WDC6698)
29 October 2023 to 15 December 2023

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Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

ADCP – Acoustic Doppler Current Profiler
BSS – Beaufort Sea State
BiOp – Biological Opinion
BZ – Buffer Zones
DAQ – Data Acquisition
dB - Decibels
EA – Environmental Assessment
EPU – Electronic Processing Unit
ESA – Endangered Species Act
EEZ – Economic Exclusion Zone
EZ – Exclusion Zone
FFT – Fast Fourier Transform
FONSI – Finding of No Significant Impact
GPS – Global Positioning System
HE – High Energy
HF – High Frequency
IHA – Incidental Harassment Authorization
ITS – Incidental Take Statement
IRIS – Incorporated Research Institutions for Seismology
LDEO – Lamont-Doherty Earth Observatory
LE – Low Energy
LF – Low Frequency
MBES – Multibeam Echosounder
MCS – Multi-Channel Seismic
MGL – R/V Marcus G. Langseth
MMPA – Marine Mammal Protection Act
NMFS – National Marine Fisheries Service
NRP – Navigation Reference Point
NSF – National Science Foundation
OBS – Ocean Bottom Seismometer
OPR – Office of Protected Resources
PAM – Passive Acoustic Monitoring
PASSCAL – Portable Array Seismic Studies of the Continental Lithosphere
PI – Principal Investigator
PTS – Permanent Threshold Shift
PSO – Protected Species Observer
RME – PAM sound card manufacturer company name (not an acronym)
RMS – Root Mean Square
RPS – PSO provider company name (not an acronym)
R/V – Research Vessel
SBP – Sub-bottom Profiler
TOAD – Time of Arrival Distance
TTS – Temporary Threshold Shift
US – United States
USGS – United States Geological Survey
USB – Universal Serial Bus
UPRM – University of Puerto Rico Mayagues
UTGI – University of Texas Institute of Geophysics
UTC – Coordinated Universal Time
VSA – Vessel Strike Avoidance
WHOI – Woods Hole Oceanographic Institution

1 EXECUTIVE SUMMARY

The research vessel (R/V) *Marcus G. Langseth* (*MGL*), which is owned and operated by Columbia University's Lamont-Doherty Earth Observatory (LDEO), conducted three, two-dimensional (2D) seismic surveys off the north and south coasts of Puerto Rico. The three seismic surveys (referred to herein as "surveys") included: (1) a low-energy multi-channel seismic (MCS) survey conducted between 29 October 2023 and 02 November 2023; (2) a high-energy MCS survey conducted between 03 and 19 November 2023; and (3) a high-energy ocean-bottom seismometer (OBS) survey conducted between 21 November and 15 December 2023. The operational activities were conducted in support of research proposed by Principal Investigators (PIs) Dr. U.ten Brink (United States Geological Survey – USGS), Dr. S. Han (University of Texas Institute of Geophysics - UTGI), Dr. J.P. Canales (Woods Hole Oceanographic Institution - WHOI), and Dr. E. Vanacore (University of Puerto Rico Mayagues - UPRM). In addition, the PIs collaborated with Dr. I. Greyemeyer (GEOMAR Helmholts Centre for Ocean Research) for the ultra-deep sea OBSs required for the survey.

The purpose of the low-energy survey was to support USGS research and understanding of Earth processes and the natural hazards they pose to Puerto Rico and the Virgin Islands to increase public safety and reduce risk of economic loss. The purpose of the high-energy surveys was to provide new constraints for examining earthquake and tsunami hazards associated with the Puerto Rico Trench region.

This report was prepared to meet the reporting requirements for the survey required under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). On 27 April 2023, LDEO, USGS, and National Science Foundation (NSF) applied to the US National Marine Fisheries Service (NMFS) for an Incidental Harassment Authorization (IHA) that would allow for the potential harassment of small numbers of protected marine mammals incidental during the seismic survey. NSF and USGS issued final Environmental Analysis (EA) on 26 September 2023. NMFS issued their Biological Opinion (BiOp) on 04 October 2023 and the IHA on 06 October 2023. NSF issued a Finding of No Significant Impact (FONSI) on 23 October 2023 and USGS on 11 October 2023.

Mitigation measures were implemented to minimize potential impacts to marine mammals and protected species. These measures included, but were not limited to, the use of NMFS approved Protected Species Observers (PSOs) for visual and acoustic monitoring, the designation and implementation of buffer zones (BZ) and exclusion zones (EZ) (where the presence of a protected species would require a mitigation action), and the implementation of ramp-up procedures, mitigation actions (including delayed operations and shutdowns), and vessel strike avoidance (VSA) maneuvers. Continuous protected species observation coverage during the survey was provided by RPS, the PSO provider contracted for the survey. PSOs monitored and reported on the presence and behavior of protected species and directed the implementation of the mitigation measures, as described in the regulatory documents issued for the survey.

A team of five PSOs, one of which was designated as the team Lead, was present onboard the *MGL* throughout all three parts of the survey program to conduct visual and acoustic monitoring. Throughout the entire survey program, PSOs conducted visual monitoring for a total of 547 hours and 53 minutes and acoustic monitoring for a total of 506 hours and 47 minutes. Visual and acoustic monitoring were conducted simultaneously for a total of 256 hours and 45 minutes. The seismic source was active for a total of 528 hours and 36 minutes, which occurred during 267 hours and 35 minutes of visual monitoring and 460 hours of acoustic monitoring.

There were two visual detections of protected species during the survey program including one sighting of a spinner dolphin (*Stenella longirostris*) and one sighting of common dolphins (*Delphinus delphis*).

There was one acoustic detection of protected species during the survey program consisting of unidentifiable dolphins.

Protected species detections resulted in the implementation of no mitigation actions during the survey program. There was one VSA maneuver implemented for visual detections of protected species.

The IHA issues by NMFS authorized 14,123 Level B takes for 21 species and two species groups of marine mammals, including four species listed as endangered. There were 30 Level A takes authorized for three species and one species group, including one species listed as endangered. For this report, the

definition of Level A and Level B takes are the same as found in the MMPA and the NMFS issued BiOp regarding what constitutes a take. There were no specified number of authorized takes for ESA-listed sea turtle species or ESA-listed seabird species.

Throughout the survey program, no marine mammals were observed within the predicted 160-decibel (dB) radius and no sea turtles were observed within the 175-dB radius (where there is a potential for a behavioral response and temporary threshold shift (TTS)) (NMFS Biological Opinion 10.3.2.1) while the acoustic source was active, constituting potential Level B takes. There were no protected species observed within the predicted radius at which there is a potential for auditory injury (based upon each species hearing range and how that overlaps with the frequencies produced by the sound source), constituting potential Level A takes.

2 INTRODUCTION

The following report details protected species monitoring and mitigation as well as seismic survey operations undertaken as part of the low-energy and high-energy 2D marine geophysical surveys on board the R/V *Marcus G. Langseth* (*MGL*) off the north and south coasts of Puerto Rico from 29 October 2023 to 15 December 2023.

This document serves to meet the reporting requirements dictated in the IHA issued to NSF by NMFS on 06 October 2023. The IHA authorized takes of specific protected species incidental to the survey. NMFS has stated that seismic source received sound levels equal to or greater than 160 dB re 1 µPa root mean square (RMS) (160 dB) could potentially disturb marine mammals, temporarily disrupting behavior, such that they could be considered non-lethal 'takes' (Level B harassment). In April 2018, NMFS released a revised version of technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing, which established thresholds for permanent threshold shift (PTS) onset, (TTS), and Level A harassment (auditory injury), for marine mammal species. Predicted distances to Level A harassment vary based on species specific hearing groups – low frequency cetaceans, mid frequency cetaceans, high frequency (HF) cetaceans, phocid pinnipeds, and otariid pinnipeds– and how each group's hearing range overlaps with the frequencies produced by the sound source. For sea turtles, per the ESA, NMFS has stated that received sound levels equal to or greater than 175 dB represents the current best understanding of the threshold at which they exhibit behavioral responses.

NMFS requires that measures such as BZs, EZs, delayed operations, ramp-ups, and shutdowns be implemented to mitigate for potentially adverse effects of the acoustic source sounds on protected species. The BZs and EZs were established from any element on the acoustic source array as areas where the presence of a protected species would require the implementation of a mitigation action (see Section 6). For all protected species, the occurrence of an individual detected approaching, entering, or within their designated EZ would require the implementation of a shutdown of the seismic source. NMFS specified a 100-meter EZ for the low-energy survey and a 500-meter EZ for the high-energy survey for most marine mammals as it encompasses all zones within which auditory injury (Level A harassment) could occur on the basis of instantaneous exposure, provides additional protection from the potential for more severe behavioral reactions for marine mammals at relatively close range to the acoustic source, provides a consistent area for PSOs to conduct effective observational effort, and is a distance within which detection probabilities are reasonably high for most species under typical conditions.

In accordance with the IHA, the PSO team conducted onboard environmental management briefings with the vessel personnel prior to the start of source operations for each part of the survey. The lead PSOs covered the mitigation and monitoring protocols, communication procedures, roles and responsibilities of the monitoring team and any additional operational procedures for this survey.

The IHA is attached as Appendix A.

2.1 Project Overview and Location

The research activities included a 2D low-energy MCS survey in the Caribbean Sea off the south coast of Puerto Rico, a 2D high-energy MCS survey in the Northwest Atlantic ocean off the north coast of Puerto Rico, and a 2D high-energy OBS survey off both north and south coasts of Puerto Rico, between approximately 17 to 21 degrees North and 63.6 to 68.5 degrees West, within the Exclusive Economic Zone (EEZ) and coastal zone of Puerto Rico, and the EEZs of the Dominican Republic, the U.S. Virgin Islands, and the British Virgin Islands (Figure 1). The closest distance from the survey areas to the land was approximately 2.5 kilometers on the southern coast of Puerto Rico and approximately 22 kilometers on the northern coast of Puerto Rico. Water depths in the survey areas were between 100 and 8,400 meters.

The primary goal of the low-energy MCS survey was to support USGS research to understand earth processes and the natural hazards they pose to Puerto Rico and the Virgin Islands. The low-energy survey was located over the 2019-2020 area of seismic activity in the Caribbean Sea and will define the geometry of the faults that ruptured and produced earthquakes and other seismogenic structures.

The primary goal of the high-energy MCS and OBS surveys was to investigate the Puerto Rico Trench, its' outer rise, and across the island of Puerto Rico. The data will illuminate the depth, geometry, and physical properties of the seismogenic fault interface between the subducting Atlantic plate and the overlaying accretionary wedge/Puerto Rico arc/Caribbean plate, as well as seismogenic structures in the accretionary wedge and submarine slopes of the island of Puerto Rico.

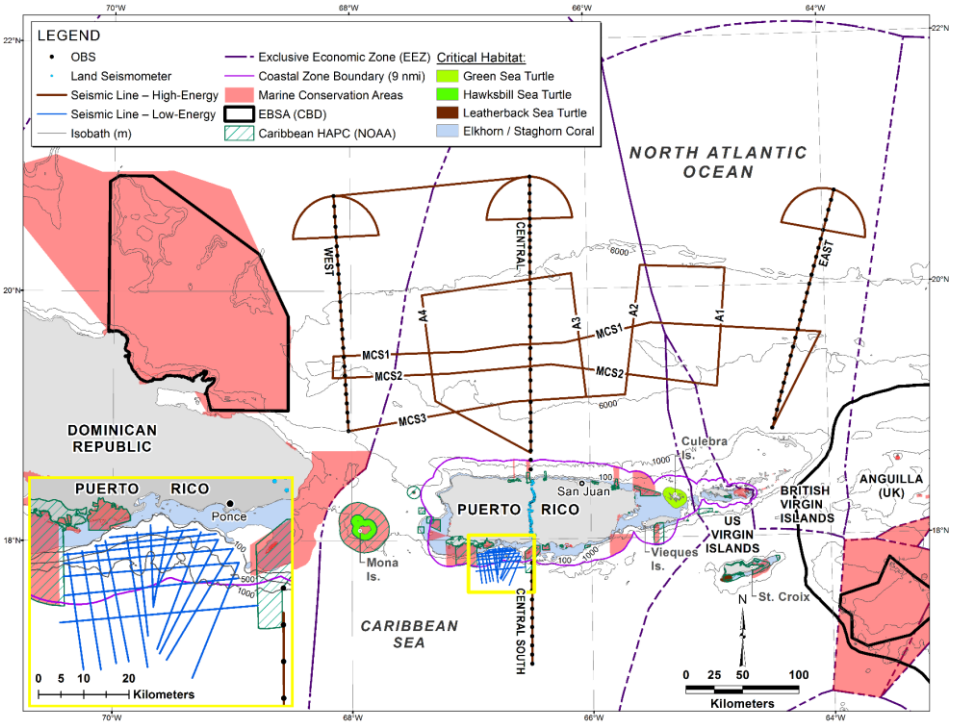


Figure 1: Location and planned survey lines of the seismic surveys.

All operations for the survey were conducted solely by *MGL*. The vessel is 72 meters (236.2 feet) in length and has a beam of 17 meters (55.8 feet) and a maximum draft of 5.9 meters (19.4 feet). The vessel's cruising speed was approximately 10 knots during transits and varied between three and five knots during seismic survey operations.

Seismic source operations for the low-energy MCS survey were conducted between 30 October and 02 November 2023, and included four days with source operations totaling 454.45 kilometers acquired over 18 survey lines (Figure 2). Seismic source operations for the high-energy MCS survey were conducted between 05 and 18 November 2023, and included 14 days with source operations totaling 2,143.35 kilometers acquired over 15 survey lines (Figure 3). Seismic source operations for the high-energy OBS survey were conducted between 24 November 2023 and 13 December 2023, and included 12 days with source operations totaling 2,675.20 kilometers acquired over seven survey lines and one test line, including the north-central survey line that was acquired twice due to issues with the OBSs during the first attempt (Figure 4). Two of the high-energy survey lines were acquired with both MCS and OBS data.

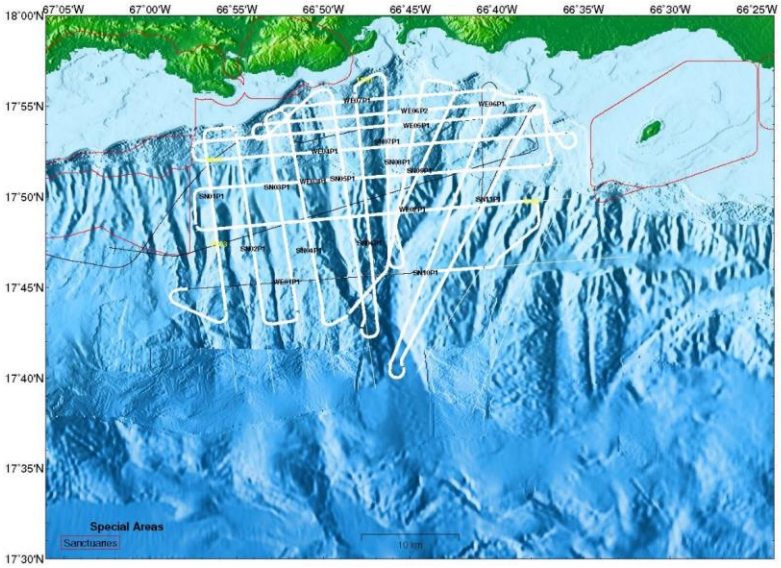


Figure 2: Survey lines acquired during the USGS low-energy 2D seismic survey.

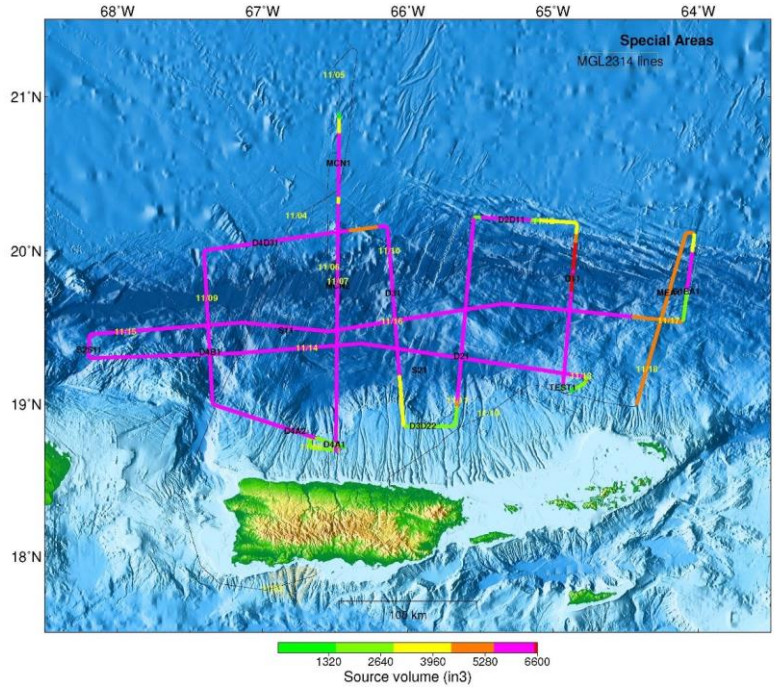


Figure 3: Survey lines acquired during the high-energy MCS 2D seismic survey.

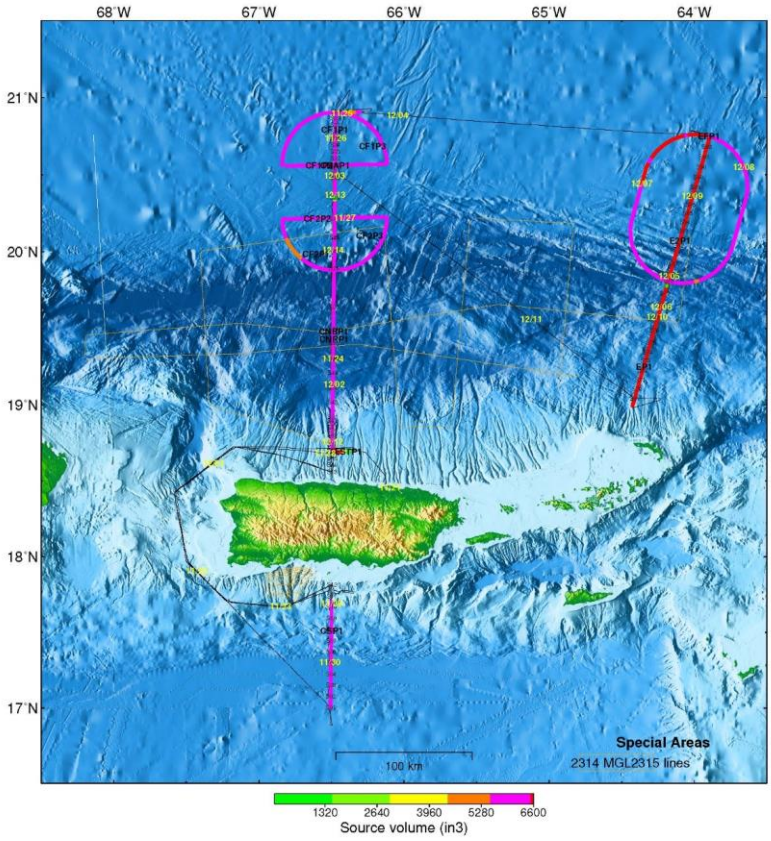


Figure 4: Survey lines acquired during the high-energy OBS 2D seismic survey.

2.1.1 Energy Source and Receiving Systems

For the low-energy USGS survey, the energy source consisted of a single towed seismic source array comprised of two 45/105 cubic inch (in^3) GI elements that had a total operating volume of 90 in^3. The elements were towed at a depth of three meters and had an operating pressure of 1,900 pounds per square inch (psi) (plus or minus 100 psi). The dominant frequency components ranged from two to 188 Hertz (Hz), and nominal source levels ranged from 231.1 dB re: 1 µPa (zero to peak) to 237 dB re: 1 µPa (peak-to-peak). The shot point interval was 12.5 meters. The first element on the array was situated at the center of the surface float positioned 287 meters from the navigation reference point (NRP), which was located on the PSO observation tower. This positioned the first element 258 meters from the stern of the vessel, and the second element was positioned 2.45 meters astern of the first element.

For both high-energy surveys, the energy source consisted of four towed seismic source sub-arrays, each with nine source elements (for a total of 36 source elements). The source array utilized Bolt 1500LL and Bolt 1900LLX elements ranging in volume from 40 to 360 cubic inches (in^3), with an operating pressure of 1,950 pounds per square inch. The dominant frequency components ranged from two to 188 Hertz (Hz), and nominal source levels ranged from 258 dB re: 1 µPa (zero to peak) to 264 dB re: 1 µPa (peak-to-peak). The maximum source volume with all 36 elements active was 6,600 in^3; however, when there were

issues with the elements and during times when source sub-arrays were brought onboard for maintenance, the total source volume was reduced to varying lower volumes depending on how many of the elements/sub-arrays were disabled. The source elements were towed at a depth of 12 meters for both MCS and OBS parts of the high-energy survey. The shot point interval for the MCS part of the survey was 50 meters, while the shot point interval for the OBS part of the survey was 300 meters for the northern survey lines and 120 meters for the single southern survey line. For both MCS and OBS parts of the high-energy survey, the center of the source was situated 276 meters from the NRP, which placed the first elements on the arrays 247 meters from the stern of the vessel.

The receiver systems for the surveys included a single towed hydrophone streamer for the MCS parts of the survey and ocean bottom seismometers for the OBSs part of the survey. While the streamer received the returning acoustic source signal and transferred the data to the on-board processing system, the OBSs stored the returning acoustic source signals internally for later analysis after the devices were retrieved from the seafloor back to the vessel.

The towed hydrophone streamer for the low-energy MCS survey was 900 meters in length and was towed at a depth of four meters. The head float for the streamer was positioned 338 meters from the NPR (309 meters from the stern of the vessel and 43 meters astern of the source array). The towed hydrophone streamer for the high-energy MCS survey was 13,650 meters in length and was towed at a depth of 12 meters. From 04 to 07 November 2023, the streamer head-float was positioned 325 meters from the NRP (296 meters from the stern of the vessel and 49 meters astern of the source arrays). From 08 November to 18 November 2023, the streamer was moved further astern to prevent the source arrays from getting tangled with the lead-in and was positioned 382 meters from the NRP (353 meters from the stern of the vessel and 106 meters astern of the source arrays).

The receiver for the OBS part of the high-energy survey included OBSs from WHOI, Scripps, and GEOMAR. The WHOI and Scripps OBSs were deployed in water depths less than 6,000 meters, while the GEOMAR OBSs were deployed in water depths greater than 6,000 meters. During deployment, the OBSs were attached to a steel anchor that was used to sink the devices to the seafloor. To retrieve an OBS, the operators onboard the vessel triggered a burn-wire assembly, which releases the OBS from the anchor, allowing it to float to the surface where it was retrieved by the vessel (the anchor is left on the seafloor). There were a total of 12 OBSs deployed along the south-central survey line, 26 OBSs deployed along the north-central survey line, and 25 OBSs deployed along the north-east survey line. The OBSs were retrieved after the acquisition of each survey line and re-deployed along the next line. The north-central survey line was acquired a second time at the end of the survey due to issues with the OBSs during the initial acquisition of the line, and during the second acquisition there were 12 OBSs deployed within and on either side of the trench.

There were an additional 100 land seismometers from the incorporated Research Institutions for Seismology (IRIS) Portable Array Seismic Studies of the Continental Lithosphere (PASSCAL) Instrument Center at New Mexico Tech that were positioned along the island of Puerto Rico to connect the north and south central OBS survey lines. These land seismometers were placed before the OBS survey began and remained in position for additional time after the completion of the survey.

Additional sound sources used in support of research efforts included a Kongsberg EM 122 multi-beam echosounder (MBES), Knudsen Chirp 3260 sub-bottom profiler (SBP), and a Teledyne RDI 75 kHz Ocean Surveyor acoustic doppler current profiler (ADCP). The hull mounted MBES operated at frequencies between 10.5 and 13 (usually 12) kilohertz. Each ping consisted of eight (in water depths greater than 1000 meters) or four (in water depths less than 1000 meters) successive fan-shaped transmissions. The transmitting beam width was one or two degrees fore-aft and 150 degrees perpendicular to the ship's line of travel. The maximum source level was 242 dB re: 1 µPa m (rms). The hull-mounted SBP beam was transmitted as a 27-degree cone, which was directed downward by a 3.5 kilohertz transducer. The nominal power output was 10 kilowatts; however, the actual maximum radiated power was three kilowatts or 222 dB re: 1 µPa m (rms). The ping duration was 64 seconds, and the interval was one second. The hull-mounted ADCP operated at a frequency of 75 kilohertz and a maximum source level of 224 dB re: 1 µPa m (rms) over a conically shaped 30-degree beam. The MBES and SBP operated simultaneously to provide information about near seafloor sedimentary features and to map the topography of the ocean floor. The ADCP was used to measure water current velocities.

3 MITIGATION AND MONITORING METHODS

The PSO monitoring program on the *MGL* was established to meet the standards set forth in the IHA and BiOp requirements. Survey mitigation measures were designed to minimize potential impacts of the *MGL's* seismic source activities on marine mammals and other protected species of interest. The following monitoring protocols were implemented to meet these objectives.

- Visual observations were conducted to provide real-time sighting data, allowing for the implementation of mitigation procedures as necessary.
- A passive acoustic monitoring (PAM) system was operated 24 hours a day during high-energy seismic source operations to augment visual observations and provide additional marine mammal detection data.
- Effects of marine species exposed to sound levels constituting a defined take were observed and documented. The nature of the probable consequences was discussed when possible.

In addition to the mitigation objectives outlined in the project permit documents, PSOs collected and analyzed necessary data mandated by the IHA.

3.1 Mitigation Methodology

Mitigation actions were implemented for visual and acoustic detections of protected species, including marine mammals, sea turtles, and ESA-listed seabirds, as outlined in the IHA, BiOp, and EA. These actions included the establishment of BZs and EZs as the areas in which the presence of a protected species would trigger a mitigation action, and the implementation of delayed operations and shutdowns (where the seismic source was fully silenced) for protected species detected approaching, entering, or within their designated BZ and EZ Table 1 and Table 2). Throughout the detections, PSOs and PAM operators would keep in frequent contact with each other and the seismic team, relaying information on the location and movement of the protected species, and the implementation of any needed mitigation actions and clearances to begin/resume operation of the seismic source.

Before the seismic source could be activated from silence, a 30-minute clearance search period of the BZs and EZs was conducted during both daylight and night-time hours. For the low-energy survey, this search period was conducted by two PSOs. For the high-energy surveys, this search period was conducted by two PSOs and one PAM operator. In the event of a detection of protected species within their designated zones (Table 2) or as outlined in Table 1, a delay of source activation operations would be implemented. Source operations would not be cleared to begin until the protected species were observed exiting their designated zones, or if they were not observed exiting their zone, then 15 or 30 minutes (species dependent, see Table 2) following the final detection of the individual(s) within their zone.

Once the seismic source was active, the BZs from any element on the source array were established as areas in which the presence of a protected species would initiate an alert to the seismic operators that the animal was detected, and that the implementation of a mitigation action may soon be required. The EZs from any active source element were established as areas in which the detection of a protected species would require a shutdown of the seismic source. For marine mammals and sea turtles, the detection of one approaching, entering, or within their designated zone would require a shutdown (excluding the specified shut-down exemption delphinid species per the IHA and BiOp). For ESA-listed sea birds, the detection of one foraging or diving within their designated zone would require a shutdown.

Upon the implementation of a shutdown for a detection of marine mammals, a ramp-up was required to resume source activity once the protected species were confirmed to have exited their designated EZs. For sea turtles and ESA-listed seabirds, source activity could resume to the previous operative volume without a ramp-up once the protected species were confirmed to have exited their designated EZs. If the protected species could not be confirmed to have exited their designated EZ (i.e., if they dove/submerged within the zone and were not re-sighted), then clearance for source activity to resume would not be given until 15 or 30 minutes (species dependent, see Table 2) following the final detection of the individual(s) within their zone.

The IHA also outlined additional mitigation actions for specific protected species while the acoustic source was active as outlined in Table 1.

Table 1: Specific detections of protected species and their required mitigation actions.

Detection of:	Mitigation Action Required
A large whale with a calf detected 1,500 meters from the seismic source.	Delayed operation of inactive source and shutdown of active source.
An aggregation of six or more large whales detected 1,500 meters from the seismic source.	Delayed operation of inactive source and shutdown of active source.
Any beaked whale or pygmy or dwarf sperm whale detected at 1,500 meters from the seismic source.	Delayed operation of inactive source and shutdown of active source.
Any marine mammal species not authorized for take observed approaching, entering, or within the 160-dB radius.	Delayed operation of inactive source and shutdown of active source.
Any marine mammal species for which the total authorized takes has been met observed approaching, entering, or within the 160-dB radius.	Delayed operation of inactive source and shutdown of active source.
Any other marine mammals detected approaching, entering, or within their designated buffer and exclusion zones.	Delayed operation of inactive source (buffer zone) and shutdown of active source (exclusion zone).
Any sea turtle species detected approaching, entering, or within their designated buffer and exclusion zones.	Delayed operation of inactive source (buffer zone) and shutdown of active source (exclusion zone).
Any ESA-listed sea bird species detected diving and/or foraging within their designated buffer and exclusion zones.	Delayed operation of inactive source (buffer zone) and shutdown of active source (exclusion zone).
Any dolphin species with a shut-down exemption detected approaching, entering, or within their designated exclusion zones with an active source.	None.

Table 2: Separation distances, buffer and exclusion zones sizes for each species / species group expected to occur in the survey area during the low energy (LE) and high energy (HE) surveys.

Species/Species Groups	Separation Distance (meters)	Buffer Zones (meters)		Exclusion Zones (meters)		Delay Duration (minutes)
		LE survey	HE survey	LE survey	HE survey	
Large whale with a calf	100	500	1,500	500	1,500	30
Groups of six or more large whales	100	500	1,500	500	1,500	30
Beaked whales	100	500	1,500	500	1,500	30
Pygmy and dwarf sperm whales	100	500	1,500	500	1,500	30
Sperm whales	100	200	1,000	100	500	30
Mysticetes	100	200	1,000	100	500	30
Killer whales, Risso's dolphins, pilot whales	50	200	1,000	100	500	30
All other small delphinids[1] and porpoises	50	200	1,000	100	500	15
Pinnipeds (1 element) >1,000 m water depth	50	431	431	431	431	15
Pinnipeds (1 element) 100-1,000 m water depth	50	647	647	647	647	15
Pinnipeds (2 elements) >1,000 m water depth	50	438	438	438	438	15

Species/Species Groups	Separation Distance (meters)	Buffer Zones (meters)		Exclusion Zones (meters)		Delay Duration (minutes)
		LE survey	HE survey	LE survey	HE survey	
Pinnipeds (2 elements) 100-1,000 m water depth	50	657	657	657	657	15
Pinnipeds (36 element) >1,000 m water depth	50	6,733	6,733	6,733	6,733	15
Pinnipeds (36 element) 100-1,000 m water depth	50	10,100	10,100	10,100	10,100	15
Sea turtles	none	100	300	100	150	15
ESA-listed sea birds	none	100	150	100	150	15

1 Except exempt species of the genera *Delphinus, Lagenodelphis, Stenella, Steno, and Tursiops* per the NMFS IHA.

Specific acoustic source operation procedures outlined in the IHA and BiOp that were relevant to these surveys included:

1. Ramp-ups could not be less than five minutes for the low-energy survey and not less than 20 minutes for the high-energy surveys. For the low-energy survey, the ramp-up was conducted by enabling one gun and then five minutes later enabling the second gun. For the high-energy surveys, ramp-ups began with the smallest volume element and continued in stages by doubling the number of active elements, with each stage being approximately the same duration. For both high and low energy surveys, the time between ramp-up completion and start of data acquisition had to be minimized.
2. Testing of individual elements or strings required a 30-minute clearance search period but no ramp-up. Testing of more than one element or string required both a 30-minute clearance search and a ramp-up to the maximum source volume being tested.
3. Brief periods (less than 30 minutes) or operational silence for reasons other than a protected species shut-down did not required a ramp-up to resume source operations provided that: (1) PSOs maintained constant acoustic and/or visual observations, and (2) no detections of protected species occurred within the applicable exclusion zone during that silent period. For the high-energy surveys only, any brief period of silence at night or in periods of poor visibility (e.g., BSS of four or greater) required a ramp-up to resume source operations, but if constant monitoring was maintained, a 30-minute clearance search period was not required. For the low-energy survey only, any brief period of silence at night did not require monitoring or a ramp-up to resume source operations. For both surveys, any longer shutdowns required both a 30-minute clearance search period and a ramp-up.

Table 3 outlines the predicted 160 dB radius (Level B harassment zone for marine mammals) and the predicted 175 dB radius (Level B harassment zone for sea turtles) for both a single 40 in^3 element and the full source volume of 6,600 in^3 used for the high energy surveys, and the two 45/105 in^3 GI elements used for the low-energy survey, which varied depending on the water depth. Table 4 Table 3outlines the predicted Level A harassment zones for each hearing group, which differed for the high-energy and low-energy parts of the survey, including low frequency cetaceans (all mysticete species), mid-frequency cetaceans (sperm whales, beaked whales, and all delphinid species), high frequency cetaceans (Kogia and porpoise species), and sea turtles.

Table 3: Predicted 160 and 175 dB zones implemented during the high-energy (HE) and low-energy (LE) seismic surveys.

Source	Volume (in^3)	Water Depth (meters)	160 dB radius (meters) – Level B harassment zone for marine mammals	175 dB radius (meters) – Level B harassment zone for sea turtles
(HE) 1 element	40	>1,000	431	77
		100-1,000	647	116

Source	Volume (in^3)	Water Depth (meters)	160 dB radius (meters) – Level B harassment zone for marine mammals	175 dB radius (meters) – Level B harassment zone for sea turtles
(HE) 36 elements	6,600	>1,000	6,733	1,864
		100-1,000	10,100	2,796
(LE) Two 45/105 GI elements	90	>1,000	438	78
		100-1,000	657	117

Distances are from any single elements on the array.

Table 4: Predicted Level A harassment zones implemented during the high-energy (HE) and low-energy (LE) seismic surveys.

Source	Volume (in3)	Low frequency cetaceans (meters)	Mid-frequency cetaceans (meters)	High frequency cetaceans (meters)	Sea turtles (meters)
(HE) 36 elements	6,600	320.2	13.6	268.3	15.4
(LE) Two 45/105 GI elements	90	5.49	1.10	35.34	0.45

Distances are from any single elements on the array.

3.2 Visual Monitoring Survey Methodology

There were five experienced PSOs on board the *MGL* during throughout the survey program to conduct monitoring for protected species, record and report detections, and request mitigation actions in accordance with the IHA and BiOp. The PSOs onboard were NMFS approved and held certifications from a recognized Bureau of Ocean Energy Management (BOEM) PSO course and are listed in Appendix B. Visual monitoring was primarily carried out from an observation tower (Figure 5) located 18.9 meters above the surface of the water, which allowed a 360-degree viewpoint around the vessel and seismic source.

Figure 5: Protected Species Observer stern view of observation tower with mounted big-eye binoculars.

The PSO tower was equipped with Fujinon 7x50 and Steiner Marine 7x50 binoculars, as well as two mounted 25x150 Big-eye binoculars for visual monitoring. A D-300-2MS Night Optics USA, Inc.

monocular and two Butler Creek PVS-7-night vision devices were also available for visual monitoring during reduced/restricted lighting conditions if needed. Two Canon 80D cameras with 300-millimeter lenses were also provided to document protected species detections and other wildlife. Inside the tarpaulin tent the PSOs were provided a laptop for data entry; a telephone and two hand-held VHF radios for communication with the PAM operator, seismic operators, and the bridge; and a monitor that displayed pertinent information about the vessel (position, speed, heading, water depth), source activity (line number, number of active elements, operating volume), and environmental conditions (wind speed and direction, air and sea temperatures). Environmental conditions along with vessel and acoustic source activity were recorded at least once an hour, and every time there was a change in one or more of the above variables. Most visual monitoring was preferably held from the PSO tower; however, during severe weather or when the ships exhaust was blowing on the tower, monitoring would be conducted from the bridge (approximately 12.8 meters above sea level) or the bridge-wings (approximately 12.3 meters above sea level).

Visual monitoring methods were implemented in accordance with the survey requirements outlined in the IHA. A minimum of two PSOs were required to be on duty conducting monitoring during all daylight hours (30 minutes before sunrise to 30 minutes after sunset) while the vessel was at sea. Visual monitoring during the transits with the survey gear secured onboard were conducted to implement any needed vessel strike avoidance maneuvers and to gather baseline data on the presence and abundance of protected species in the areas during periods of acoustic source silence. Scheduled watches were a maximum of four hours followed by at least one hour of scheduled break time.

Visual observations were conducted around the entire area of the vessel and acoustic source, divided between the two PSOs on watch. The smaller monitoring area for each observer increased the probability of protected species being sighted. PSOs searched for blows, fins, splashes or disturbances of the sea surface, large flocks of feeding sea birds, and other sighting cues indicating the possible presence of a protected species. Upon the visual detection of a protected species, PSOs would identify the animals' range to the vessel and acoustic source. Range estimations were made using reticle binoculars, the naked eye, and by relating the animal(s) to an object at a known distance, such as the acoustic source arrays and streamer head float. PSOs would also identify to species, if possible, upon initial detection to ensure that the proper mitigation measures were implemented, should any be required.

As required by the IHA (section 5(d)(iii)), PSOs recorded the following information for each protected species detection:

I. Date, time of first and last sighting, observers on duty during the detection, location of the observers, vessel information (e.g., position, speed, heading), water depth, and acoustic source activity (e.g., volume and number of active elements).

II. Species, detection cue, group size (including number of adults, juveniles, and calves), visual description (e.g., overall size, shape of the head, position and shape of the dorsal fin, shape of the flukes, height, and direction of the blow), observed behaviors (e.g., porpoising, logging, diving, etc.), and the initial and final pace, heading, bearing, and direction of travel in relation to both the vessel and the source (e.g., towards, away, parallel, perpendicular, etc.).

III. Initial, closest, and final distance to the vessel and the source, time when entering and exiting the exclusion zones, type of mitigation action implemented, total time of the mitigation action, description of other vessels in the area, and any avoidance maneuvers conducted.

PSOs took notes during the sighting event, and once the detection concluded, the detection details were recorded in a datasheet per the requirements of the IHA. Each sighting event was linked to an entry on an effort datasheet where specific environmental conditions (e.g., Beaufort Sea State, wind force, swell height, visibility, and glare) and vessel activity were logged.

Species identifications were made whenever the distance from the observer, length of the sighting, and visual observation conditions allowed. Marine mammal identification manuals (*Whales, Dolphins, and Other Marine Mammal of the World; Guide to Marine Mammals of the world; Readers Digest Whales, Dolphins, and Porpoises*) were consulted, and photos were examined to confirm identifications were consulted, and photos were examined to confirm identifications.

3.3 Passive Acoustic Monitoring Methodology

Passive Acoustic Monitoring (PAM) was used to augment visual monitoring efforts in the detection, identification, and locating of marine mammals, especially during periods of time when visual monitoring was not effective (periods of darkness or low visibility). Acoustic monitoring was conducted continuously during all high-energy seismic operations and to the maximum extent possible during periods of acoustic source silence. There was no acoustic monitoring required or conducted during the low-energy survey. When the acoustic source was activated from any extended period of silence, acoustic monitoring was conducted for at least 30 minutes prior to the activation of the source for the pre-clearance search along with the two visual PSOs. PAM shifts were a maximum of four hours in duration followed by at least one hour of scheduled break time.

In accordance with the NMFS issued IHA and Incidental Take Statement (ITS), in the event of an issue with PAM equipment, acoustic source activity could continue for 30 minutes without acoustic monitoring while the PAM operator diagnosed the issue. If the diagnosis indicated that the PAM system needed maintenance, operations could continue for an additional 10 hours without acoustic monitoring, during daylight hours only, provided that: (1) the Beaufort Sea State (BSS) was less than or equal to a BSS 4; (2) with the exception of delphinids, no marine mammals were acoustically detected in the applicable exclusion zones in the previous two hours; (3) active acoustic source operations without acoustic monitoring did not exceed a cumulative total of 10 hours within any 24 hour period; and (4) NMFS was notified via email as soon as practicable of the time and location in which operations occurred without an active PAM system.

The PAM system was located in the main science lab which allowed ample space for the equipment to be set-up, quick communication with the PSOs and seismic technicians, and access to the vessel's instrumentation screens. Information about the vessel (e.g., position, heading, and speed), water depth, source activity (e.g., line number, total source volume, number of active elements), and the PAM system (e.g., cable deployments/retrievals, changes to the system, background noise score, hydrophone depth) were recorded at least once an hour, and whenever any of the parameters changed.

Acoustic monitoring for marine mammals was conducted aurally, utilizing Sennheiser headphones, and visually with the PAMGuard software program. Low frequency (LF) to mid-frequency delphinid whistles, clicks, and burst pulses, as well as sperm whale clicks and baleen whale vocalizations, could be visualized in PAMGuard's spectrogram modules. Sperm whale, beaked whale, Kogia species, and delphinid clicks could also be visualized in LF and HF click detector modules. Settings adjustments to amplitude range, amplitude triggers, and spectral content filters, among others, could be made in PAMGuard's spectrogram and click detector modules to maximize the distinction between cetacean vocalizations and ambient signal. The map module within PAMGuard could be utilized to attempt localizing the position and range of vocalizing marine mammals. Sound recordings could be made using the HF and LF sound recording modules when potential marine mammal vocalizations were detected, or when the operator noted unknown or unusual sound sources.

As required by the IHA, PAM operators recorded the following information during acoustic detections of protected species:

I. Detection number, date, time of first and last detection, operator on duty, any associated visual detection number, vessel information (position, speed, heading), water depth, and acoustic source activity.
II. Species (if determinable), number of individuals, methods/modules on which vocalizations were detected, and vocalization characteristics (e.g., signal type, frequency and amplitude range, patterns, etc.).
III. Determinable bearings and ranges to the vessel, hydrophones, and seismic source, type, and duration of any implemented mitigation actions.

3.3.1 Passive Acoustic Monitoring Parameters

A PAM system designed to detect most species of marine mammals was installed on board the *MGL*. The system was developed by Seiche Measurements Limited and consisted of the following main

components: a 255 meter hydrophone cable (configured as a separate 230 meter steel-reinforced tow cable and detachable 25 meter hydrophone array); a 100 meter deck cable; a rack-mounted electronic processing unit (EPU) that incorporated a buffer unit, RME Fireface 800 unit and computer; two desktop monitors; a keyboard and mouse; acoustic analysis software package; and headphones for aural monitoring. A complete spare system of all components was also present on board in the event that any of the main system components became damaged or inoperable. The diagram in Figure 6 is a simplified depiction of the PAM system installed on the *MGL*.

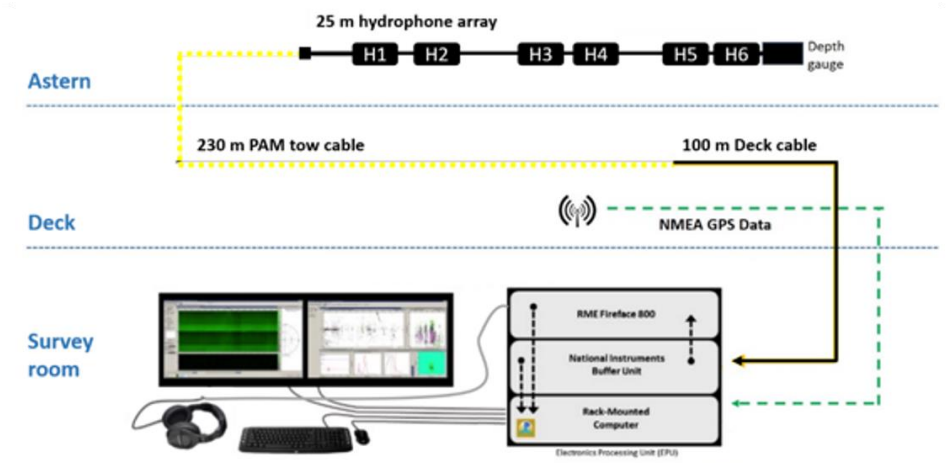


Figure 6: Simplified pathway of data through the PAM system onboard the *MGL*

The hydrophone cable contained six hydrophone elements and a depth gauge molded into a 25-meter section of the cable. The six-element linear hydrophone array allowed the system to sample a large range of marine mammal vocalization frequencies. The hydrophone pair closest to the end by the depth gauge were used for low frequencies between 10 hertz and 24 hertz, the middle hydrophone pair was used for mid frequencies between 200 hertz and 200 kilohertz, and the forward hydrophone pair closest to the connector to the tow cable was used for high frequencies between two kilohertz and 200 kilohertz.

The deck cable interfaced between the hydrophone cable deployed astern of the vessel and the EPU located in the main science lab. The rack-mounted EPU was set up with the two pre-installed, wall-mounted monitors supplied by the *MGL*, a keyboard, a mouse, and headphones. The EPU contained a buffer unit with Universal Serial Base (USB) output, an RME Fireface 800 ADC unit with firewire output, and a rack-mounted computer. A Global Positioning System (GPS) feed of GNGGA strings was supplied from the ship's Seapath navigation system and routed to the computer, reading data every five seconds. Data from the hydrophone cable's depth transducer was routed through the buffer unit to the computer, via USB connection. PAMGuard *Beta* version 1.15.17 was the software version utilized for the survey program.

Raw feed from the two high frequency hydrophone elements was digitized in the buffer unit using an analogue-digital National Instruments data acquisition (DAQ) soundcard at a sampling rate of 500 kilohertz. The output was filtered for HF content and visualized using the PAMGuard software, which used the difference between the time that a signal arrived at each of the two hydrophones to calculate and display the bearing to the source of the signal. A scrolling bearing/time module displayed the filtered data in real time, allowing for the detection and directional mapping of click trains. Additional components of the HF click detector system in PAMGuard included: an amplitude/time display that registered click

intensity data in real time, as well as click waveform, click spectrum, and Wigner plot displays, providing the PAM operator immediate review of individual click characteristics in the identification process.

Raw feed from the two low frequency and two mid frequency hydrophone elements was routed from the buffer unit to the RME Fireface 800 unit, where it was digitized at a sampling rate of 56 kilohertz. The relatively low frequency (LF) output was further processed within PAMGuard by applying Engine Noise Fast Fourier Transform (FFT) filters, including click suppression and spectral noise removal filters (e.g., median filter, average subtraction, Gaussian kernel smoothing and thresholding). Filtered LF content was visualized in three spectrograms, one displaying a channel feed at frequency ranges of zero to 48 kilohertz, the second displaying a channel feed at a frequency range of 500 to 1,000 kilohertz, and the third displaying a channel feed at a frequency range of zero to 500 kilohertz. LF click detector modules allowed for review of individual click characteristics as well as the detection and tracking of click trains.

A map module on the LF system interfaced with GPS data provided by the vessel to display the vessel location and could be used to determine range and bearing estimates based on clicks tracked in the click detector module. PAMGuard contained a function for calculating the range to vocalizing marine mammals based upon the least squares fit test. This method is most effective with animals that are relatively stationary in comparison to the moving vessel, such as sperm whales. The mathematical function estimated the range to vocalizing marine mammals by calculating the most likely crossing of a series of bearing lines generated from tracked clicks or whistles and plotted on a map display. The bearings of detected whistles and moans were calculated using a Time-of-Arrival-Distance (TOAD) method (where the signal time delay between the arrival of a signal on each hydrophone was compared), and presented on a radar display, along with amplitude information for the detected signal as a proxy for range.

Additional modules displayed on the LF monitor included a LF sound recorder and clip generator. The clip generator module within PAMGuard could be used to generate short sound clips in response to either an automatic detection or the operator manually selecting a portion of the spectrogram display. This module was useful in the event that the whistle-and-moan detector falsely triggered and identified a non-biological sound (i.e., echosounder) or if it missed detecting tonal signatures that the operator determined to be vocalizations.

3.3.2 Hydrophone Deployment

The hydrophone cable was deployed from a hydraulic winch on the port stern of the vessel's aft deck where the acoustic source arrays were deployed. Two deck cables, a main and a spare, were installed along the deck-head running from the winch to the main science lab. A Chinese finger attached to the tow cable approximately 125 meters ahead of the connector to the hydrophone array was secured to the port side boom via lifting rope. This reduced the tension on the cable remaining on the winch and served as a method to pull the cable further to port and away from the source arrays. This deployment method placed the trailing end of the hydrophone cable approximately 125 meters from the port stern of the vessel (Figure 4) and 122 meters ahead of the first elements on the source arrays. One piece of chain of seven kilograms was attached and secured to the tow cable to increase tow depth and to decrease the chance of entanglement with the source arrays' umbilicals. The tow depth of the hydrophones varied between 12 and 30 meters and averaged 16.9 meters throughout the seismic survey.

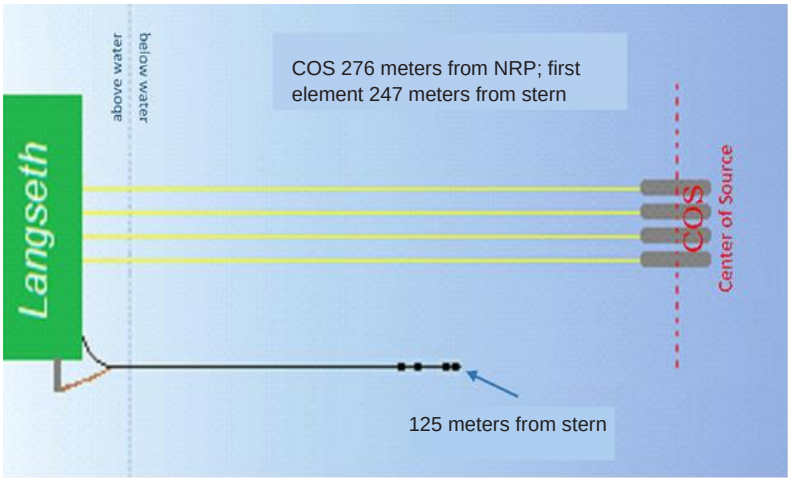


Figure 7: Location of the PAM cable in relation to the seismic gear during the survey.

4 MONITORING EFFORT SUMMARY

4.1 Survey Operations Summary

4.1.1 General Survey Parameters

The Puerto Rico survey program was conducted in three parts, with the first low-energy MCS survey occurring between 29 October 2023 and 02 November 2023, the second high-energy MCS survey occurring between 03 November 2023 and 19 November 2023, and the third high-energy OBS survey occurring between 21 November and 15 December 2023.

Table **5** outlines the survey parameters for each part of the survey program, with all port calls occurring in San Juan, Puerto Rico and one offshore crew change via crew boat occurring near Ponce, Puerto Rico. During survey operations, data was acquired continuously according to the survey plan, with source operations only suspended when operationally necessary as outlined in Table 6.

Table 5: Survey parameters.

Survey Parameter	Date	Time (Coordinated Universal Time (UTC))	Location
Low-energy MCS Survey			
Mobilization – depart port	29 October 2023	15:10	San Juan, Puerto Rico
Start of gear deployment	30 October 2023	10:00	survey site
First seismic source activity	30 October 2023	12:35	survey site
Start of acquisition	30 October 2023	13:43	survey site
End of acquisition	02 November 2023	15:59	survey site
All gear onboard	02 November 2023	18:15	survey site
Crew change	02 November 2023	21:44	offshore near Ponce, Puerto Rico
High-energy MCS survey			
Start of gear deployment	03 November 2023	13:07	survey site
First seismic source activity	05 November 2023	05:10	survey site
Start of acquisition	05 November 2023	05:41	survey site
End of acquisition	18 November 2023	03:49	survey site
All gear onboard	18 November 2023	19:00	survey site
De-mobilization – arrive at port	19 November 2023	11:00	San Juan, Puerto Rico
High-energy OBS survey			
Mobilization – depart port	21 November 2023	11:12	San Juan, Puerto Rico
Start of gear deployment	22 November 2023	07:38	survey site
First seismic source activity	24 November 2023	21:46	survey site
Start of acquisition	24 November 2023	22:31	survey site
End of acquisition	13 December 2023	06:22	survey site
All gear onboard	14 December 2023	20:32	survey site
De-mobilization – arrive at port	15 December 2023	13:20	San Juan, Puerto Rico

Table 6: Suspension of source operations during the survey.

Date	Time Source Silenced	Date	Time Source Re-activated	Reason for Interruption to Acquisition
30 October 2023	12:44	30 October 2023	13:30	Mechanical/technical shutdown - guns flooded with water, recover for maintenance.

Date	Time Source Silenced	Date	Time Source Re-activated	Reason for Interruption to Acquisition
31 October 2023	06:52	31 October 2023	12:55	Line aborted due to streamer issues - recover gear.
02 November 2023	16:00	04 November 2023	05:10	End USGS survey, retrieve all gear, transit towards Ponce for crew change, transit to north side of island and deploy gear to begin high energy survey.
05 November 2023	20:06	06 November 2023	15:45	Streamer and source maintenance.
07 November 2023	16:19	07 November 2023	18:32	Silent for line change that entered marine sanctuary.
08 November 2023	16:01	08 November 2023	16:04	Compressor issue.
12 November 2023	19:59	12 November 2023	21:18	Line change.
18 November 2023	03:49	24 November 2023	21:46	End of MCS survey, transits, port call for crew change, deploying OBSs.
26 November 2023	04:31	26 November 2023	04:44	Mechanical/technical shutdown - compressor failure.
27 November 2023	23:12	28 November 2023	21:58	All gear retrieved for transit to south side of the island then re-deployed to acquire south survey line.
29 November 2023	08:37	05 December 2023	13:58	All gear retrieved for OBS retrieval from south and north central lines and re-deployment of OBSs on north-east line.
06 December 2023	01:35	06 December 2023	02:01	Mechanical/technical shutdown - loss of ship's clean power.
08 December 2023	03:49	12 December 2023	03:12	All gear retrieved for OBS retrieval from north-east line and re-deployment back on the north-central line.

4.1.2 MBES, SBP, and ADCP Operations

Throughout the survey program, the MBES was active for a total of 838 hours 41 minutes, SBP was active for a total of 547 hours 53 minutes, and the ADCP was active for a total of 848 hours 19 minutes. The MBES, SBP, and ADCP were activated for the first time at 16:03 UTC on 29 October 2023 and the MBES and ADCP were disabled for the last time at 12:39 UTC on 15 December 2023. The SBP was disabled at 18:01 UTC on 24 November 2023 at the request of the PI due to interference with other equipment and it was not enabled again for the remainder of the survey program. Throughout the survey program, the MBES, SBP, and ADCP were de-activated and re-activated multiple times, including between 19 and 21 November 2023 while the vessel was at dock for crew change and during all OBS retrieval operations.

4.1.3 Acoustic Source Operations

Throughout the entire survey program, the seismic source was active on 30 days for a total of 528 hours and 36 minutes. This total included: four hours and eight minutes of ramp-up, 12 minutes of testing, 495 hours and 51 minutes of operations on a survey line (55 hours and 36 minutes at a volume of 90 in^3 for the low-energy survey, 63 hours and 12 minutes at a volume of 6600 in^3 for the high-energy surveys, and 377 hours and three minutes at variable reduced volumes for the high-energy surveys), and 28 hours and 25 minutes of operations not on a survey line (12 hours and 40 minutes at a volume of 90 in^3 for the low-energy survey, one hour and 57 minutes at a volume of 6600 in^3 for the high-energy surveys, and 13 hours and 48 minutes at variable reduced volumes for the high-energy surveys). Table 7 summarizes the seismic source operations over the course of the survey program.

For the low-energy MCS survey, the seismic source was ramped-up three times totaling 20 minutes, with each ramp-up having a duration between six and seven minutes. All ramp-ups occurred during the day and were cleared by visual monitoring only. The seismic source was active on four days for a total of 68 hours and 36 minutes, including the time for the ramp-ups, 55 hours and 36 minutes on a survey line, and 12 hours and 40 minutes not on a survey line.

For the high-energy MCS survey, the seismic source was ramped-up four times totaling one hour and 37 minutes, with each ramp-up having a duration between 20 and 31 minutes. Three of the ramp-ups occurred during daylight hours and one occurred during the night, and all ramp-ups were cleared by both visual and acoustic monitoring. The seismic source was active on 14 days for a total of 287 hours and 24 minutes, including the time for the ramp-ups, 274 hours and 40 minutes on a survey line, and 11 hours and seven minutes not on a survey line. There was one instance during this part of the survey where source activity was resumed without a ramp-up during daylight hours after a brief period of mechanical/technical silence.

For the high-energy OBS survey, the seismic source was ramped-up six times totaling two hours and 11 minutes, with each ramp-up having a duration between 21 and 22 minutes. There was one daytime ramp-up, two dusk ramp-ups, and three night-time ramp-ups. Two of the night-time ramp-ups were cleared by acoustic monitoring only after a brief period of mechanical/technical source silence, and the remaining four ramp-ups were cleared by both visual and acoustic monitoring. The seismic source was active on 12 days for a total of 172 hours and 36 minutes, including the time for the ramp-ups, 165 hours and 35 minutes on a survey line, four hours and 38 minutes not on a survey line, and 12 minutes of testing, which consisted of three single element tests.

The geospatial data for source operations are provided as a shapefile attachment to this report.

The monitoring effort, source operations and protected species detections for this survey are provided as an excel dataset in Appendix Cand the basic data summary form found in Appendix D.

Table 7: Total acoustic source operations during the survey.

Acoustic Source Operation	Overall Project		Low-energy Survey		High-energy Surveys	
	Number	Duration (hh:mm)	Number	Duration (hh:mm)	Number	Duration (hh:mm)
Source Tests	3	00:12	0	00:00	3	00:12
Ramp-up	13	04:08	3	00:20	10	03:48
Day-time ramp-ups	7	01:48	3	00:20	4	01:28
Reduced visibility ramp-ups (night/dawn/dusk)	6	02:20	0	00:00	6	02:20
Full/Reduced Volume on a Survey Line		495:51		55:36		440:15
Full/Reduced Volume not on a Survey Line		28:25		12:40		15:45
Total Time Acoustic Source Was Active		**528:36**		**68:36**		**460:00**

4.1.4 Interactions with Other Vessels

In addition to visually monitoring for protected species, PSOs also observed and documented interactions with other marine vessel traffic. Such interactions included but were not limited to another vessel or another vessels' towed gear/equipment interacting with the *MGL's* towed gear/equipment, and the *MGL* having to deviate from planned survey operations (i.e., diverge from the survey line, increase/decrease speed) because of another vessel.

There were no such interactions with other vessels during the survey program.

4.2 Visual Monitoring Survey Summary

Visual monitoring was conducted by two PSOs during all daylight hours, beginning 30 minutes before sunrise and ending 30 minutes after sunset each day, initiating when the vessel left dock at the beginning of the program and terminating upon the vessels return to dock at the end of the program (Table 8). During transit and other periods with no source operations, observations were undertaken by two PSOs for VSA and to collect baseline data about protected species abundance in the survey areas. Visual monitoring was also conducted at night on two occasions for night-time pre-clearance searches and ramp-ups.

Table 8: Initiation and termination of visual monitoring during the survey.

Visual Monitoring	Date	Time (UTC)
Initiation for the low-energy MCS survey	29 October 2023	15:10
Termination for low-energy MCS survey	02 November 2023	22:24
Initiation for the high-energy MCS survey	03 November 2023	10:00
Termination for high-energy MCS survey	19 November 2023	11:00
Initiation for the high-energy MCS survey	21 November 2023	11:12
Termination for high-energy MCS survey	15 December 2023	13:20

Visual monitoring on the *MGL* was conducted over a period of 47 days for a total of 547 hours 53 minutes throughout all three parts of the survey program. Of the overall total visual monitoring effort, 49% (267 hours and 35 minutes) was undertaken while the acoustic source was active, and 51% (280 hours and 18 minutes) was undertaken while the acoustic source was silent. Visual monitoring while the acoustic source was silent was mainly conducted during the transits and equipment deployment and retrieval. Table 9 details visual monitoring with acoustic source operations on the *MGL* throughout the seismic survey.

Table 9: Total visual monitoring effort during the survey.

Visual Monitoring Effort	Overall Project		Low-energy MCS		High-energy MCS		High-energy OBS	
	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort
Total monitoring while acoustic source active	267:35	49%	37:39	65%	148:25	75%	81:31	28%
Total monitoring while acoustic source silent	280:18	51%	19:59	35%	50:01	25%	210:18	72%
Total monitoring effort	**547:53**	**-**	**57:38**	**-**	**198:26**	**-**	**291:49**	**-**

Visual observations on the *MGL* were preferentially conducted from the PSO tower, which provided a 360-degree view of the water around the vessel and the acoustic source. Visual watches were conducted from other locations, including the bridge and bridge wings if monitoring conditions could not be undertaken from the tower, such as during rough weather and sea conditions which made the tower unsafe, or when the vessel was heading directly into the wind, blowing the engine exhaust onto the tower. PSOs conducted visual monitoring mainly from the tower (53%, 287 hours and 51 minutes) and from the bridge (46%, 253 hours and 54 minutes) throughout the survey program. The majority of the monitoring from the bridge occurred during the OBS survey, when the vessel would position the vessel into the wind for extended periods of time to remain on station during the OBS deployment and retrieval operations.

4.3 Acoustic Monitoring Survey Summary

Acoustic monitoring was conducted continuously throughout seismic source operations and to the maximum extent possible while the acoustic source was silent during the high-energy surveys only (Table 10). Periods without source activity or acoustic monitoring occurred when the PAM hydrophone cable was secured on board the vessel during transits, during deployment and recovery of the seismic gear and OBSs, and during times when operations were suspended due to rough weather and sea conditions or gear maintenance. There was no acoustic monitoring required or conducted during the low-energy MCS survey.

Table 10: Initiation and termination of acoustic monitoring watches during survey.

Acoustic Monitoring	Date	Time (UTC)
Initiation for the high-energy MCS survey	05 November 2023	00:26
Termination for high-energy MCS survey	18 November 2023	06:57
Initiation for the high-energy MCS survey	24 November 2023	18:04
Termination for high-energy MCS survey	13 December 2023	08:28

Acoustic monitoring was conducted over 26 days for a total of 506 hours 47 minutes. Of the overall total acoustic monitoring effort, 91% (460 hours) was undertaken while the acoustic source was active, and 9% (46 hours 47 minutes) was undertaken while the acoustic source was silent. Acoustic monitoring while the acoustic source was silent was mainly conducted during the brief periods of time between recovery/deployment of the seismic gear and recovery/deployment of the PAM cable. Table 11 details acoustic monitoring with acoustic source operations.

Table 11: Total PAM effort during the survey.

Acoustic Monitoring Effort	Overall Project		High-energy MCS		High-energy OBS	
	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort
Total monitoring while acoustic source active	460:00	91%	287:24	93%	172:36	87%
Total monitoring while acoustic source silent	46:47	9%	20:55	7%	25:52	13%
Total monitoring effort	**506:47**	**-**	**308:19**	**-**	**198:28**	**-**

Acoustic monitoring was suspended five times throughout the survey program between the initial deployment of the hydrophone cable at the start of each part of the survey and the final retrieval of the hydrophone cable at the end of each part of the survey. Acoustic monitoring downtime totaled 258 hours eight minutes, all of which occurred while the acoustic source was silent. Table 12 outlines the dates, times, and reasons for each instance of acoustic monitoring downtime.

Table 12: Acoustic monitoring downtime during the survey.

Acoustic Monitoring Stopped		Acoustic Monitoring Resumed		Total Downtime (hh:mm)	Downtime with Source Active (hh:mm)	Downtime with Source Silent (hh:mm)	Reason for Downtime
Date	Time	Date	Time				
2023-11-05	22:34	2023-11-05	22:39	00:05	00:00	00:05	PAM stopped to retrieve cable for streamer maintenance, then resumed as plans changed for order of gear retrieval

2023-11-06	00:27	2023-11-06	10:34	10:07	00:00	10:07	streamer and source maintenance.
2023-11-28	01:00	2023-11-28	15:06	14:06	00:00	14:06	all gear retrieved for transit around island then all gear deployed to acquire south line.
2023-11-29	10:46	2023-12-05	10:14	143:28	00:00	143:28	all gear retrieved for OBS retrieval and re-deployment operations.
2023-12-08	06:12	2023-12-12	00:34	90:22	00:00	90:22	all gear retrieved for OBS retrieval and re-deployment operations.
Total acoustic monitoring downtime				**258:08**	**-**	**258:08**	

4.4 Simultaneous Visual and Acoustic Monitoring Summary

Simultaneous visual and acoustic monitoring was conducted to the maximum extent possible during the two high-energy surveys for a total of 256 hours 45 minutes. Of the overall simultaneous monitoring effort, 90% (229 hours 56 minutes) was conducted while the acoustic source was active (Table 13). Additional visual monitoring conducted during transit periods and while OBS instruments were deployed/retrieved and was not accompanied by acoustic monitoring as the varied vessel speed would causes the hydrophone cable to migrate to the water surface, out of the ideal tow position, where increased background noise would impair acoustic detection capabilities.

Table 13: Simultaneous visual and acoustic monitoring effort during the survey.

Simultaneous Visual and Acoustic Monitoring	Overall Project		High-energy MCS		High-energy OBS	
	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort	Duration (hh:mm)	% of Overall Effort
Total monitoring while acoustic source active	229:56	90%	148:25	93%	81:31	84%
Total monitoring while acoustic source silent	26:49	10%	11:32	7%	15:17	16%
Total monitoring effort	**256:45**	**-**	**159:57**	**-**	**96:48**	**-**

4.5 Environmental Conditions

Environmental conditions can have an impact on the probability of detecting protected species. The environmental conditions present during visual observations undertaken during the survey program were generally considered to be 'very good.'

Visibility was classified as 'excellent' if it extended greater than 10 kilometers and 'very good' if it was between seven and 10 kilometers. 58% and 26% of monitoring effort on the *MGL* was undertaken at 'excellent' and 'very good' visibility levels, respectively (Table 14). The entire predicted harassment zone radii, BZs, and EZs were not visible on multiple occasions, mainly due to precipitation and reduced lighting before sunrise and after sunset and during night-time visual monitoring. During these times, it is possible that protected species were not detected within these zones.

Reduced visibility was mainly attributed to periods of rain and haze, the brief periods of reduced lighting before sunrise and after sunset, and any time visual monitoring was required for a nighttime ramp-up.

Table 14: Visibility during the survey (in kilometers).

Total	<0.05	0.05-0.1	0.1-0.3	0.3-0.5	0.5-1	1-2	2-5	5-7	7-10	>10
Duration (hh:mm)	01:03	00:00	01:18	05:10	05:59	13:13	15:28	44:42	142:42	318:18

Precipitation was recorded during visual monitoring on the *MGL* for a total of 202 hours 51 minutes. Most of the precipitation recorded was light rain (18%) or haze (13%) (Table 15).

Table 15: Precipitation during the survey.

Total	None	Heavy Rain	Moderate Rain	Light Rain	Heavy Fog	Moderate Fog	Thin Fog	Haze	Sleet	Snow
Duration (hh:mm)	345:02	04:08	16:05	96:55	00:00	00:00	13:11	72:32	00:00	00:00

The BSS recorded during visual monitoring ranged from level one to level six. Most visual observations on the *MGL* were undertaken in conditions where the BSS was level 4 (40%) or level 5 (27%), which were considered 'good' to "fair' conditions for the detection of protected species (Table 16).

Table 16: BSS during the survey.

Total	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9
Duration (hh:mm)	00:00	03:11	47:23	116:07	221:18	146:30	13:24	00:00	00:00	00:00

Wind speeds recorded visual monitoring ranged between one and 38 knots. Most of the visual monitoring on the *MGL* occurred during recorded wind speeds 10 to 15 knots (35%) and from 16 to 20 knots (31%) (Table 17).

Table 17: Wind speed during the survey.

Total	<10	10-15	16-20	21-25	26-30	>31
Duration (hh:mm)	65:30	191:01	172:11	95:22	16:54	06:55

Swell heights during visual observations were generally low, with swells of less than two meters recorded for the majority of visual observations (89%) (Table 18). All two-to-four-meter swells occurred during the OBS survey near the end of the project.

Table 18: Swell height during the survey.

Total	<2m	2-4m	>4m
Duration (hh:mm)	488:02	59:51	00:00

Visual monitoring was conducted primarily when severe glare (55%) was present (Table 19). During times of moderate to severe glare, it is possible that the detection of protected species was hindered.

Table 19: Glare during the survey.

Total	None	Mild	Moderate	Severe
Duration (hh:mm)	78:35	72:24	96:24	300:30

5 MONITORING AND DETECTION RESULTS

5.1 Visual Detections of Protected Species

Visual monitoring efforts during the survey program resulted in a total of two visual detections of protected species, including one sighting of one spinner dolphin and one sighting of four common dolphins (summarized in Appendix E).

Table 20 lists the total number of detections and total number of individuals for each protected species observed during the survey program.

Maps of the protected species detections are shown in Figure 8.

Table 20: Number of visual detection records collected for each protected species during the survey.

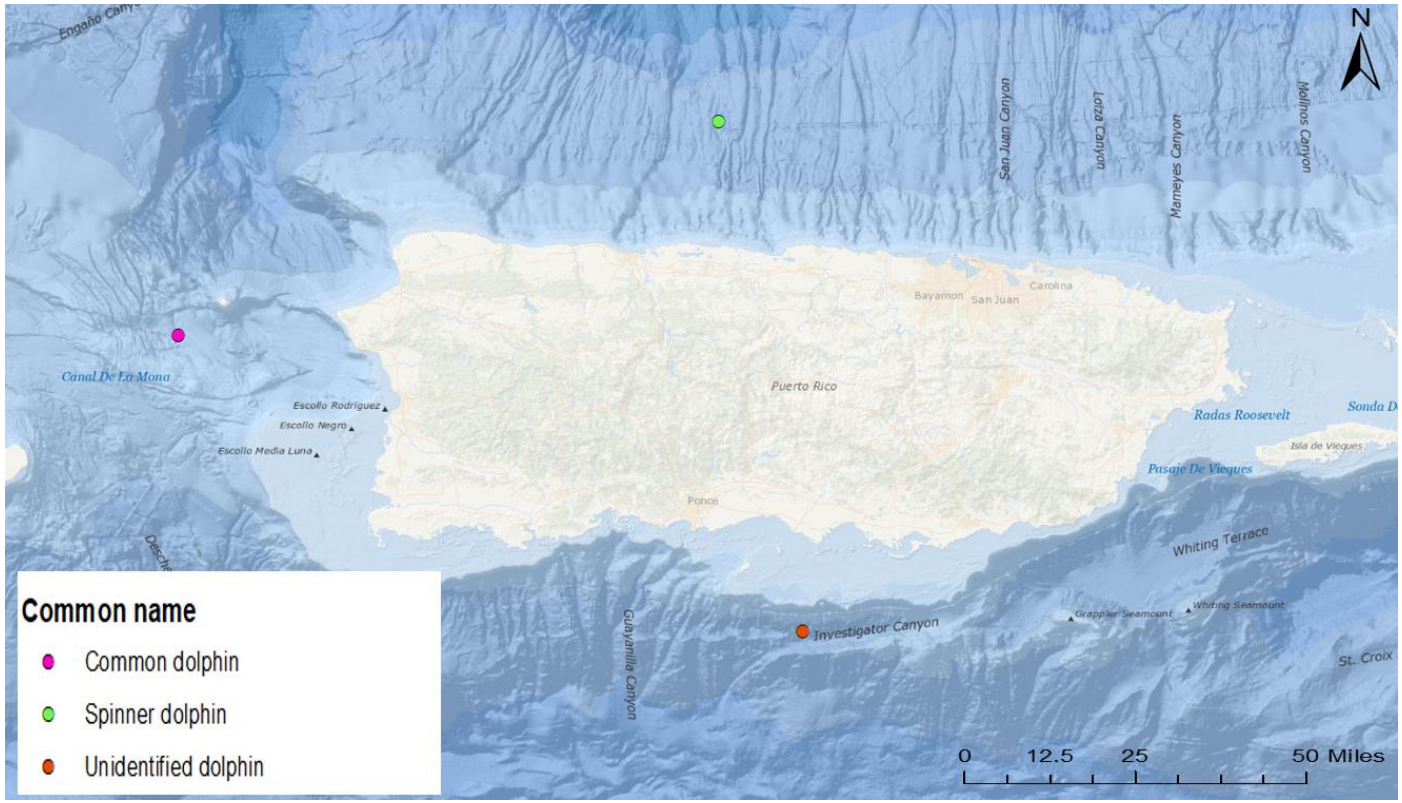
Species	Total Number of Detection Records	Total Number of Animals
Dolphins		
Common dolphin	1	4
Spinner dolphin	1	1
Total	**2**	**5**

Both visual detections occurred while the vessel was in transit with the seismic source silent and secured onboard the vessel in water depths of 687 and 2,032 meters. The sighting of the spinner dolphin occurred on the first day of the survey program while the vessel was in transit on the north side of the island. The sighting of common dolphins occurred during the OBS survey part of the program while the vessel was in transit from the south side of the island to the north side of the island. The spinner dolphin was observed very briefly jumping out of the water twice, while the common dolphins were observed for several minutes swimming and surface nearby the vessel.

5.2 Acoustic Detections of Protected Species

There was one acoustic detection of protected species during the survey program consisting of one detection of unidentifiable dolphins. The detection consisted of at least eight individuals and occurred in water depths of 1,331 meters shortly after the start of a ramp-up during the OBS survey part of the program on the south side of the island. The detection was three minutes in duration, occurred at dusk, and the dolphins were not visually sighted. The vocalizations from the dolphins consisted of high frequency clicks, and while the clicks could not be tracked within the PAMGuard software, the operator estimated that the dolphins were most likely within 500 meters of the hydrophones and active seismic source. However, given the characteristics of the vocalizations detected, the operator determined that the dolphins were most likely one of the shutdown exemption species and no mitigation actions were required. Screenshots of the acoustic detection can be found in Appendix F.

Figure 8: All protected species detections observed by common name during the survey.



5.3 Other Wildlife

Observations of other wildlife included 11 species of birds and two genera/species of fish. A complete list of birds and other marine wildlife observed and identified, in addition to the approximate number of individuals observed and the number of days on which they were observed, can be found in Appendix G. No adverse impacts to any other wildlife species as a result of research activities were observed.

There were no sightings of any ESA-listed seabirds during the survey program.

6 MITIGATION ACTION SUMMARY

There were no mitigation actions implemented during the survey program.

6.1 Vessel Strike Avoidance (VSA) Maneuvers

There was one VSA maneuver implemented during the survey program for the visual sighting of the common dolphins. Initially the dolphins were observed swimming and surfacing outside of the required separation distance in the same direction, and a VSA of having the vessel maintain the same course and speed parallel to the dolphins' course was implemented. Although the dolphins did briefly enter the required separation distance during the detection, their approach to the vessel was voluntary and no further VSA maneuvers were required.

Commented [SHE1]: Implanted or implemented?

6.2 Protected Species Known to Have Been Exposed to 160 Decibels or Greater of Received Sound Levels

Numerous protected species are known to occur within the survey area, including nine species listed as endangered or threatened under the ESA. These species included four marine mammals, including blue whale, fin whale, sei whale and sperm whale; and five species of sea turtles, including green sea turtle, olive ridley sea turtle, leatherback sea turtle, hawksbill sea turtle, and loggerhead sea turtle. NSF came to a "no effect" determination for seabirds due to their unlikely presence; however, PSOs monitored for two ESA-listed sea birds including the roseate tern and the black-capped petrel in the unlikely event they were encountered in the survey area.

NMFS granted an IHA authorizing Level B harassment (exposure to sound pressure levels equal to or greater than 160 dB re: 1 µPa rms) where there is a potential for behavioral changes) for 14,123 individuals from 23 species or species groups, including four whale species listed as endangered. Three species of whales (humpback, minke, and sei) and one whale species group (Kogia) were authorized for a total of 30 individuals for Level A harassment (exposure to sound pressure levels where there is a potential for auditory injury based upon each species hearing range). There were no specific numbers authorized for level A or level B harassment of sea turtles.

During seismic source operations, no protected species were observed within the predicted 160 and 175 dB radii (where there is a potential for a behavioral response) while the acoustic source was active, constituting potential Level B takes. There were no protected species observed within the predicted radius at which there is a potential for auditory injury (based upon each species hearing range and how that overlaps with the frequencies produced by the sound source), constituting potential Level A takes/exposures.

The number of potential takes may be an underestimation and, therefore, may be a minimum estimate of the actual number of protected species potentially exposed to received sound levels within the predicted Level A and Level B harassment zones. It is possible that the estimated numbers of animals recorded were underestimates due to some individuals not being visually sighted or having moved away before they were observed (Table 21).

Table 21: Number of authorized and potential Level A and B harassment takes / exposures during the survey.

Species	IHA Authorized Level B Takes/ Exposures	Total Potential Takes/ Exposures During Seismic operations
Humpback whale	262	0
Minke whale	58	0
Fin whale	2	0
Sei whale	22	0
Blue whale	1	0
Sperm whale	482	0
Beaked whales	540	0
Risso's dolphin	164	0
Rough-toothed dolphin	477	0
Bottlenose dolphin	2132	0
Pantropical spotted dolphin	779	0
Atlantic spotted dolphin	1540	0
Spinner dolphin	1932	0
Striped dolphin	318	0
Clymene dolphin	1589	0
Fraser's dolphin	213	0
Common dolphin	88	0
Short-finned pilot whale	1833	0
Killer whale	2	0
False killer whale	218	0
Pygmy killer whale	130	0
Melon-headed whale	987	0
Kogia spp.	354	0

6.3 Implementation and Effectiveness of the Biological Opinion and IHA

To minimize the potential impacts to marine mammals during the seismic survey, LDEO and PSOs were prepared to implement mitigation measures whenever these protected species were detected approaching, entering, or within their designated exclusion zones as outlined in the IHA and BiOp. There were no mitigation actions implemented for protected species during the survey program. The confirmation of the implementation of each term and condition of the project permit documents are described in this report.

If an injured or dead protected species was discovered, the incident was to be reported to the NMFS Office of Protected Resources (OPR), NMFS, and the NMFS Southeast Regional Stranding Coordinator as soon as possible. The report would include a detailed description of the incident (time, date, location, species identification, description of the animal, condition of the animal/carcass, observed behaviors if the animal was alive, and general circumstances under which the animal was discovered), including pictures when possible. There were no sightings of dead or injured protected species during the survey program.

To prevent the occurrence of the vessel striking a marine mammal during transits, PSOs and vessel crew members maintained a vigilant watch for marine mammals, and the vessel was prepared to slow down, stop, or alter course as appropriate to avoid striking a protected species. The vessel speed had to be reduced to 10 knots or less when mother/calf pairs, pods, or large assemblages of cetaceans were observed near the vessel. The vessel had to maintain the minimum separation distances as described in Table 2. If a marine mammal was sighted during transits, the vessel was to act as necessary to avoid violating the relevant separation distances (e.g., attempt to remain parallel to the animal's course, avoid excessive speed or abrupt changes in direction until the animal left the area). If marine mammals were sighted within the relevant separation distances, the vessel was required to reduce speed, shift the

engines to neutral, and not engage the engines until the animals were clear of the area. If a whale entered the separation zone while the vessel was stationary, the vessel would not engage the engines until the whale has exited the zone. These requirements did not apply in any case where compliance would create an imminent and serious threat to a person or vessel, or if the vessel was restricted in maneuverability due to towed equipment. There was one instance of vessel strike avoidance maneuvers being implemented for detections of protected species sighted within the required separation distance.

In the event of a ship strike of a marine mammal, the incident was to be reported to NMFS, OPR, and to the Southeast Regional Stranding Coordinator, as soon as feasible. The report would include a detailed description of the incident (date, time, location, species identification, description of the animal(s) involved, vessel speed leading up to the incident, vessel's course/heading and what operations were being conducted, status of all sound sources in use, description of avoidance measures taken if any, environmental conditions, description of the animals behavior preceding and following the strike, and estimated fate of the animal), including pictures when possible. There were no instances of the vessel striking a protected species during the survey.

PSOs likely did not detect all animals present; however, it is highly unlikely that the actual number of animals present during survey operations reached anywhere near the fully authorized levels for all species. The combination of conservative predicted mitigation zones combined with conservative take estimation by NMFS (*i.e.,* the precautionary approach), appears for most species to have resulted in an overestimation of take and of overall impact on marine species from the activity. The monitoring and mitigation measures required by the IHAs appear to have been an effective means to protect the marine species encountered during survey operations.

Appendix A: Incidental Harassment Authorization

Appendix B: Protected Species Observers Onboard the *MGL*

Appendix C: Complete Survey Raw Datasheets (Provided in Attached File in Excel Format)

Appendix D: Basic Data Summary Form

Appendix E: Visual Detections of Protected Species During the Survey

Appendix F: Screenshots of Acoustic Detections During the Survey

Appendix G: Birds and Other Wildlife Observed During the Survey

Appendix D: Basic Data Summary Form

BASIC DATA FORM			
LDEO Project Number	MGL2314, MGL2315, MGL2316		
Seismic Contractor	LDEO		
Area Surveyed During Reporting Period	North and South Coasts of Puerto Rico		
Survey Type	2D seismic		
Vessel and/or Rig Name	*Marcus G. Langseth*		
Permit Number	IHA issued on 06 October 2023 and BiOp issued on 04 October 2023		
Location / Distance of Source Deployment	287 meters (low-energy survey) and then 276 meters (high-energy surveys) from NRP in PSO tower to COS.		
Water Depth in survey area	Between 100 and 8,400 meters		
Dates of Low-Energy MCS part of survey	29 October 2023	through	02 November 2023
Dates of High-Energy MCS part of survey	03 November 2023	through	19 November 2023
Dates of High-Energy OBS part of survey	21 November 2023	through	15 December 2023
Total time source operating – all power levels:	528:36		
Time source operating on survey lines:	495:51		
Time source operating not on a survey line:	28:25		
Amount of time single 40 in³ element operations:	00:00		
Amount of time in ramp-up:	04:08		
Number daytime ramp-ups:	7		
Number of nighttime/dusk ramp-ups:	6		
Number of ramp-ups from mitigation source:	0		
Amount of time conducted in source testing:	00:12		
Duration of visual observations:	547:53		
Duration of observations while source active:	267:35		
Duration of observation during source silence:	280:18		
Duration of acoustic monitoring:	506:47		
Duration of acoustic monitoring while source active:	460:00		
Duration of acoustic monitoring during source silence:	46:47		
Duration of simultaneous acoustic and visual monitoring:	256:45		
Lead Protected Species Observer:	Amanda Dubuque		
Protected Species Observers on the Langseth:	Cassandra Frey, Elizabeth Breton, Maria Laurel, Tiffany Ramdoo		
Number of Marine Mammal Visual Detections:	2		
Number of Marine Mammal Acoustic Detections:	1		
Number of Simultaneous Visual and Acoustic Detections:	0		
Number of Sea Turtle Detections:	0		
Total Number of Protected Species Detections:	3		
List Mitigation Actions	None		
Duration of Mitigation Actions:	00:00		

Appendix E: Summary of Visual Detections of Protected Species During the Survey

Movement Codes: **TV**: towards vessel; **AV**: away from vessel; **PV/SD**: parallel vessel, same direction; **PV/OD**: parallel vessel, opposite direction; **PE (AH/BH):** perpendicular (crossing ahead or behind); **MI**: milling; **SA**: stationary; **V:** variable, **UN**: unknown**; OM**: other movement

Behavioral Codes: **NS**: normal swimming; **FT**: fast travel; **ST**: slow travel; **PO**: porpoising; **SS**: swimming below surface; **MI**: milling: **BR**: bow/wake riding; **BA**: resting/basking at surface; **FL:** floating; **SA: surface** active (lob tailing/pectoral slapping, full/partial breaching)**; R:** rolling; **DI**: dive; **DF**: dive with fluke; **FF**: feeding/foraging; **SB**: social behavior; **MT**: mating behavior; **BV**: blow visible (whale); **SV**: only splashes visible (dolphins); **DV**: dorsal fin visible; **OB**: other behavior

Record No.	Date	Time (UTC)	Species	Group Size	Vessel Position	Source Activity Initial Detection	Movement	Behavior	CPA Source/ Source Activity	Mitigation Action	Comments
1	2023-10-29	19:58	Spinner dolphin	1	18.71593°N 066.56744°W	Not deployed	PV/SD	SS, SA, FT	N/A	None	Vessel was in transit to the survey site. Possible identification and no VSA – detection was very brief.
2	2023-11-30	21:29	Common dolphin	4	18.32257°N 067.56543°W	Not deployed	PV/SD, AV	FT, SS, SA	N/A	None	Vessel was in transit, VSA was maintaining course and speed parallel to the dolphin's direction of travel.

Appendix F: Screenshots of Acoustic Detections During the Survey

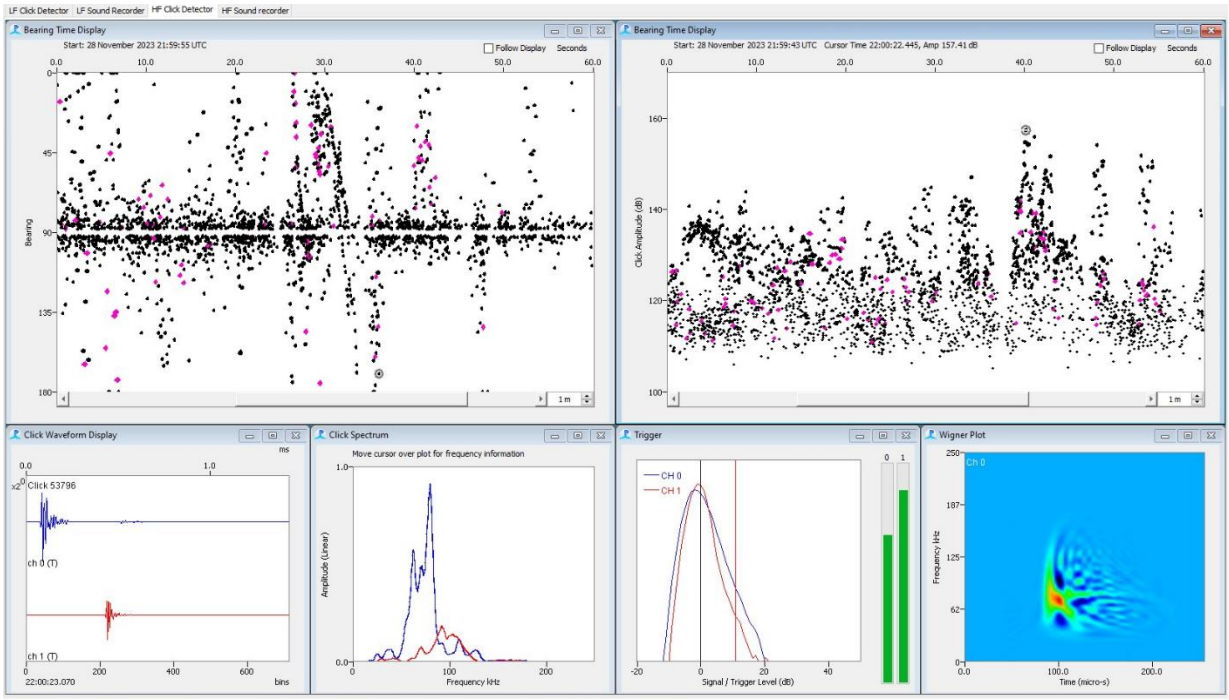


Figure 1: Unidentifiable dolphins, Pamguard high frequency click detector, 28 November 2023 (AD#01).