International Protected Species Observer Data Analysis Report

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Authors:

Principal Investigator:
S. Milne

Researchers and Consultants:
M. Butler
T. Cathery
P. Mander
J. Richardson
A. Unietis

Prepared by:

RPS

Stephanie Milne
Team Leader – U.S Offshore Renewables / Senior Environmental Manager

575 N Dairy Ashford
Suite 700
Houston, TX 77079

T +1 281 589 7257
E stephanie.milne@rpsgroup.com

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EXECUTIVE SUMMARY

Data from 420 seismic surveys conducted between 2005 and 2017 from three key areas for E&P activities, the US Gulf of Mexico, West Africa and Australia, were analysed to explore the potential effects of underwater sound from marine geophysical surveys upon marine species and compared with the findings of previous studies undertaken using similar datasets from the UK and US Gulf of Mexico. The majority of the projects, 88%, utilized a large or very large array (more than 500-cu in.; as defined by Stone (2015)).

There was a total of 32,408 visual sighting events that was analysed from all combined regions. The largest volume of data was collected in the U.S. Gulf of Mexico region, with 244 seismic surveys, yielding 20,748 sighting events of approximately 124,640 animals in 30 species groups (marine mammals and sea turtles). The smallest volume of data was collected in the West Africa region, with 4518 detection events but the dataset from this area included the second largest number of animals reported, approximately 107,124 animals in 37 species groups. The largest number of species identified was in the Australia dataset; 40 species reported in 4882 sighting events.

Sighting events were analysed in each of the three regions and as a combined dataset, which also included data contributed from other regions outside the three focus areas (26 project datasets containing 2224 sighting events). Species were grouped into categories for analysis with baleen whales, sperm whales, beaked whales, pinnipeds and sea turtles analysed separately, where sufficient records existed. All cetaceans were also analysed together.

Generally, analysis results of sighting records in each region were consistent with the results of the combined region analysis and results were generally consistent with results of similar studies, such as the Stone (2015) report, undertaken using PSO data in the past. In both the Gulf of Mexico and West Africa where the largest dataset existed, all species groups were found to occur at greater distances from the seismic source during times of full power source operation when compared to silence. Australia PSO datasets did not include closest approach to the source so this analysis could not be undertaken in that region.

In the Gulf of Mexico, where the largest dataset existed, sperm whale sighting events and delphinid sighting events were significantly shorter during full volume source operation than during source silence. A similar trend was seen in the West Africa and Australia datasets where sperm whale sighting events had a significantly shorter duration during full power operations as compared to silence. These results suggest that large whales might increase their time spent at the surface, where they are available to be sighted, when an acoustic source is active.

A behavioural analysis relative to seismic source status was undertaken for all of the species groups in each region and in all regions combined. Behaviour labels / descriptions were standardized and fit into 18 defined categories. When comparing full power source operations with silence for the ‘All Cetaceans’ species group, there were statistically significant differences between the behaviours observed: bow riding, diving and logging were more prevalent when the seismic source was silent whereas blowing, breaching and surfacing were found to be more prevalent during full power activity. These trends were observed in each of the three regions to some degree. When examining the combined dataset for source ramp-up operation mode, no species group presented any significant difference in recorded behaviour as compared to any other source operating level.

This report represents the longest term and most widespread geographical analysis of PSO data. As PSOs will continue to be a requirement to undertaking seismic survey activities in many areas of the world, the data collected can continue to provide an important resource for understanding how seismic activity impacts marine life. In addition, these data can be used to inform regulatory decision making with respect to development and adaptation of appropriate monitoring and mitigation regulations globally.

In order to maximize the potential of PSO data, companies should be encouraged to share data in a secure, centralized location such that it is available for periodic analysis and further standardization of PSO training and data collection should be prioritized.

1 INTRODUCTION

1.1 Background

Framing the Issue

Industrial, academic, recreational and military operations that occur offshore can intentionally or incidentally introduce man-made sound into the marine environment which may inhibit marine animals known to use acoustics for various life functions (Richardson, Greene, Malme, & Thomson, 1995). Marine mammals have typically been a key focus in examining the impacts of noise because underwater sound is presumed to important for successful completion of critical life processes such as feeding or breeding for many species (Hatch & Wright, 2007; Richardson et al., 1995). There are many sources of man-made noise in the oceans. However, marine seismic surveys and related technologies have been receiving increased public scrutiny regarding their potential impacts on marine life in publications ranging from scientific journals to other forms of media (Gordon et al, 2003; Nowacek et al, 2015) . Studies have been conducted to examine the effects of seismic operations on marine mammals and sea turtles; however, the extent of disturbance is still largely debated, and the degree of impact is not fully understood (Boyd et al., 2011; Dragoset, 2000; Gordon et al., 2004; Nowacek, Thorne, Johnston, & Tyack, 2007).

A Protected Species Observer (PSO) may be deployed on board vessels or platforms associated with marine seismic surveys to perform dedicated searches and to alert the crew of detections that require a mitigation action as well as to record and report on protected species detections. These personnel are variously termed as PSOs, visual observers, Marine Mammal Observers (MMOs), or Marine Fauna Observers (MFOs). Some of the terminology differences are a result of various regional guidelines as the Joint Nature Conservation Committee (JNCC) for the United Kingdom region refers to them as MMOs and Bureau of Ocean Energy Management (BOEM) in the United States (U.S.) refers to them as PSOs. In this report, these personnel shall be referred to as PSOs. This report examines the marine fauna related datasets that are commonly collected by PSOs during seismic operations in order to provide insight into the multifaceted issue of the impacts of underwater noise and to provide recommendations from lessons learned on PSO data collection and management to improve future analyses.

Marine Seismic Surveys

Marine seismic surveys utilize a seismic source to indicate the geological structure of the subsurface of the Earth in order to predict locations of oil and gas. A seismic source is defined as “any device which releases energy into the earth in the form of seismic waves” (Sheriff, 2002). The most commonly used seismic source for marine surveys is the compressed air (CA) source, mostly known as an airgun. A CA source is “a seismic source that injects a bubble of highly compressed air into the water” (Sheriff, 2002). Depending on the survey type, the CA sound source is activated at specific intervals from seconds to minutes apart over a period of days to several months. Some surveys are stationary involving the sound source being deployed off a rig or support vessel, whereas other surveys can incorporate a single vessel or a fleet of vessels that traverse large areas. The largest component of CA source frequencies are typically within the 0-120 hertz range but a small percentage of the energy produced is in higher frequencies up to 20 kilohertz (Compton, Goodwin, Handy, & Abbott, 2008; Goold & Fish, 1998; Richardson et al., 1995). This is relevant for marine mammals because the frequencies used in seismic surveys overlap with the acoustic ranges of marine mammals. There is an increasing body of research on the impacts of seismic on marine mammals and a need for more research to fully understand the potential impacts on marine mammals from seismic operations (Gordon et al., 2003; Nowacek et al., 2007).

Mitigation Measures

To acknowledge and minimize the potential impacts of seismic surveys on marine mammals and sea turtles, various mitigation measures may be encouraged or enforced by regional governments or by internal company policies. In 1995, the first formal guidelines intended to minimize the acoustic disturbance to marine mammals were introduced by the JNCC. Similar efforts providing guidelines have been developed in numerous regions around the world which may be applicable to marine mammals, turtles, basking sharks, whale sharks, and other marine species deemed to be sensitive depending on jurisdictional conservation objectives (Compton et al., 2008; Weir & Dolman, 2007). The mitigation protocols will vary from survey to survey due to variations in regional regulations and some companies may voluntarily employ mitigation procedures where no formal regulations exist. The International Association of Geophysical Contractors (IAGC) has provided a standardized set of procedures, Recommended Monitoring and Mitigation Measures for Cetaceans during Marine Seismic Survey Geophysical Operations, to be followed in situations where no formal regulation or guidance is provided. These guidelines are similar to the JNCC guidelines in the recommended procedures to be implemented, but it is at the discretion of the companies to voluntarily implement the procedures.

The monitoring requirements/recommendations and mitigation actions that are implemented vary widely between geographic areas but some of the most common protocols include:

- **Visual monitoring** –the use of PSOs to scan the ocean surface for the presence of marine species. In some areas it is required that the PSO be a dedicated observer, where they are not permitted to undertake other duties on board the vessel while assigned to visual watches. Some areas also require that the PSO be a third-party observer (i.e., not a member of the vessel or seismic crew). Many regulations contain stipulations regarding how long visual monitoring watches should last before the observer takes a break, where the goal is to ensure that the observer can remain focused on detecting animals in the area.
- **Passive acoustic monitoring (PAM)** – similar to the above requirement or recommendation for visual monitoring, acoustic observers may be required or used to monitor the surrounding waters using equipment that allows them to watch for acoustic signals from marine mammals via a computer screen and listen via headphones for the vocalizations of marine mammals which could indicate their presence in the area. This may be required or recommended only during periods when visual monitoring cannot be undertaken effectively (e.g., reduced visibility, with a focus on night time), or could be implemented day and night. Some regions require or recommend acoustic monitoring only during specific survey activities, such as prior to the initiation of the seismic source from silence. It is often recommended that an acoustic observer be trained in the set-up, troubleshooting, and use of acoustic monitoring equipment (both hardware and software) to better ensure the observer can identify acoustic sounds and signatures from various marine mammals. As with visual monitoring watches, there are often guidelines surrounding the length of acoustic monitoring watches.
- **Exclusion zones, mitigation zones, safety zones** – a defined radius around the sound source where visual and acoustic observations may be concentrated, and mitigation actions implemented should a mitigation species enter that radius. Zones may be defined as a specified distance (500 meters (m), 1000m, 1500m), either from the centre of the sound source or from the radial distance from any element of the airgun array (Compton et al., 2008; Weir & Dolman, 2007). Some of the more recent protocols base their zones upon measured or estimated received sound levels of the specific seismic array for a survey, where the zone is established from expected potential physical or behavioural impacts (National Marine Fisheries Service [NMFS], 2016). Identical zones may be applied to all marine species or zones may vary from species group to species group, depending on the postulated potential for behavioural or auditory risk to that group.
- **Pre-shooting search** – a defined period of time where a dedicated search of the exclusion zone is conducted for mitigation species prior to initiating the seismic source from silence. This search period may be conducted visually or acoustically or using both methods and varies in duration, where frequently applied search periods are either 30 minutes or 60 minutes.
- **Ramp-up, soft-start** – a gradual increase in source volume, starting at a small source output and gradually increasing to the production output over a defined period of time. The intent of ramp-up/soft-start is to alert mitigation species of pending seismic operations and to allow

sufficient time for those animals to leave the immediate vicinity. Under normal conditions, animals sensitive to these activities are expected to move out of the area.

- **Delaying initiation of source activity** – a delay to the initiation of source activity until the exclusion zone is clear of mitigation species for a defined period. This may be applied to some species or to all species. The procedures concerning how source operations may begin following a detection vary but frequently involve a required “all clear” period where there are no further detections inside the zone. Delays may be applied following visual sightings of animals or acoustic detections of animals.
- **Shutdown of active source** – an immediate cessation of source activity when a mitigation species enters the applicable zone. This procedure may be applied to some or all marine mammal species and occasionally other marine species (e.g., sea turtles). The procedures concerning how source operations may begin following a shutdown, but frequently involve a required “all clear” period where there are no further detections inside the zone and may also require that a ramp-up of the source be conducted. Shutdowns may be applied following visual sightings of animals or acoustic detections of animals.
- **Power-down of active source** – similar to a shutdown of the active source, but instead of completely shutting off all source activity, instead the output is reduced when a mitigation species enters the exclusion zone. Like shutdowns, the procedures concerning how source output is increased following the detection will vary and power-downs may be implemented for visual or acoustic detections.
- **Mitigation gun** – a period where the source level of the airgun array is reduced to the lowest volume airgun in order to maintain a minimum source level of 160 dB re 1 μPa-m (rms) and is activated at the same shot interval as the seismic survey for the duration of certain activities (United States Department of the Interior, Bureau of Ocean Energy Management (BOEM) Gulf of Mexico (GOM) Outer Continental Shelf (OCS) Region, 2016).
- **Source “pause”** – a short cessation of source activity to allow a mitigation species to pass by the source during a silent period of airgun activity, followed by returning directly back to full production volume. These have been voluntarily implemented for sea turtles because sea turtles are typically not detected unless they are within close range to the vessel/source (Nelms et al., 2016).
- **Avoidance maneuver** – in some circumstances or jurisdictions a vessel may maneuver to avoid close proximity to a protected species or area, necessitating return to the area later to complete the survey data set. Due to the limited mobility of a survey vessel towing a listening array (“streamers”) the circumstances where this mitigation option may be applied are usually limited.

PSO Training and Qualifications

Regions that require the use of PSOs during seismic operations will frequently, but not always, stipulate that the PSOs must have completed a certification or training program to qualify them to perform these duties. In some regions, a specific training program tailored to that area must be completed, while in other regions any regional PSO certification program is acceptable. Training programs vary from instructional environments with online, classroom, at-sea experience, or a combination thereof.

The qualifications for PSOs can vary dramatically from very little to no experience to being a highly specialized marine biologist. Typically, the PSO is a dedicated third-party observer but in some cases, a crew member may take on the role of a PSO where they may or may not also be performing other duties in addition to monitoring and collecting data as a PSO. Studies of PSO effectiveness have found that the use of PSOs with more training and experience impacted data completeness, accuracy and reliability with dedicated and more experienced PSOs having better data quality (Compton, 2013; Stone, 2003; Stone & Tasker, 2006). However, other studies on PSO experience suggested that more experience does not always result in more reliable data as long as training was sufficient (Kavanagh, Goldizen, Blomberg, Noad, & Dunlop, 2016).

Data Collections

In the fulfilment of their duties, PSOs collect general background information about the survey, sound source, and the observers as well as large volumes of detailed information relating to three key elements of their collected data.

1. **Seismic Operations**—the hours of activation of the acoustic source and details of any mitigation required to delay or cease acoustic activity;
2. **Location and Effort**—a record of the duration and location of visual and acoustic monitoring activity as well as meteorological conditions; and
3. **Sightings/Detections**—every observed mitigation species is recorded with a range of details about the detection, including distance from the acoustic source, source activity during the detection, species identification, behaviour, environmental conditions, etc.

Data collection varies greatly between geographic areas depending upon the reporting requirements of the regulatory agency, client, or PSO provider. However, PSO data are typically based on these three key data types which comprised the first data collection forms issued by the JNCC in 1996. Over time, those forms have evolved in order to move from standalone paper forms that were printed and completed by hand (‘deck forms’), to an Excel spreadsheet-based system that includes drop-down lists of potential responses in order to standardize data and increase the ease with which data can be submitted to regulators. In addition to the data validation measures in Excel, a guidance document is frequently provided with the forms to further ensure standardization. The current JNCC guidelines (JNCC, 2017) and forms (http://jncc.defra.gov.uk/page-1534) have been proposed for global use (provided no other requirements are in place) by the Marine Mammal Observer Association (MMOA) and by the Exploration and Production (E&P) Sound and Marine Life Joint Industry Programme (JIP) (www.soundandmarinelife.org) of the International Association of Oil and Gas Producers (IOGP) and IAGC.

Excel workbook forms are the most widely used format for data entry due to their relative simplicity, low cost, and wide availability; however, they have limitations in capabilities and flexibility and are prone to errors in data entry. Paper deck forms are also used to collect data that is later entered into an Excel spreadsheet or a software program.

Data collection techniques have recently begun to include software programs. Many software programs show promise of saving time and increasing standardization via drop-down menus, automated data checks and synchronization, and the ability to geo-reference sightings via Global Positioning System (GPS) enabled devices. However, these programs may be available at an additional expense to seismic operators and most of those are highly specialized programs that were created for use in a specific region under the regulatory protocols that exist in that area. Moreover, software programs are not completely immune from human errors or potential bugs which would need to be corrected upon discovery.

PSO Databases and Reviews

PSO data in areas which have formal mitigation regulations are submitted to the regulatory bodies that required the data collection and can be archived internally by the client, operator, or PSO provider for the survey before being archived as a standalone report or included in a larger database. At this time, there is no consistent procedure for how and where these data are stored, and most data are not shared beyond the project stakeholders unless the regulatory body publishes the data publicly—meaning that a comprehensive, global database of PSO data does not exist.

Despite the lack of access to the data in most areas, PSO data have been periodically reviewed in different regions in order to examine both the potential effects of seismic survey acquisition upon marine mammals and determine compliance levels among licence holders. In the United Kingdom, a PSO database is regularly analyzed, and reports are produced for the JNCC (Stone, 1997; Stone, 1998; Stone, 2000; Stone, 2001; Stone, 2003a; Stone 2003b; Stone, 2006; Stone, 2015). In 2006, Stone and Tasker examined MMO data from the UK and surrounding waters from 201 surveys from 1997 to 2000. In 2015, a JNCC study examined PSO data from the UK and surrounding waters from 1994-2010 (Stone, 2015). The Stone 2015 analysis was the largest analysis for this region and because there were sufficient sample sizes, it allowed for the inclusion of beaked whales, a group which are typically not included in PSO analyses due to low sample sizes, to be included in the assessment. Stone, Hall, Mendes, & Tasker (2017) reviewed the effect of CA sources on marine mammals in UK waters based on the MMO data from the JNCC report by Stone in 2015. In the United States, the BOEM funded a study that examined PSO data collected in the Gulf of Mexico between 2002 and 2008 and included a discussion of potential effects of seismic operations on marine mammals (Barkaszi, Butler, Compton, Unietis, & Bennet, 2012). Childerhouse et al. (2016) conducted a preliminary analysis of PSO data collected from New Zealand waters which included an effort and mitigation summary, along with recommendations to improve reporting. Moreover, some reports have examined individual or regional surveys using PSO data to assess the effects of seismic operations on marine mammals (Baines and Reichelt, 2014; Baines et al., 2017; Bröker et. al., 2015; Fernandes et al., 2007; Harris et al., 2001; Lalas and McConnell, 2015; Miller et al., 2005; Monaco et al., 2016; Parente and Arujo, 2011; Potter et al., 2007; Smultea et al., 2013; Weir 2007; Weir 2008a; Weir 2008b).

In addition to these regional PSO analyses, Compton (2013) conducted a global assessment of PSO data which analysed 378 sightings from 15 different countries spanning 1996 to 2005. Compton analyzed PSO data across several worldwide regions where data was collected under different regulatory regimes and made recommendations toward global practices. This study also examines PSO data across various regions with variation in data reporting as well. For this study, it is thought that the large sample size may help the quality of the statistical analyses to reveal trends and patterns over various regions.

PSOMAP

To work towards a single, global, PSO dataset, RPS developed PSOMAP (www.psomap.com), which is a database-driven, customized web-based Geographical Information System (GIS) application used to store, view, and analyze PSO data. PSOMAP has a SQL Server Express 2012 database engine with a web application user interface. This pre-existing database system was utilized in this study to standardize data into a single format in a database with querying, analysis, and mapping functionalities. This application allowed various formats of PSO data collection forms and written reports to be collated into a single database. The PSOMAP system consists of several integrated components, including secure client data and report libraries, an embedded GIS, metocean data, and integrated query, analysis, and project planning tools. The database is not open access due to the current proprietary conditions on the data.

Limitations to PSO Data

Although protected species data is gathered fairly systematically by PSOs from a platform of opportunity such as a survey vessel or rig, caution should be taken when reviewing or analyzing the data due to the limitations, variations, and biases inherent to PSOs. There are several factors which influence the ability to make or record accurate details of a detection, which can impact the associated data to contain potential inaccuracies. Some of these factors include:

1. **Human Factors**
   - Role and responsibility of a PSO-Due to the primary responsibility of a PSO to oversee real-time mitigation requirements, the data that are collected as part of these efforts, while useful, must be analyzed with a full understanding of their limitations as an activity secondary to the primary PSO responsibility of initiating appropriate mitigation actions.
   - Marine Seismic Survey Design- The PSO is constrained by the seismic survey which is designed to optimize the time spent gathering subsurface data and is not intended to study animal abundance, distribution, or behaviours as a dedicated biological survey or controlled exposure experiment.
   - Vessel and Seismic Equipment-Due to the presence of the vessel and its speed, its engine and equipment noise, towed equipment and a sound source, there is a likely differential

detectability involved in the presence of animals, as well as their abundance, distribution, and behaviour observed in relation to the ongoing survey.

- Vessels in the nearby vicinity-Vessel traffic within the area can also impact detectability. Marine seismic surveys sometimes involve a fleet of vessels which can impact detections. In some cases, PSOs maybe present on nearby vessels and more than one PSO can make the same detection. Therefore, to get accurate count of animals, duplicate detections should be addressed in more detail during recording and counted as one detection during a comprehensive analysis.
- Training and Experience-PSOs as individuals have a large range of experience, training, and resources which can impact the data collection. The variations in training and experience within regions can be substantial but can be more so when various regions with different procedures and requirements are examined as one dataset.
- The number of PSOs/rotations/watch schedules -Along with variations in individual PSOs, some surveys may employ one or multiple PSOs to observe the surrounding waters which can impact detections and reporting quality. Furthermore, the duration that PSOs spend offshore and the duration of their visual watch can impact stamina for dedicated watches and data keeping.
- Unintentional Human Bias- There are some data fields regarding detections that can be impacted by unintentional biases. For example, the additional information such as behavioural information is collected opportunistically, where the PSO records as much data as the situation permits. This limitation in time and attention available for data recording subjects the data to potential bias (Altmann, 1974; Mann, 1999). For example, the observer may notice certain behaviours in a large group and ignore or miss other behaviours exhibited by individuals in the same group (Mann 1999). Another example includes the tendency to round numbers which may be appropriate in certain situations, but it does not represent the true value and can lead to over/under estimates.
- Supplemental Monitoring -Some PSOs may have access or support from supplemental monitoring techniques to augment detection capabilities such as PAM, aerial surveys, or the use of unmanned vehicles/drones. While various monitoring techniques may have advantages and disadvantages in regard to PSO reporting, they also have limitations to consider as well.
- Recording and Reporting Protocols-Data fields can be left blank for a variety of reasons which can complicate analysis if there is not a clear protocol for recording data or if the protocols were not followed. For example, it can be difficult to determine if blank fields were left blank to mean the value was zero, it was left blank because it was unknown but should have a value, or left blank because there is no value or data to record (not applicable). Furthermore, various reporting protocols have different units and some of the accuracy may be lost during conversion processes such as changing a duration of visual effort in time to visual effort in kilometres when vessel speeds are generalized or unknown.
- Reporting Frequency-The amount and frequency required for reporting can also impact a PSO's ability to focus on surrounding waters and data quality. In some cases, an additional PSO is utilized to assist with recording data and confirming detections. In instances where only one PSO is on watch and responsible for data collection, it is possible to miss a detection due to frequent reporting requirements. For example, if PSOs following JNCC protocols do not have a hand-held GPS, then they may have to leave their observation location to get hourly coordinates from inside the bridge of a vessel. Although not examined during this study, it has been observed by reviewing PSO data that errors can become common when PSOs use an old report as a template in order to keep up with frequent reporting requirements. Errors can occur if reporting is too frequent, but they can also occur if reporting is not frequent enough as reports that span longer durations can make it more difficult to remedy reoccurring errors.

- Location of Vantage Point- The location that observations take place can impact detections and should be generally be suitably elevated, stable, provide a 360 degree or wide and unobstructed view of the surrounding waters, and reduce exposure to the elements.
- Equipment used-The equipment used can have various impacts on the data collected. Binoculars are a standard requirement however there are many variations of lens and magnifications which can impact the ability to make detections or species identifications. Likewise, having reticules on binoculars may assist with distance estimations. There is also a variety of equipment that can be used beyond binoculars such as range finders, radios to communicate detections, or a hand-held GPS.

2. **Environmental Factors** – There are many environmental factors that can impact data collection or have been documented to influence the probability of making a detection.
   - Weather/visibility
   - Time of day/night and amount of daylight
   - Sea state, swell height, and Beaufort
   - Cloud coverage and sun glare
   - Water depth and water turbidity
3. **Biological Factors** – There are several biological factors that influence data accuracy such as
   - The brevity or time spent at the surface/dive durations-animals must be at the surface for PSOs to observe them.
   - Distance of some detections
   - The size, spread, or mobility of a group or individuals
   - The animal behaviour-some species may typically have more conspicuous behaviours making them harder to detect.
   - Visual cues-Sometimes birds or other cues like the size of a whale's blow might be available to PSOs to assist in making a detection.
   - The natural characteristics of species which can make some animals easier to detect and identify.

It should be noted that many other dedicated biological surveys face some of same challenges such as potential interference caused by the vessel or its equipment, observer bias, and other hardships related to gathering data on marine species. While the drawbacks with the PSO data can be identified, they can be accounted for during analysis or reduced by implementing enhanced data collection techniques using standardized protocols to produce higher quality datasets. The behavioural analysis in this report may provide a general pattern of responses through consistent records across multiple surveys taken during real conditions. However, the conditions of PSO mitigation monitoring do not readily allow monitoring of specific detections over long periods, in a manner that might possibly allow for determination of a clear and direct response by the species of concern to the acoustic source itself.

Uses for PSO data

PSO data has the potential to be a valuable dataset to all stakeholders involved in the Exploration & Production (E&P) life cycle. The PSO data can be used demonstrate industry compliance with environmental regulations which may help Oil and Gas (O&G) companies in permitting or license applications. Alternately, regulators may use PSO data to monitor for compliance and assess the effectiveness of mitigation and monitoring measures and evaluate the need for protections of certain species. Oil and Gas companies may also use historical PSO data to help budget for mitigation time on projects or examine potential costs related to mitigation for marine mammals under various mitigation measure requirements. For the many areas where marine mammal data are sparse, data collected by

PSOs represent a valuable resource that can supplement Environmental Impact Assessments and help to inform operators about which mitigation measures may be the most practical or commonly used in an area.

PSO datasets provide opportunities to record species in offshore and remote areas that can be costly or difficult to access. Due to the data collection opportunities provided to PSOs they have been able to report information on poorly documented species (Weir, 2006a; Weir, 2010; Weir, 2011; Weir et al., 2012), add to knowledge on occurrence through confirming species in an area range they were not previously recorded in (Weir, 2006a; Weir, 2006b; Weir et al., 2010; Weir et al., 2011; Weir et al., 2013), examine habitat preferences (Weir et al., 2012), identify spatio-temporal trends in distribution(Weir, 2011), describe morphological appearances and behaviours (Weir & Coles, 2007; Weir et al., 2010), provide data on rare events that otherwise might not have been observed (de Boer, 2010b; Koski et al., 2008; Koski et al., 2009) and provide insight into the potential effects of underwater sound on marine species(Baines & Reichelt, 2014; Baines et al., 2017; Bröker et al., 2015; Fernandes et al., 2007; Harris et al., 2001; Lalas & McConnell, 2015; Miller et al., 2005; Monaco et al., 2016; Parente & Arujo, 2011; Potter et al., 2007; Smultea et al., 2013; Weir, 2007; Weir, 2008a; Weir, 2008b). PSO data provide useful management and conservation information such as detailing the occurrence and presence of species. The data can augment the data from dedicated biological surveys and the PSO data can provide records of animal distribution and abundance in the immediate vicinity of the activity of concern. Those data have also been used effectively in ecological studies to describe associations with particular environmental variables or help confirm species occurrence for the International Union for Conservation of Nature (IUCN) Red List assessments.

1.2 Aim and Objectives

The primary aim of this study was to 1) evaluate the quality of existing PSO data regarding compatibility with an international database, 2) collate PSO data from three general regions, and 3) to test how a global database could be used to address inquiries about the potential impacts of seismic surveys on marine mammals and sea turtles. To provide an international assessment with varying field reporting requirements, PSO data were collated from three regions:

1. Gulf of Mexico
2. West Africa
3. Australia

These areas were selected because they all have varying regulatory regimes which apply different mitigation guidelines and reporting. The data collection standards and formats vary across each of these three regions. This report focused on these three areas as an experimental and initial step toward global PSO data collection. The regional datasets were analyzed separately and then combined into a single, standardized dataset (Appendix A). The combined and standardized datasets can then be used for many kinds of analyses, including but not limited to, looking at the effects of sound from marine geophysical surveys.

To achieve this goal, the following tasks were met:

- Create a combined PSO dataset for the Gulf of Mexico, West Africa, and Australia in a single, consistent format;
- Create a common data exchange format to facilitate data export and use;
- Summarize and synthesize PSO data regarding marine mammal and sea turtle distribution;
- Assess PSO data with regard to underwater sounds from geophysical surveys using similar methods from previous regional studies. Sighting information compared to seismic source activity and behaviour observations compared to CA source status were specifically examined.
- Archive data into PSOMAP, a web-based data portal with data query and GIS tools

A secondary objective was to take the lessons learned from collating and analyzing the PSO data across the regions to determine practical improvements for the collection and management of the data. At the end of the report, suggestions are provided for how to fill data gaps along with recommendations for improving current PSO practices in order to strengthen data quality and to optimize the potential use of PSO data for research purposes while maintaining the primary purpose of providing mitigation monitoring.

2 METHODS

2.1 Data collection process

This study focused on three key areas for E&P activities: The Gulf of Mexico, West Africa, and Australia. These areas all have varying regulatory regimes which apply different mitigation guidelines. The data collection standards and formats varied across, and within, each of the three regions.

As a global service provider of PSO personnel to the geophysical industry, the study group (RPS) was already in possession of a large volume of PSO data. Data already in possession underwent a rigorous internal review process, were already in the appropriate format for the study, but needed client permissions for use in this study. The internal reviews were conducted by Project Managers familiar with common errors to the forms and involved scanning the written report and excel data for errors. Errors were corrected based on context clues and surrounding data or by directly contacting the PSOs for clarification. Depending on the type and amount of errors, the corrected reports and data would be sent back to the PSO to help prevent a continuation of errors in the future. Furthermore, the forms in the Gulf of Mexico often have formulas nearby that help flag potential errors which assists the review process that is done by the PSOs and the Project Manager. For some of the reports and data collected in the Gulf of Mexico region, an in-house application was developed and applied to assist in the internal QC process and run through an automated series of checks. Data that were not in-house had to be reviewed, organized, and sequentially converted to a compatible exchange format via the MMO Import Tool which was developed for this project. All PSO data collected needed permissions for use in this study unless already publicly available via regulatory agencies.

2.1.1 Gulf of Mexico

The Gulf of Mexico was selected because it has a large volume of PSO data that has been refined on seismic exploration programs for over a decade (United States Department of Justice, 2016). A bulk of the programs have been focused on the northern U.S. Gulf of Mexico; however, a number of programs have been completed in the southern Gulf of Mexico in Mexican waters. Programs which were conducted in the U.S. Gulf of Mexico have been subject to regulation since 2002, and PSO data have been extensively archived and are publicly available. Regulations for seismic surveys in Mexican waters were passed in 2016, after the data collection phase of this study was complete. Surveys included in this study, conducted in the area prior to the regulations being implemented, varied largely in implementation of PSO usage, mitigations, and reporting. The data collection parameters for this study focused on the U.S. Gulf of Mexico data from 2009 to 2017.

In the U.S. Gulf of Mexico, the Bureau of Ocean Energy Management (BOEM) is responsible for ensuring that geological data are collected in an environmentally responsible manner and allows seismic operators to conduct surveys according to their permit and the current NTLs. The BOEM NTL 2016-G02 Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program stipulates the mitigation measures with which the operator must comply, the requirements for PSO training, and the PSO data collection and submission requirements. Although BOEM does not require PSO data to be collected via a standard form, it does list a minimum of data fields required for the PSO program. Therefore, PSO data from the U.S. Gulf of Mexico can be variable but were typically a slightly altered version of the JNCC forms. Notable alterations included additional formulas to show the durations of times, output spreadsheets to facilitate reporting and summary information, and a chronological order of operations (e.g., the pre-shooting watch was recorded on the left-hand side before the start of ramp-up/soft-start, whereas the JNCC forms record the pre-shooting search on the right-hand side after operations). Additionally, some of the altered forms had additional fields such as the PSO provider project number, an optional input for the seismic line or sequence number, the number of PSOs on watch, the location of acoustic monitoring (remote, vessel, or rig), if a detection was also observed on a nearby vessel with PSOs, and time spent bow riding. The previous analysis of PSO data in the U.S. Gulf of Mexico from 2002 to 2008 indicated that data collected were extremely variable in the early years and began to become more consistent in the years closer to 2008 (Barkaszi et al., 2012).

In the U.S. Gulf of Mexico, PSO reports and the associated raw data in Excel files are submitted on a bi-weekly basis on the 1st and 15th of each month. Therefore, depending on the length of the survey and the number of seismic vessels, a survey may have several PSO reports associated with it. In Mexican waters, reports were submitted at varied intervals—surveys which crossed into U.S. waters submitted reports bi-weekly, while surveys solely in Mexican waters submitted PSO reports weekly, monthly, or as a final project report. Although raw data from the Excel files was used for the analysis, the number of reports and the associated projects helps provide an idea of the data collection efforts from each region.

A total of 2379 PSO reports/Excel files from 244 seismic surveys were collected for this region. The PSO reports had a total of 350,691 hours and 38 minutes of visual monitoring effort. The shortest report covered a period spanning a single day, while the longest report had a duration of 32 days. The RPS study group were already in possession of the majority of those reports, which were already reviewed and loaded into PSOMAP. Permissions for use of the U.S. Gulf of Mexico data in this study area were not needed because the data are publicly available from the BOEM Data Center (https://www.data.boem.gov). Any data gaps discovered in the U.S. Gulf of Mexico data that were not already in the possession of RPS were filled by retrieving PSO reports from the BOEM online Data Center and by contacting BOEM directly. Permissions for use of the Mexican Gulf of Mexico data were received from the data owners, and any data where permissions were not received were redacted from the dataset prior to analysis.

2.1.2 West Africa

West Africa is an increasingly important region for hydrocarbon exploration, with countries including Angola, Gabon, Nigeria, and Mauritania all very active (Petrowire reports, 2016-2017). While no statutory guidelines relating to mitigation for marine mammals are in place in these countries, most require EIAs to be undertaken, where mitigation is then an important recommendation and subsequent license condition. There has been a wealth of PSO data collected in this region. However, due to the varied government processes and various clients separately gathering data, there has not been a systematic assessment for PSO data in this region aside from the publications from PSOs onboard the surveys.

The PSO data from West Africa that were obtained by RPS for this study spanned the years from 2005 to 2016 and were collected in the Exclusive Economic Zones (EEZs) of the following countries: Angola, Equatorial Guinea, Gabon, Ivory Coast, Liberia, Mauritania, Morocco, Namibia, Republic of Congo, Senegal, South Africa, and Western Sahara.

Typically, PSO reports and raw data in Excel for West Africa were submitted at the end of a survey but there were some cases where they were submitted more frequently; therefore, some surveys had more than one report/Excel file affiliated with them. All data from the West African region required RPS to obtain permissions to use the data from the seismic operators that supported the initial collection of the data. A total of 69 PSO reports/Excel files from 56 surveys were obtained with permissions for the West Africa region. The 69 reports totalled 33,564 hours and 47 minutes of visual monitoring. The shortest report covered a period spanning over two days, while the longest report had a duration of 755 days.

2.1.3 Australia

In Australia, the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) sets forth a minimum of reporting requirements and requires reports to be submitted at the end of a project; however, some reports were submitted more frequently. Sighting data are recorded within the Cetacean Sightings Application software and were available upon request. This region was selected for analysis because it was expected that the data collection would have mostly consistent data due to the Cetacean Sightings Application and to test how the data could be included in a global dataset despite its differences from JNCC reporting. A majority of external data received for the Australian region were the PSO data archives from the Australian Antarctic Division. A total of 105 PSO data files from 94 surveys for Australia and New

Zealand were included in this study. The 105 data files spanned the years 2008 to 2017, had 54375 hours and 12 minutes of visual monitoring effort. The shortest data file covered a period of one day, while the longest data file covered a duration of 1,594 days.

2.1.4 Survey and Source Volume Summary

The surveys were classified for this report using a classification similar to the Survey Type drop-down options in the JNCC forms:

- **Two dimensional (2D):** Involves a single vessel which tows one sound source and one set of receivers to provide a general picture of the geology over a wide area.
- **Three dimensional (3D):** May be conducted with multiple synchronized sound sources and hydrophone streamers to provide more detailed information about an area
- **Four dimensional(4D):** Involves repeating identical 3D surveys over a period of time in the same area to determine changes in the amount and location of oil and natural gas in the reservoir.
- **Wide-azimuth (WAZ):** Involves advanced 3D surveying techniques. These surveys use multi-vessel operations involving both streamer and source vessels.
- **Site:** Uses one sound source and one set of receivers towed over a small area to check for possible hazards.
- **Vertical seismic profiling (VSP):** A VSP typically deploys a sound source from a rig or a vessel while the receivers are typically placed vertically down a drilled well to give a detailed view of the geology near the wellbore.
- **Ocean bottom cable (OBC):** Utilizes a sound source and ocean bottom seismographs (OBS) which are stationary receivers that can be placed inside an ocean bottom cable (OBC) or an ocean bottom node (OBN).
- **Other:** Included surveys were labelled as High Resolution, Ultra High Resolution (UHR), Testing, Research and Development, Hi-Res Hazard/Archaeological Survey, Systems Integration Trial, and Blasting. There were also some project names that did not indicate the survey type that were listed in the ‘other’ category regarding they type of survey.

The majority of surveys were 3D surveys or VSPs with most of the surveys from the dataset occurring in 2010 (Figure 2-1, Figure 2-2). However, there were several instances where more than one acquisition technique was applied or it was not certain which specific category (site, 2D, 3D, 4D, OBC, VSP, WAZ) a survey belonged to. For example, several 2D or 3D surveys also employed an OBS and were categorized as OBC and not as a 2D or 3D survey. For the following chart, surveys were classified by the secondary listing (3D WAZ as WAZ) and by reviewing comments and project names.

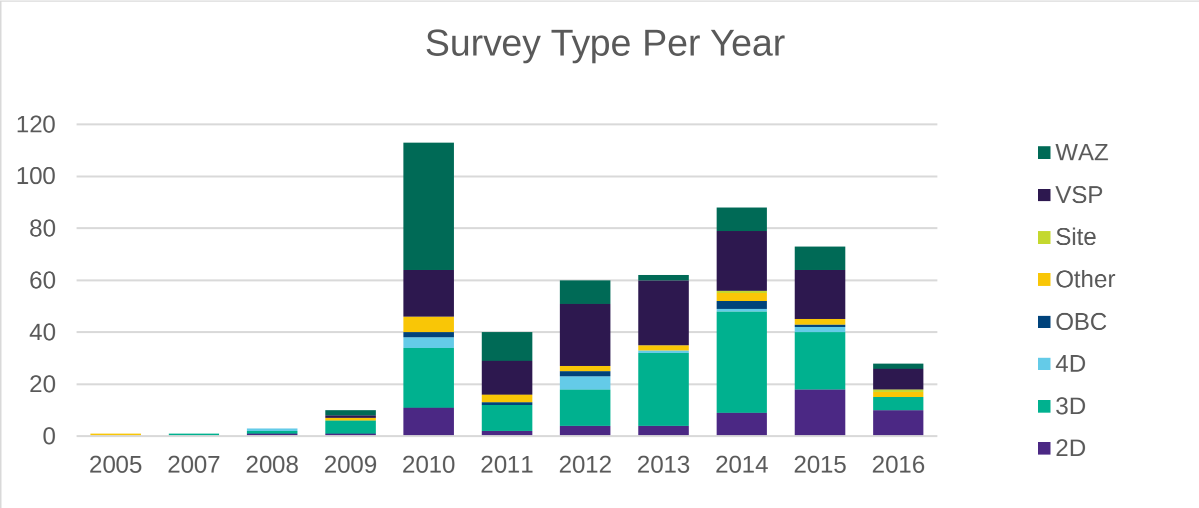

Figure 2-1: Bar chart of categorized survey type

Figure 2-1 includes the two dimensional (2D), three dimensional (3D), four dimensional (4D), Site, Ocean bottom Cable (OBC), Vertical seismic profile (VSP), Wide-azimuth (WAZ)) per survey by year for combined U.S. Gulf of Mexico, West Africa, and Australian datasets.

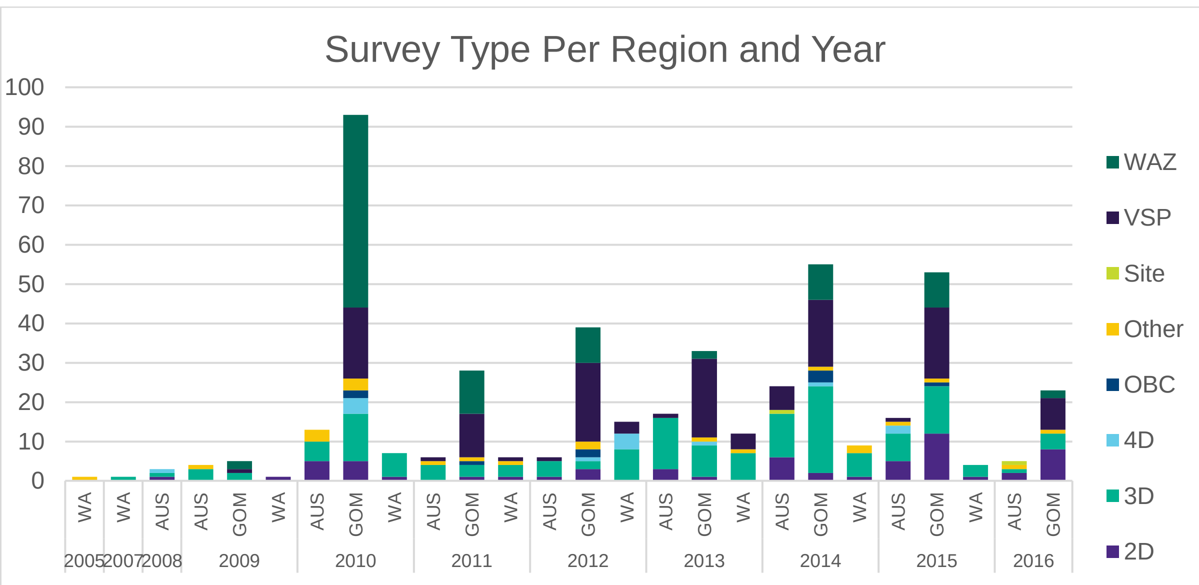

Figure 2-2: Bar chart of categorized survey type

Figure 2-2 includes the two dimensional (2D), three dimensional (3D), four dimensional (4D), Site, Ocean bottom Cable (OBC), Vertical seismic profile (VSP), Wide-azimuth (WAZ)) per survey by region and year.

Stone (2015) categorized source array sizes into a small array (total CA source volume less than 500 cubic inches), large array (CA source volume 500-5,500 cu in.), and very large array (exceeding 5,500 cu in.). The Stone et al. (2017) and Stone (2015) reports showed some responses when larger arrays that had an airgun volume of 500 cubic inches or more were active, but the responses were less evident when small arrays were active. Of the surveys analyzed in this study, the smallest array recorded was 10 cu in. and the largest array recorded was 9,475 cu in. Out of the PSO data received, seven percent of the forms recorded a zero for source volume, which indicated that the data were incomplete or that the survey did not deploy or activate the CA source whilst the PSOs were onboard. Only five percent of surveys recorded a source volume of less than 500 cu in. The majority of the surveys, 64 percent, utilized a large array (500-5,000 cu in.) and 24 percent utilized a very large array (equal to or more than 5,000 cu in.). Therefore, due to the large percentage of surveys having a large or very large array, this report does not distinguish between large and small arrays.

2.2 Data entry and quality control

2.2.1 Data entry / standardization – MMO Import Tool

As part of the wider PSO Data Analysis JIP project, a necessary step was to take the collected data sources and compile into a single, standardized format suitable for onward use in the data analysis phase of the project. This was an important part of the process, as any inconsistencies or inaccuracies in the data sources needed to be identified and resolved if the collected data were to be analyzed as a homogeneous dataset and for the resulting analysis to be accurate.

As data were received in several different formats, it was decided to first convert the data into a common exchange format which could then be manually reviewed by an RPS Project Manager with expertise in PSO data collection and format, and quality controlled before uploading to PSOMAP.

The standardized data format is provided in Appendix A.

A bespoke software application, the MMO Import Tool, was developed as part of this study to load and review the data, then export the datasets in an exchange format to upload into PSOMAP. The MMO Import Tool would run through a series of checks and flag potentially incorrect or inconsistent data. To handle the many formatting errors and inconsistencies, this product had to be applied to each dataset received as many of the datasets required direct intervention by a trained member of the RPS staff and specific fixes applied to enable each file to load accurately.

A total of 10 data formats were provided, each of which was coded separately for import via the MMO Import Tool. The majority of data were in one of five common formats; however, of these projects in common formats, a number were modified in some way, requiring specific software intervention to decode the data and streamline into a consistent format through the MMO Import Tool.

2.2.2 WebGIS data upload – PSOMAP

Data from the MMO Import Tool were separated into regional subsets to correspond to the existing regional database design of PSOMAP, where data are separated into 14 regional databases (Figure 2 3). To delineate the regions, manageable bodies of water were identified first—i.e. Arctic, Antarctic, Caribbean, Mediterranean, Indian. Following the identification of these 5 regions, along with the Gulf of Mexico, the Atlantic and Pacific oceans were left to be defined. It was determined that the best approach to separating these final two larger bodies of water into manageable regions was to define boundaries that broke each region down into quadrants—Northwest, Northeast, Southwest, and Southeast. North and South quadrants of these areas were divided at the equator, or 0° latitude. The East and West quadrants of the Pacific were defined at the antimeridian, or 180° longitudinal meridian both east and west of the Prime Meridian. The East and West quadrants of the Atlantic were defined to be as close to the geographic center between the adjacent land masses as possible, generally following the path of the Mid-Atlantic Ridge.

Regional data were then loaded into PSOMAP as an XML exchange format through an import script developed specifically for this project. As an initial control, data imported through this process were validated for location accuracy in the MMO Import Tool to ensure all georeferenced data points fell within the boundaries of the region in which they were loaded. These data were also reviewed for proper formatting due to restrictions in accepted field formats in the database design, including but not limited to: the specification of number formats, date formats, and time formats for many fields. Any data not falling within the appropriate region boundaries and/or not conforming to PSOMAP formatting requirements was rejected by the platform during import with an error message allowing the user to pinpoint and manually amend the issue prior to re-attempting upload of the data to PSOMAP.

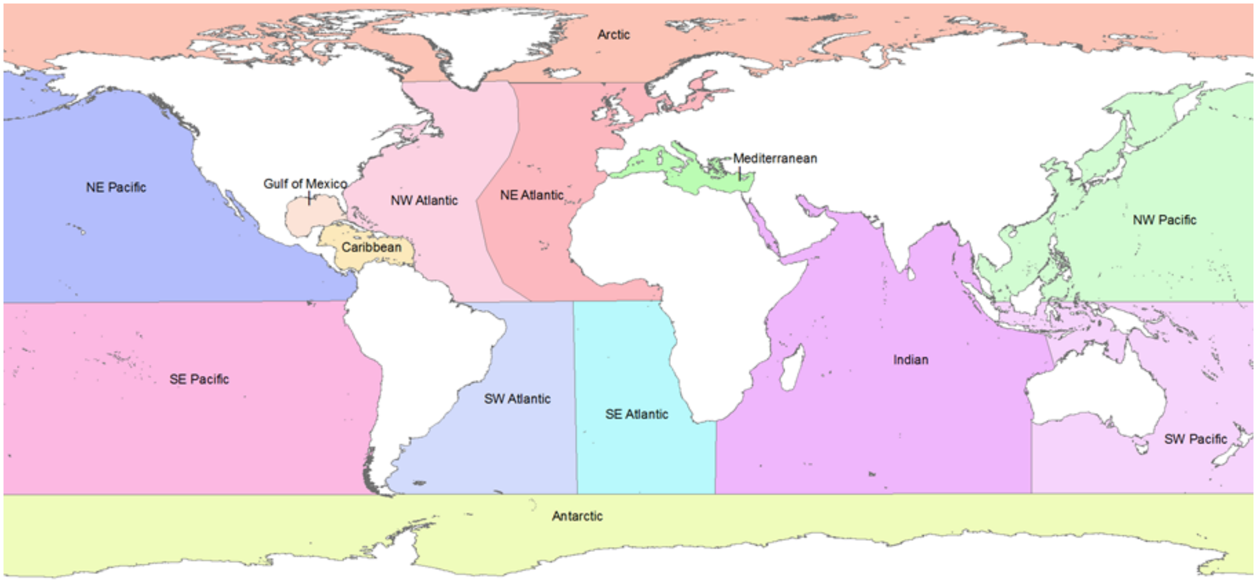

Figure 2-3: PSOMAP regions corresponding to the 14 regional databases

2.2.3 Quality control

There were several steps in the study process where data were reviewed manually or underwent an automatic check that ensured data were in the correct parameters (Figure 2 4). Prior to being incorporated into PSOMAP, data went through manual QC by a Project Manager with extensive PSO data collection experience to evaluate for formatting errors, position errors, and erroneous data when viewed in the MMO Import Tool. The MMO Import tool provided the initial level of quality control for positional data (effort and sighting) by allowing the data reviewer to visualize effort and sighting data on a map on manipulatable timescales (from daily to the entire survey period). The reviewer looked for effort points that appeared outside of the survey region- not necessarily an indication of an error, but that would trigger a closer examination of that datapoint to determine if the vessel had moved out of the area for operational regions while monitoring continued. The reviewer also examined sighting datapoints, visualizing them overlapped with effort where any inconsistencies also triggered a closer examination of any other data source available that could allow for a correction (reports, notes in the comments sections of dataforms)

The Gulf of Mexico dataset had associated written reports which were consulted at times to confirm or correct data. Despite reports being regularly reviewed prior to submission to the regulator in this region, a small sample of photos from the written reports were reviewed again to review species identifications since it would be too costly and time consuming to review photos for all or most detections. The West Africa and Australian region did not have photos with the datasets provided. The photos reviewed had correct species identifications thus the species identifications were kept as they were recorded for this report. Some data fields contained rounded numbers which were also kept as is due to the difficulty of determining the specific number during post processing.

During import to PSOMAP, position errors and data format errors were automatically evaluated as part of the import process. Once all datasets were incorporated into PSOMAP, complete datasets spanning the study period of 2005 to 2017, for each of the defined regions in PSOMAP were exported as CSV files for a final quality control review, with the project team manually reviewing each regional dataset and evaluating for position accuracy, data consistency, erroneous data, missing data, invalid data and confirming outliers in the data. Once this final QC step was completed, the datasets were compiled into comprehensive datasets for each study region (Gulf of Mexico, West Africa, and Australia) and submitted for analysis to a specialized statistics team.

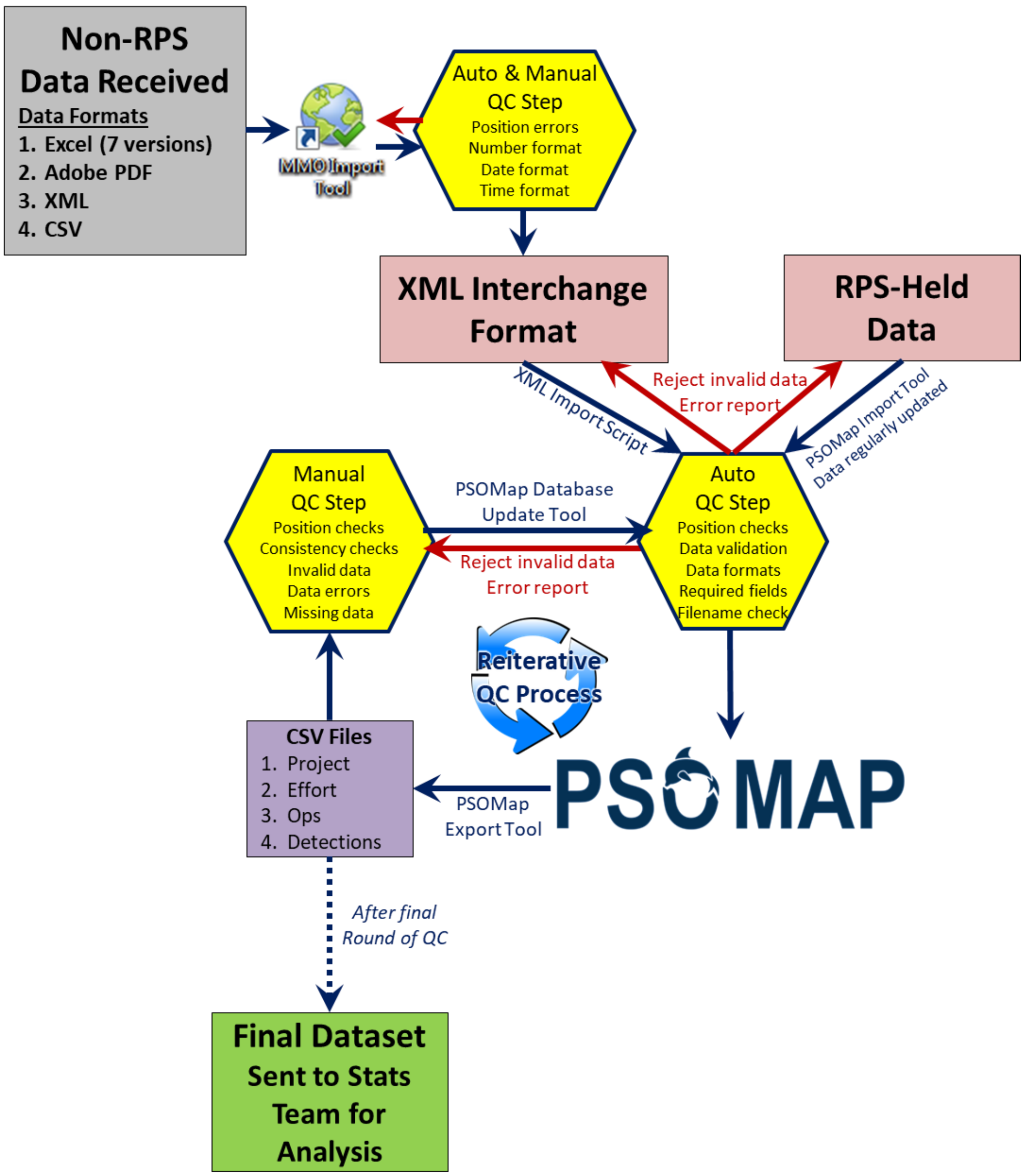

Figure 2-4: Quality Control and Standardization Work Flow

2.3 Data analyses

The PSOMAP database was used to standardize the PSO data collected from the Gulf of Mexico, West Africa, and Australia. The PSO data had discrepancies between the regions such as labelling or metrics, therefore the PSOMAP database provided a platform to format the jurisdictional data collection requirements so that they could be collated, queried, and analyzed. The functionality within the PSOMAP database was able to provide a basic census of data such as the number of sightings and species counts. Statistical analysis was carried out using the software package MiniTab.

The standardized data were analyzed using established statistical techniques and approaches described in the Statistical Analysis section of this report that enabled comparisons with previous studies undertaken for the JNCC (Stone, 2015) and Minerals Management Service (MMS)/Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) (Barkaszi et al., 2012). Using MiniTab, two statistical techniques, Kruskal-Wallis analysis of variance and Chi-squared analysis, were used to analyze animal responses to survey activities. Further multivariate approaches were considered as detailed in section 2.4 below. For each region, an initial analysis was undertaken independently and then subsequently any differences between regions were assessed. Regional data were also combined to provide a broad global analysis, detailed separately in Appendix A.

The analysis accounted for potential duplication of detections from single or multivessel surveys and these were removed from all datasets where applicable. In some instances, one detection could be counted more than once due to observations from two or more vessels that were in visual range of one another. Additionally, single vessel surveys can produce duplicative data by recording a detection twice because the UTC day changed. The sighting number would remain the same and it would create two rows of the exact same data but with differing dates. Likewise, multispecies detections can be recorded on one line which excluded a species from the analysis, or it was recorded on two lines as two separate detections with the same detection number. Duplicates were identified and removed when observations had the same three criteria: airgun status, species category and project identification reference (Project ID).

Other factors such as platform height and Beaufort scale were examined to determine if those factors would greatly influence the results. While no there is no set minimum for an appropriate platform height for PSOs to observe from, 5 meters or less was selected as the minimum where it could potentially reduce the effectiveness of visual observations. The dataset included the lower vantage points due to a low percentage (1%) having an observation point at 5 meters of less. Studies have shown Beaufort to have an impact on marine mammal detectability (Barlow, 2015). Beaufort is a subjective scale from 1 to 8 of sea state conditions and wind speed. Sighting rates decrease with increasing Beaufort levels with some species such as beaked whales being less likely to be detected on the vessel track during a Beaufort 5 (Barlow, 2013; Barlow, 2015). Therefore, the dataset also examined the Beaufort recorded with detections. Detections with a Beaufort of 5 or more were kept in the analysis due to the low numbers. In the Gulf of Mexico around 10% of the detections recorded a Beaufort at 5 or more. In West Africa around 6% of the detections had a Beaufort of 5 or more. Although the Australian region records have a field for Beaufort scale in their reporting, the data provided listed wind speed in this field instead of a Beaufort Sea state number so this data could not be used.

2.4 Statistical analyses

Data from three CA source activity modes (ramp-up/soft-start, reduced power/mitigation source, and full volume) were analyzed separately with each activity level compared against sightings where CA source were silent. Sightings of different species groups (baleen whales, beaked whales, delphinids, sperm whales, sea turtles, and pinnipeds) were analyzed separately. In addition, an analysis was undertaken for all cetaceans combined (excluding sea turtles and pinnipeds) to capture the overall trends and incorporate data for unidentified species of cetacean or unique categories with very limited sample sizes (e.g., Kogia). Data analyses comprised two core methodologies (Section 2.4.1 and 2.4.2 below) which are consistent with the previous BOEMRE study (Barkaszi et al., 2012) and Stone and Tasker (2006).

Other advanced statistical techniques were considered such as Evolutionary Polynomial Regression (EPR), which is a hybrid approach incorporating elements of modelling from three established methods: Multivariate Regression, Genetic Programming, and Artificial Neural Networks. Additional variables including depth, sea state and firing duration were analyzed however the resulting relationships were determined statistically insignificant. Therefore, for directly comparable results, the statistical methods were kept consistent with the previous BOEMRE study (Barkaszi et al., 2012) and Stone and Tasker (2006).

2.4.1 Analysis of Sighting Records

Sighting records were sorted by their Project ID for use in determination of sightings frequency per 1,000 hrs effort per project, average sightings duration per Observation ID, and the average closest distance of approach of animals to CA sources per project. Traditional generalized linear modelling (GLM) techniques were assessed and the data were found not to be normally distributed, therefore a Kruskal-Wallis analysis of variance was used to determine the significance of correlation between different activity modes and sighting frequency, sightings duration, and closest distance of approach to the seismic source for each species group.

Factors such as location, season, weather, monitoring method, and observer ability may impact sighting results (Stone 2015). This report addresses those potential sources of bias by collating information by project ID and considering effort per project ID. In order to mitigate potential bias linked to geographical location and depth, the project ID data were further aggregated by protraction area, at the level of 50km Grid ID, based upon a generated, global 50km grid shapefile. Inclusion of a minimum of a least two airgun activity modes was required within a protraction area, therefore where areas contained either only active or only inactive airgun firing categories for any activity mode/species group, the projects from these 50km Grid IDs were removed from the dataset prior to running the Kruskal-Wallis analysis. In this way geographical representation was maintained when analyzing differences associated with airgun firing modes.

2.4.2 Analysis of Behaviour Observations

Behavioural observations comprised the analysis of individual sightings events for variations in animal behaviour correlated with airgun activity modes. Where data was non-normally distributed, a Chi-Squared analysis was applied to determine differences in the frequencies of recorded behaviours between each airgun activity mode in turn against inactivity. The analytical approach accounted for all individual behaviours recorded per sighting for each of individual and combined regions. Where multiple behaviours occurred the sightings record was duplicated for each of the individual behaviours prior to analysis. As performed for the analysis for sighting records, geographical bias was also mitigated for prior to running the Chi-Squared analysis by aggregating sightings at the level of 50km Grid ID, based upon a generated, global 50km grid shapefile. Inclusion of a minimum of a least two activity modes was required, therefore where areas contained sightings occurring either only during activity or only during inactivity for any activity mode/species group the sightings from these 50km Grid IDs were removed prior to running the Chi-Squared analysis. In this way geographical representation was maintained when analyzing differences associated with airgun firing modes. An analysis combining regions was also carried out for the behavioural analysis, detailed in Appendix A.

The behaviour categories analyzed included:

- **Blowing** – respiring / breathing
- **Bow Riding** – when cetaceans swim on the pressure wave of a boat
- **Breaching / Jumping / Acrobatic behaviour** – surface activity including individuals' bodies breaching the surface of the water entirely
- **Diving** – submerging below the surface
- **Diving with flukes** – submerging while displaying tail flukes
- **Fast travel** – swimming at a high rate of speed
- **Feeding** – includes foraging or observations with fish in mouth
- **Mating** – displaying reproductive behaviours
- **Milling** – moving in an area with no clear direction of travel
- **Porpoising** – swimming in and out of the water at regular intervals

- **Resting at surface / Logging** – laying stationary at the surface
- **Spy hopping** – bringing only the head and eyes above water
- **Surfacing** – emerging to the surface of the water
- **Swimming** – includes traveling in a direction; indicates observed movement of the animals and would not be used to describe animals that appeared to be logging or floating at the surface
- **Swimming below the surface** – swimming without breaking the surface of the water
- **Tail or pectoral fin slapping** – raising the tail or pectoral fin(s) out of the water and slapping them back down on the surface with force, creating noise
- **Other** – any item not included in the above list, explained in the comments field of the data forms

A minimum of five sightings per behaviour category were required for inclusion of that behaviour in the analysis for a statistical assessment to be performed in MiniTab, consistent with the previous study methodology (Barkaszi et al., 2012). Small samples were included to provide some insight into rare species groups. An initial analysis was run per species category comparing behaviour frequency distributions across all behaviour categories (combined behaviour analysis). Where significant differences in behaviour was identified for a species category, Chi-Squared analysis was undertaken on each individual behaviour category to determine which of these behaviours showed the most significant differences between airgun activity modes compared to silent operation.

2.4.3 Analysis of Direction of Travel

Using the same statistical analysis method as behavioural observations (Section 2.4.2), a Chi-Squared analysis was applied to determine differences in the frequencies of recorded directions of travel between each airgun activity mode in turn against silent. Geographical bias was removed using the same method as Section 2.4.2 above.

The directions of travel categories analyzed included:

- Away from ship
- Crossing path of ship
- Milling
- Parallel to ship in opposite direction
- Parallel to ship in same direction
- Towards ship

Analysis was run per species category comparing direction of travel frequency distributions across all directional categories. As with the behaviour analysis, a minimum of five sightings per category were required for inclusion of that direction in the analysis for a statistical assessment to be performed in MiniTab, consistent with the previous study methodology (Barkaszi et al., 2012). Small samples were included to provide some insight into rare species groups.

2.5 Mitigation Summary

Counts were taken directly from spreadsheets to provide a mitigation summary with a focus on shutdowns, delays, reduced power levels, and voluntary pauses. The majority of detection reports specifically stated if there was a mitigation action conducted within a predefined drop-down list that was categorized into a shutdown, delay, a voluntary turtle pause or a reduction in power. In the cases where the mitigation action was listed as a power-down followed by a shutdown it was counted as two separate mitigation actions (i.e., one power-down and one shutdown). In addition, a comments field was consulted as sea turtle pauses were sometimes recorded as shutdowns but explained in the comments. None of the studied regions, however, are required to conduct pauses for any mitigation species—thus, these are all considered voluntary pauses. Due to the variety of regulation in many of the regions included in the dataset, the mitigation analysis followed the species group categorization used in this report (baleen whales, sperm whales, beaked whales, dolphins, and sea turtles).

3 RESULTS

3.1 Data collection process and challenges

One of the most challenging aspects of this study occurred in the very initial phase of data collection. It was anticipated that a significant amount of time would be required to:

1. Generate a list of all possible companies (seismic contractors, oil and gas companies, regulatory agencies, etc.) to contact requesting access to data. The complete list of companies contacted is provided in Appendix B.
2. For each company to make an internal decision as to whether they could contribute; where possible multiple communications would be required from RPS to explain the project further.
3. For companies to locate the data internally and then provide the data.

While it was felt that a conservative estimate for the time needed for this phase had been applied, in fact, this was largely underestimated and twice the amount of time was needed to collect the data that were eventually received. The collection efforts were likely impacted by the recent downturn in the energy in industry as many of the individuals that were involved in projects with PSO data were no longer with their companies and their successors were not able to determine where the data were stored. It is also suspected that the reduction in staff at many companies contributed to the lack of response from many companies as there were fewer people available to address requests such as this one. These challenges are worth noting as it reinforces the significant effort needed just to gather the data to undertake a study of this nature, and highlights the importance of data being stored in a single location such that it can be available for future use.

Permission was not requested from companies for any PSO datasets collected in the U.S. Gulf of Mexico because all PSO datasets are made public on the BOEM website (https://www.data.boem.gov).

RPS reached out to 79 energy companies and survey contractors requesting data contributions to the study, focusing on obtaining permission to use datasets from the West Africa, Australia and other regions that RPS was already in possession of having collected it offshore on behalf of the company (referred to as “inhouse data” from here forward) and in receiving additional datasets that had been collected by other PSO providers for that company. Each company that was contacted was provided with background to the study and its goals. Contributions in regions of focus were encouraged but it was also noted that data collected outside of the regions could still be provided. Companies were provided with details for a secure company-specific File Transfer Protocol (FTP) site where they could upload data to contribute. Where RPS was in possession of data that had been collected on a survey on behalf of that company, those project datasets were described, and permission was specifically sought for inclusion of that data. Permission was sought from the “end client” on a survey project so where a survey was acquired by a survey company on behalf of an energy company, permission was requested from the energy company. To request permission to use multi-client survey data, the survey company was contacted.

Of the 79 companies that were contacted, 50 did not respond at all, after RPS had made three attempts to contact each of a minimum of two relevant persons in that organization. An additional 11 companies responded to the request and expressed interest but either had no data to contribute or were not able to come to a decision by the end of the data collection period (Figure 3 5). A total of 16 companies elected to share some or all of their PSO data. Of those 16, six companies provided new datasets (i.e., data that RPS did not already possess). Many of the companies that were happy to participate in the study noted that RPS could use any data that they were already in possession of, but indicated that they were not able to locate any data to provide themselves. Only two companies responded denying permission for any of their data to be included where no explanation was provided in one case and in another, multiple stakeholders needing to provide permission was cited and no further responses were received to RPS’ requests to request permission from those additional stakeholders.

An additional 32 datasets in the West Africa and Other regions were available in-house but were excluded from the study either because permission was denied to include them or no response was received from the company owning the data.

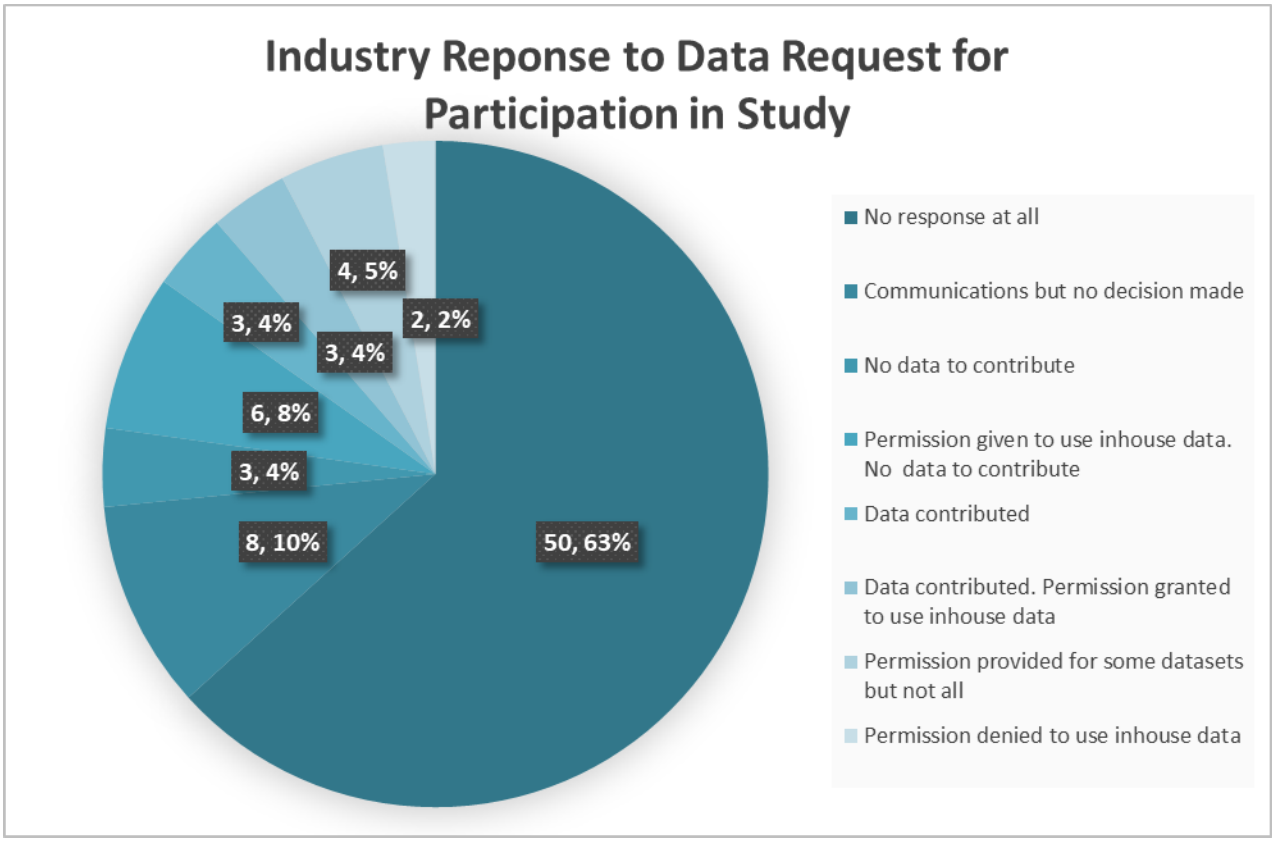

Figure 3-1: Responses from energy and survey companies to request to contribute data to the IOGP study

3.2 Detections by region

3.2.1 Gulf of Mexico

A total of 20,748 sighting records were obtained for the sighting analyses and a total of 124,640 individual animals were identified. Cetaceans comprised 18,334 (88%) records with 25 species identified. The most common cetacean encountered was the common bottlenose dolphin, Tursiops truncatus, (N=2,351 records); the most common large cetacean identified was the sperm whale, Physeter macrocephalus, (N=2,211 records, Figure 3-2).

Five species of sea turtles occur in the Gulf of Mexico: Kemp's Ridley (Lepidochelys kempii), loggerhead (Caretta caretta), green (Chelonia mydas), leatherback (Dermochelys coriacea), and hawksbill (Eretmochelys imbricata) (Valverde & Holzwart, 2017). Sea turtles consisted of 2,414 (12%) of the remaining records with 6 species identified. It is likely that an Olive Ridley sea turtle (Lepidochelys olivacea) sighting was misidentified due to the severe glare and brevity of the sighting and because they are generally not known to occur in the Gulf of Mexico.

Sea turtles had the smallest average group size (1.0), whilst dolphins had a reported average group size of 16.3 individuals. Whales and specifically sperm whales both had an average group size recorded at 2.0

individuals, with baleen whales having an average group size of 1.6 individuals (Table 3-1). Pinnipeds are not present in this region and therefore analysis of pinnipeds was not undertaken.

The northern Gulf of Mexico is known to have a resident population of Bryde's whale (Balaenoptera edeni) but all other baleen whales are considered rare in the northern Gulf of Mexico (Rosel & Wilcox, 2014). PSO records indicated rare sightings of minke whales (Balaenoptera acutorostrata) in the northern Gulf of Mexico but did not have photos to confirm the detections. The sightings of minke whales were made by experienced PSOs and were classified as probable.

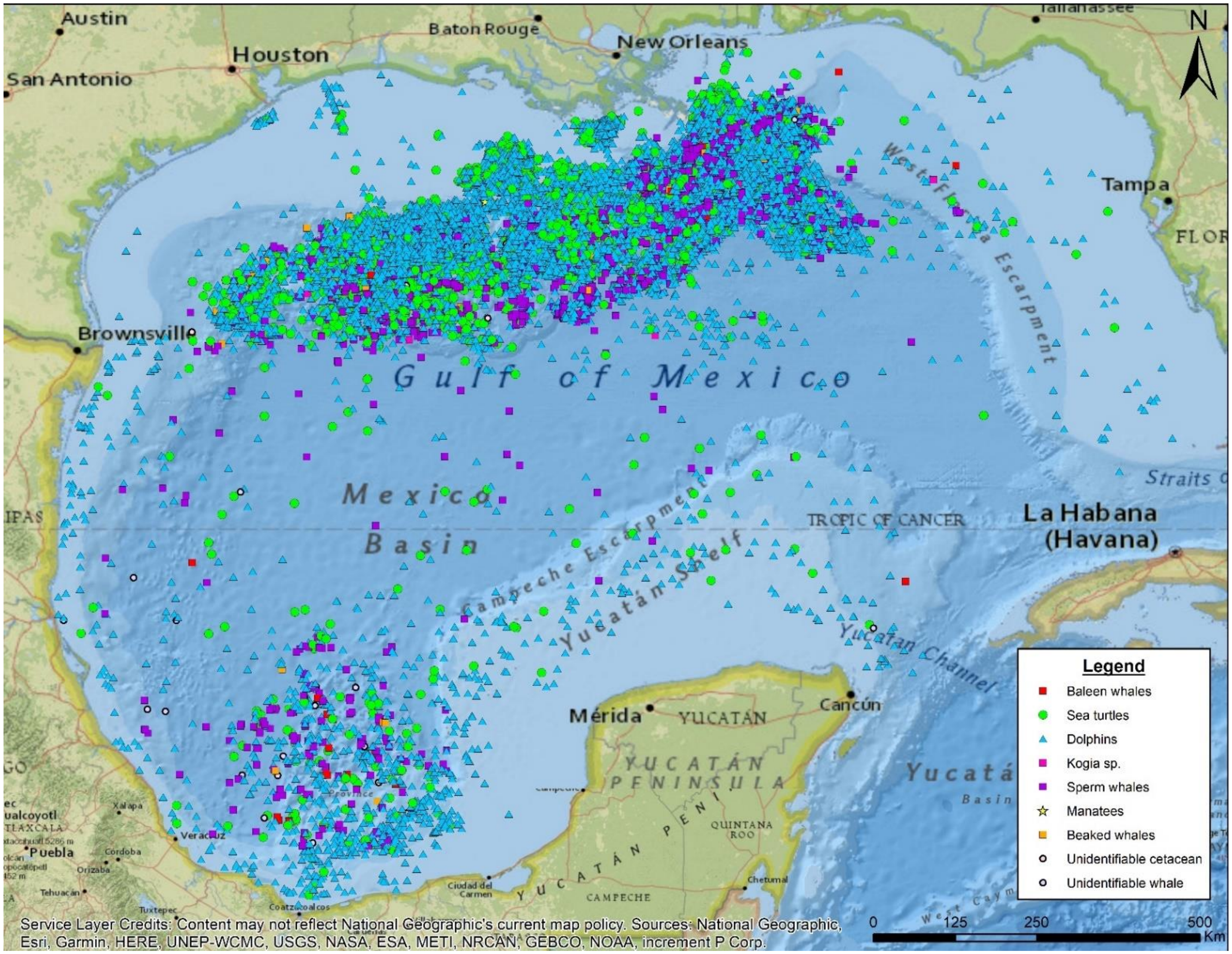

Figure 3-2: Map of Gulf of Mexico detections by species group.

Table 3-1: Species Sighting Summaries by Lowest Identified Taxonomic Group in the Gulf of Mexico

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
WHALE								
	Balaenopteridae							
		Balaenoptera	*brydei*	Bryde's whale	15	25	1.7	1760.7
			acutorostrata	Common minke whale	2	2	1.0	1650.0
		Megaptera	*novaeangliae*	Humpback whale	13	26	2.0	2869.2
	Kogiidae							
		Kogia	*breviceps*	Pygmy sperm whale	9	16	1.8	618.9
			sima	Dwarf sperm whale	4	7	1.8	1358.5
	Physeteridae							
		Physeter	*macrocephalus*	Sperm whale	2211	4416	2.0	1498.4
	Ziphiidae							
		Mesoplodon	*densirostris*	Blainville's beaked whale	4	12	3.0	1048.0
			europaeus	Gervais' beaked whale	5	13	2.6	970.0
		Ziphius	*cavirostris*	Cuvier's beaked whale	6	11	1.8	1285.0
				Unidentified baleen whale	15	21	1.4	2560.0
				Unidentified beaked whale	33	60	1.8	1346.1
				Unidentified *Kogia* whale	5	6	1.2	1754.0
				Unidentified whale	33	61	1.8	2363.9

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
DOLPHIN								
	Delphinidae							
		Delphinus sp.		Common dolphin	4	30	7.5	582.5
		Feresa	*attenuatta*	Pygmy killer whale	66	608	9.2	728.0
		Globicephala	*macrorhynchus*	Short-finned pilot whale	428	4439	10.4	707.5
			melas	Long-finned pilot whale	2	6	3.0	160.0
		Grampus	*griseus*	Risso's dolphin	90	756	8.4	684.1
		Lagenodelphis	*hosei*	Fraser's dolphin	50	1803	36.1	1047.7
		Orcinus	*orca*	Killer Whale	5	21	4.2	2106.0
		Peponocephala	*electra*	Melon-headed whale	113	3476	30.8	700.0
		Pseudorca	*crassidens*	False killer whale	67	704	10.5	926.1
		Stenella	*frontalis*	Atlantic spotted dolphin	266	3317	12.5	316.4
			clymene	Clymene dolphin	123	2977	24.2	624.9
			attenuata	Pantropical spotted dolphin	1547	32544	21.0	468.7
			longirostris	Spinner dolphin	135	3931	29.1	832.0
			coeruleoalba	Striped dolphin	23	678	29.5	881.5
		Steno	*bredanensis*	Rough-toothed dolphin	343	5603	16.3	516.6
		Tursiops	*truncatus*	Common bottlenose dolphin	2351	18217	7.7	270.9
				Unidentified dolphin	10366	38414	3.7	494.0

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
TURTLE								
	Cheloniidae							
		Caretta	*caretta*	Loggerhead sea turtle	823	837	1.0	190.4
		Chelonia	*mydas*	Green sea turtle	559	565	1.0	237.7
		Eretmochelys	*imbricata*	Hawksbill sea turtle	43	43	1.0	183.2
		Lepidochelys	*kempii*	Kemp's Ridley sea turtle	226	228	1.0	204.1
		Lepidochelys	*olivacea*	Olive Ridley sea turtle	1	1	1.0	0.0
	Dermochelyidae							
		Dermochelys	*coriacea*	Leatherback sea turtle	353	353	1.0	309.5
				Unidentified shelled sea turtle	409	413	1.0	252.5

3.2.2 West Africa

A total of 4,518 sighting records were obtained for the sighting analyses and a total of 107,124 individual animals were identified. Cetaceans comprised 4,244 (94%) of records with 31 species identified. Sea turtles consisted of 274 (6%) of the remaining records with 6 species identified.

The most common cetacean encountered was the humpback whale (Megaptera novaeangliae [N=975 records]); the most common small cetacean identified was the short-finned pilot whale, (Globicephala macrorhynchus [N=169 records] [Table 3-2]).

Sea turtles had the smallest average group size (1.4), whilst dolphins had a reported average group size of 44.3 individuals. Sperm whales had an average group size recorded at 3.1 individuals and baleen whales at 8.8 individuals (Table 3-2). Pinnipeds are not present in this region and therefore analysis was not undertaken.

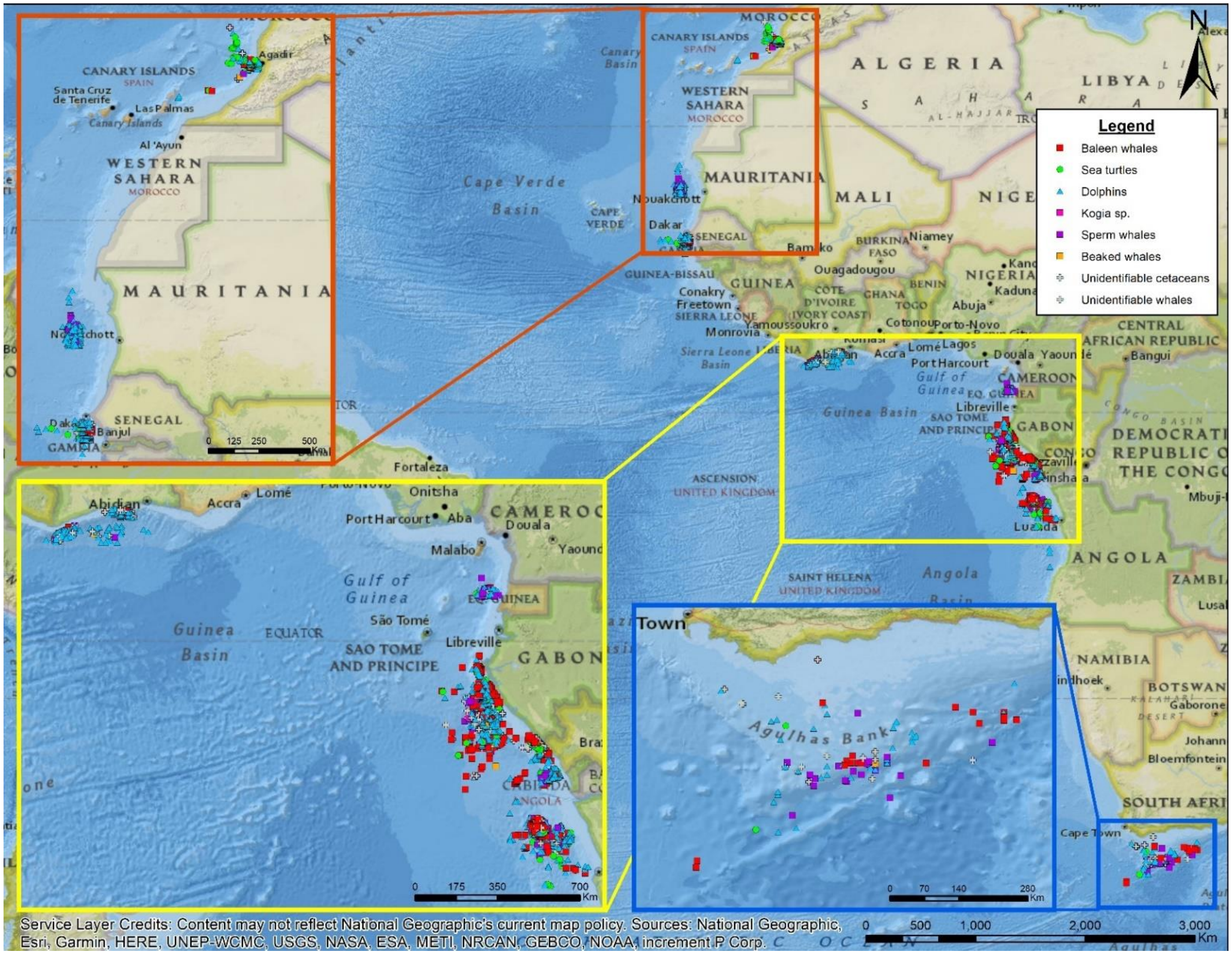

Figure 3-3: Map of West Africa detections by species group

Table 3-2: Species Sighting Summaries by Lowest Identified Taxonomic Group in West Africa

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
WHALE								
	Balaenopteridae							
		Balaenoptera	*brydei*	Bryde's whale	12	18	1.5	841.7
			acutorostrata	Common minke whale	3	4	1.3	570.0
			borealis	Sei whale	35	44	1.3	1198.3
			physalus	Fin whale	20	38	1.9	1291.5
			musculus	Blue whale	1	1	1.0	3537.0
		Megaptera	*novaeangliae*	Humpback whale	975	44671	45.8	1352.0
				Unidentified baleen whale	173	273	1.6	1541.2
				Unidentified whale	454	344	0.8	1010.9
				Unidentified beaked whale	12	22	1.8	1617.5
				Unidentified cetacean	62	77	1.2	1494.4
	Kogiidae							
		Feresa	*attenuata*	Pygmy killer whale	8	187	23.4	946.9
		Kogia	*breviceps*	Pygmy sperm whale	1	1	1.0	2000.0
			sima	Dwarf sperm whale	5	7	1.4	860.0
	Physeteridae							
		Physeter	*macrocephalus*	Sperm whale	186	575	3.1	2032.8

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
	Ziphiidae							
		Ziphius	*cavirostris*	Cuvier's beaked whale	3	3	1.0	283.3
DOLPHIN								
	Delphinidae							
		Delphinus sp.		Common dolphin	155	7043	45.4	773.9
		Delphinus	*sp*	Short-beaked common dolphin	13	1462	112.5	461.5
		Globicephala	*macrorhynchus*	Short-finned pilot whale	169	2835	16.8	945.0
		Grampus	*griseus*	Risso's dolphin	67	861	12.9	912.9
		Lagenodelphis	*hosei*	Fraser's dolphin	3	230	76.7	1000.0
		Orcinus	*orca*	Killer whale	12	120	10.0	1067.3
		Peponocephala	*electra*	Melon-headed whale	16	961	60.1	1033.1
		Pseudorca	*crassidens*	False killer whale	17	121	7.1	580.9
		Stenella	*frontalis*	Atlantic spotted dolphin	80	4419	55.2	620.5
			clymene	Clymene dolphin	48	2516	52.4	815.3
			attenuata	Pantropical spotted dolphin	30	2233	74.4	908.2
			longirostris	Spinner dolphin	32	1751	54.7	1312.5
			coeruleoalba	Striped dolphin	63	2528	40.1	1112.9
		Steno	*bredanensis*	Rough-toothed dolphin	23	978	42.5	559.1
		Tursiops	*truncatus*	Common bottlenose dolphin	110	3076	28.0	1409.0

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
				Unidentified dolphin	1456	29375	20.2	1569.3
TURTLE								
	Cheloniidae							
		Caretta	*caretta*	Loggerhead sea turtle	59	94	1.6	86.6
		Chelonia	*mydas*	Green sea turtle	2	2	1.0	295.0
		Lepidochelys	*kempii*	Kemp's Ridley sea turtle	3	7	2.3	166.7
		Lepidochelys	*olivacea*	Olive Ridley sea turtle	20	22	1.1	254.5
	Dermochelyidae							
		Dermochelys	*coriacea*	Leatherback sea turtle	32	32	1.0	456.6
				Unidentified shelled sea turtle	158	193	1.2	338.6

3.2.3 Australia

A total of 4,882 sighting records were obtained for the sighting analyses and a total of 39,226 individual animals were identified. Cetaceans comprised 4,035 (83%) of records with 33 species identified. Sea turtles consisted of 80 (2%) of the remaining records with 7 species identified. Pinnipeds consisted of 767 (15.7%) of the other records with 3 species identified (Figure 3 3). The flatback sea turtle (Natator depressus) is indigenous to Australia waters and does not have a global distribution like other sea turtles (MarineBio, 2013).

The most common cetacean encountered was the common dolphin, Delphinus sp, (N=624 records); the most common large cetacean identified was the humpback whale (N=555 records; Table 3-3).

Pinnipeds had the smallest average group size (1.3), whilst dolphins had a reported average group size of 25.0 individuals. Sperm whales had an average group size recorded at 2.8 individuals, sea turtles at 2.7 individuals, and baleen whales at 1.4 individuals (Table 3-3).

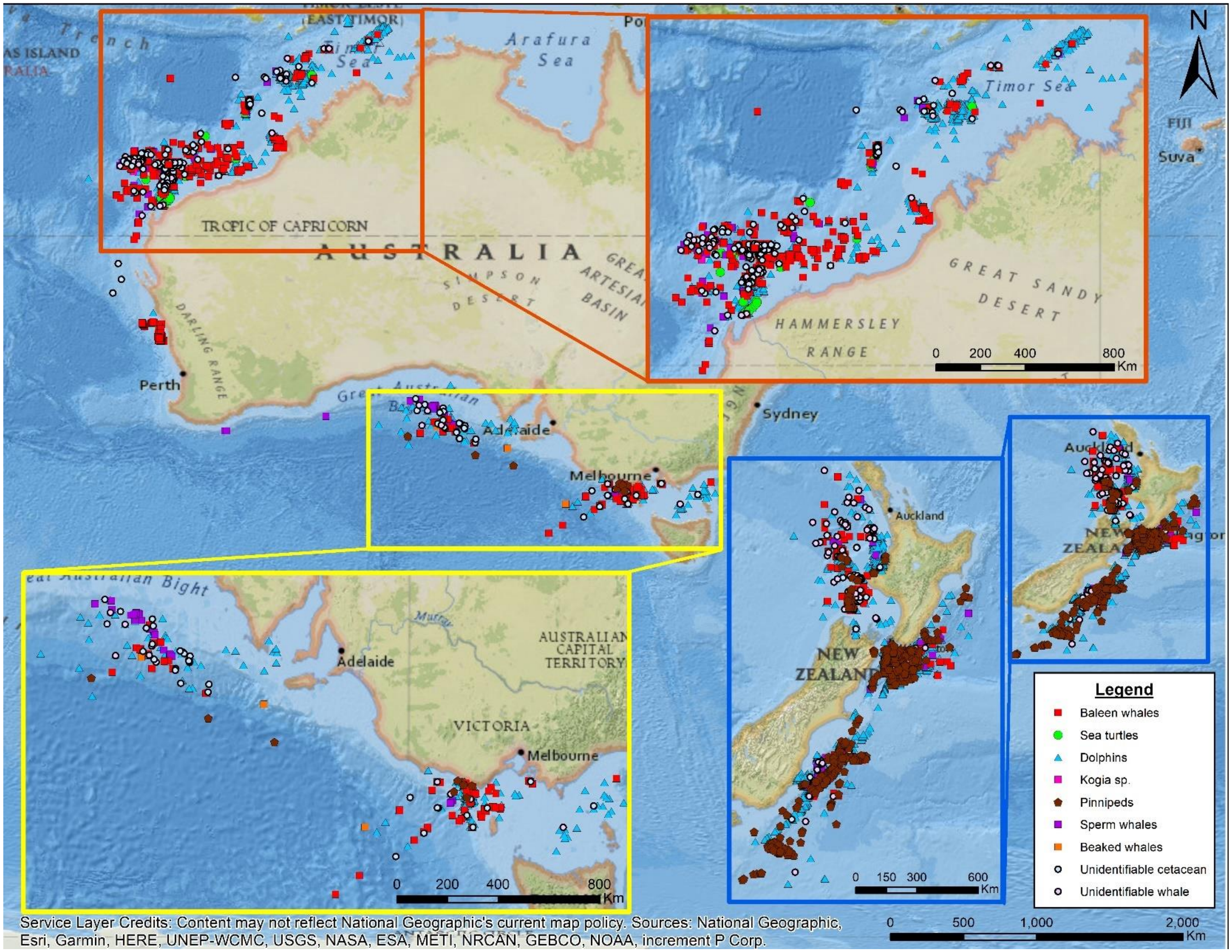

Figure 3-4: Map of Australia detections by species group.

Table 3-3: Species Sighting Summaries by Lowest Identified Taxonomic Group in Australia

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
WHALE								
	Balaenopteridae							
		Balaenoptera	*brydei*	Bryde's whale	16	22	1.4	n/a
			borealis	Sei whale	17	24	1.4	n/a
			bonaerensis	Antarctic minke whale	3	4	1.3	n/a
			acutorostrata	Common minke whale	14	16	1.1	n/a
			musculus	Blue whale	380	569	1.5	n/a
			physalus	Fin whale	19	32	1.7	n/a
				Unidentified baleen whale	185	257	1.4	n/a
				Unidentified beaked whale	7	8	1.1	n/a
				Unidentified cetacean	316	748	2.4	n/a
				Unidentified whale	163	346	2.1	n/a
		Megaptera	*novaeangliae*	Humpback whale	555	954	1.7	n/a
	Balaenidae							
		Eubalaena	*australis*	Southern right whale	2	2	1.0	n/a
	Kogiidae							
		Kogia	*sima*	Dwarf sperm whale	1	15	15.0	n/a
	Physeteridae							

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
		Physeter	*macrocephalus*	Sperm whale	157	435	2.8	n/a
	Ziphiidae							
		Tasmacetus	*shepherdi*	Shepherd's beaked whale	1	3	3.0	n/a
DOLPHIN								
	Delphinidae							
		Delphinus sp.		Common dolphin	624	13502	21.6	n/a
				Long-beaked common dolphin	1	800	800.0	n/a
		Feresa	*attenuatta*	Pygmy killer whale	3	20	6.7	n/a
		Globicephala	*macrorhynchus*	Short-finned pilot whale	23	639	27.8	n/a
			melas	Long-finned pilot whale	115	2444	21.3	n/a
		Grampus	*griseus*	Risso's dolphin	8	132	16.5	n/a
		Lagenodelphis	*hosei*	Fraser's dolphin	1	1	1.0	n/a
		Lagenorhynchus	*obscurus*	Dusky dolphin	33	2912	88.2	n/a
		Lissodelphis	*peronii*	Southern right whale dolphin	2	95	47.5	n/a
		Orcinus	*orca*	Killer Whale	12	38	3.2	n/a
		Peponocephala	*electra*	Melon-headed whale	1	30	30.0	n/a
		Pseudorca	*crassidens*	False killer whale	23	405	17.6	n/a
		Stenella	*attenuata*	Pantropical spotted dolphin	16	467	29.2	n/a
			longirostris	Spinner dolphin	92	3306	35.9	n/a
			coeruleoalba	Striped dolphin	4	165	41.3	n/a

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance From Airguns (m)
		Tursiops	*truncatus*	Common bottlenose dolphin	197	3482	17.7	n/a
			aduncus	Indo-Pacific bottlenose dolphin	31	411	13.3	n/a
				Unidentified dolphin	1013	5725	5.7	n/a
TURTLE								
	Cheloniidae							
		Natator	*depressus*	Flatback sea turtle	22	28	1.3	n/a
		Caretta	*caretta*	Loggerhead sea turtle	2	2	1.0	n/a
		Chelonia	*mydas*	Green sea turtle	5	5	1.0	n/a
		Eretmochelys	*imbricata*	Hawksbill sea turtle	1	1	1.0	n/a
		Lepidochelys	*olivacea*	Olive Ridley sea turtle	2	26	13.0	n/a
	Dermochelyidae							
		Dermochelys	*coriacea*	Leatherback sea turtle	9	9	1.0	n/a
				Unidentified shelled sea turtle	39	38	1.0	n/a
PINNIPED								
	Otariidae							
		Arctocephalus	*pusillus*	Australian Fur Seal	52	64	1.2	n/a
			forsteri	New Zealand Fur Seal	686	1007	1.5	n/a
				Unidentified Seal	29	37	1.3	n/a

3.3 Data quality issues

3.3.1 Common data errors

Use of Excel

Whilst Microsoft Excel provides an excellent product for recording data in the field in part because of its flexibility, that very flexibility can cause problems because the alterations that it allows can be problematic when combining different spreadsheets into a database. Commonly, the spreadsheets are provided as fully-accessible files, allowing the user to change the structure or cell formatting. It causes significant issues when users add in columns, especially when they rename or remove the column header title at the top of the column, which can disrupt formulas found within current forms. It also causes problems when a user changes the format of a cell from a numerical value to a text value. Users may not realize that they do this, but this can cause issues with reading data. Additionally, recording of positions with Excel causes many problems with data recording. A potential solution would be to have a software program that can import and check Excel files, provide timely feedback on questionable data, and ensure the data are properly routed to a database for further analysis.

Date Formats

There are many problems with the manner in which users record dates in Excel. Several cases were found where data had been entered as MM-DD-YYYY but the underlying spreadsheet had interpreted this as DD-MM-YYYY, but as the date was displayed in a numerical format (e.g. 01/04/2017) this isn't apparent to the user, but will become apparent when a computer reads the underlying spreadsheet value.

This problem can be further compounded as it is possible to apply individual formatting to individual cells, and there was a case where the date format changed from MM-DD to DD-MM within individual cells in a row. In this case, manual intervention was needed to read the data.

There was also one case where even the Excel Application was confused by the entered date values and extensive manual intervention was required to read the data.

Time Formats

Some of the data formats did not reference time correctly, as a simple HH:MM is recorded with no reference to the underlying time system. To correctly load those data into a central world-wide database and analyse correctly, the time reference system should be recorded. There were also instances where users input a start time in local time and an end time in UTC. These instances were evident and corrected when reviewing the durations of activities.

3.3.2 Geodetic accuracy

Of the data loaded from Excel Spreadsheets into the MMO Import Tool for QC, over 70% of the data files/spreadsheets had some sort of positioning errors.

These positioning errors were not limited to a single recording format. All formats suffered from the same errors and these are linked to recording the degrees and minutes in separate columns, along with the duplication of end position to the start position of the following record.

Often these positioning errors were easily visible when data are loaded into a map display of the MMO Import Tool.

3.3.3 Data comparability

One of the biggest challenges loading the data into a standardized format was aligning all the different data values to a common reference standard. A number of fields in all the formats processed allow for user entry, leading to a large number of variations in the recording of important parameters. The parameters affected were:

- Survey Type
- Source Activity
- Weather Logging (Wind Direction, Swell Height, Visibility, Sun Glare and Precipitation)
- Mitigating Action
- Behaviour
- Species
- Direction of Travel
- Observation Type
- Detection Type

Formats that allowed free-form data entry also required manual corrections for slight variations. For example, behaviour entries resulting in Porpoising, Porpoised, Porposing, Porposed, Poirpoising and Poirpoised.

3.4 Analysis of sightings records relative to airgun status

This section details the results of the analysis of sightings records data relative to airgun status, in relation to each of three sightings characteristics – minimum distance of approach, duration of sighting, and sightings rate. The species group 'Beaked Whales' only had species recorded during more than one airgun status for the Gulf of Mexico, and subsequently the 'Combined regions'—thus, the 'Beaked Whales' data for West Africa and Australia are not included in these analyses. The species group 'Pinnipeds' only had species recorded for Australia, Other Regions, and 'Combined Regions'.

3.4.1 Sightings by source activity – Minimum distance of approach

Gulf of Mexico

The median closest distance of approach to the seismic source was compared between active seismic source conditions and silence. Table 3-4 summarises the Kruskal-Wallis analysis of variance results. 'Delphinids', 'Sperm Whales' and the 'All Cetaceans' species groups were found to occur at greater distances from the seismic source during times of full power source operation when compared to silence, which was statistically significant (Kruskal-Wallis, $p<0.05$), as can be seen in Table 3-4. A similar pattern can be seen during mitigation source operation. 'Baleen Whales' and 'Beaked Whales', which did not have records during mitigation source operation and were excluded from this analysis category. 'Sperm Whales' and the 'All Cetaceans' the differences were significant greater during mitigation firing (Kruskal-Wallis, $p<0.05$). When comparing the distance to source between ramp-up and silence, the sample sizes were very low for 'Baleen Whales' and there were no records for 'Beaked Whales' during ramp-up (Figure 3-5). A significant difference was found for only the 'Sperm Whales' and the 'All Cetaceans' species groups (Kruskal-Wallis, $p<0.05$).

Figure 3-6 shows the distribution of the data for distance of sightings in Gulf of Mexico. The proportion of sightings of all cetaceans within a given range of airgun arrays was reduced during periods when airgun activity was firing at all distances, with Mitigation Firing the lowest percentage of sightings.

Table 3-4: Kruskal-Wallis analysis of variance results for the closest approach to the seismic source in the Gulf of Mexico, grey bar = excluded from analysis due to limited sample size

	Species Group	***Count***	***Firing Median***	***Silent Median***	***H***	***p- value***
Full Power vs. Silent	**All Cetaceans**	3270	527.5	452.5	108.26	0.00
	Baleen Whales	19	2000	2000	0.01	0.93

	Delphinids	1706	500	485	43.66	0.00
	Sperm Whales	724	1700	825	121.59	0.00
	Turtles	757	230	200	3.28	0.07
	Beaked Whales	34	1687.5	1000	2.27	0.13
Mitigation Firing vs. Silent	**All Cetaceans**	1667	600	452.5	20.18	0.00
	Delphinids	861	500	485	3.04	0.08
	Sperm Whales	366	2000	825	32.21	0.00
	Turtles	389	200	200	0.10	0.75
Ramp-up vs. Silent	**All Cetaceans**	1682	500	452.5	5.69	0.02
	Baleen Whales	8*	1000	2000	0.43	0.51
	Delphinids	886	500	485	2.19	0.14
	Sperm Whales	356	1500	825	8.71	0.00
	Turtles	389	150	200	3.13	0.08

*Sample number less than 5 for Ramp-up

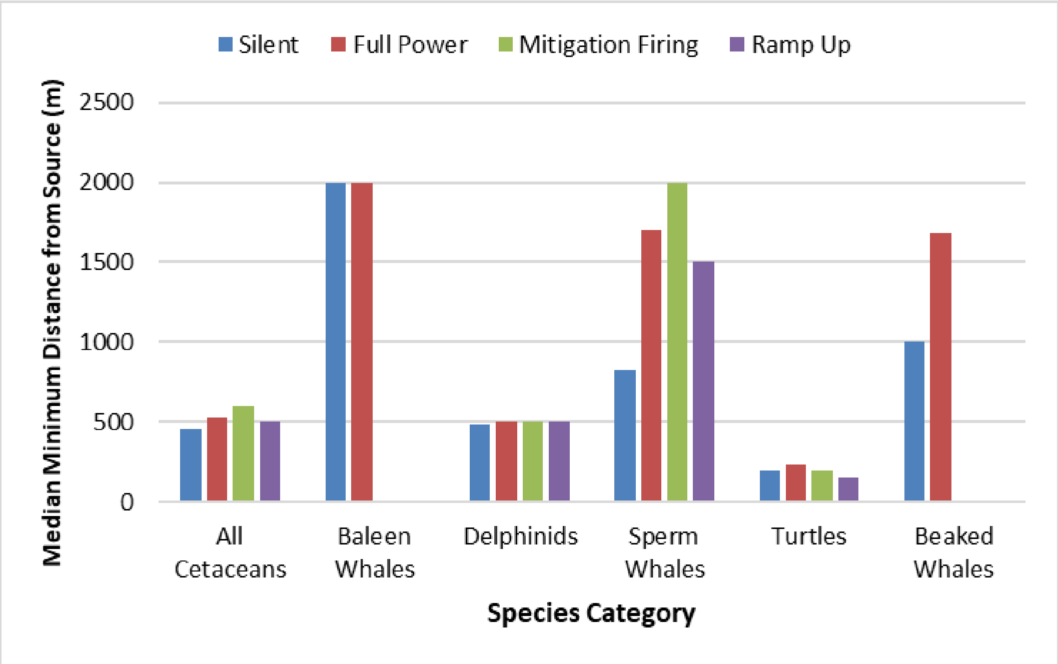

Figure 3-5: Comparison of the Distance to the Seismic Source during Full Power, Mitigation, Ramp-up and Silence (Control) in the Gulf of Mexico.

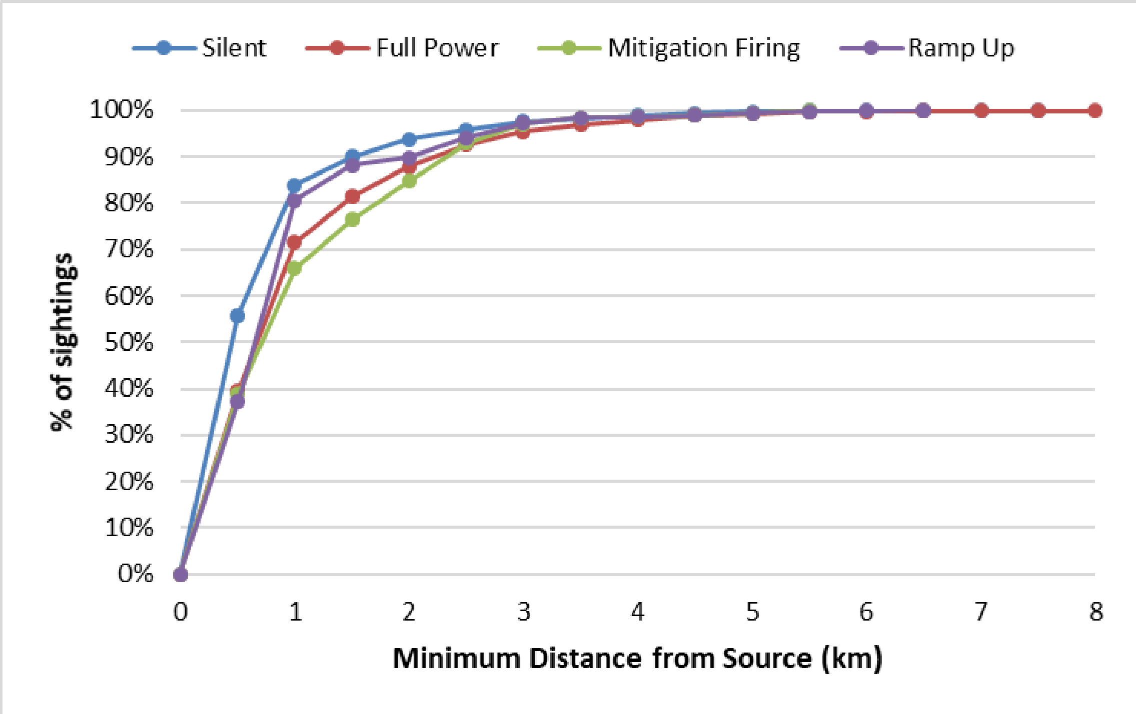

Figure 3-6: Proportion of sightings occurring within specified distances of airgun arrays, in relation to airgun activity, in the Gulf of Mexico.

West Africa

The median closest distance of approach to the seismic source was compared between active seismic source conditions and silence. Table 3-5 summarises the Kruskal-Wallis analysis of variance results. ‘All Cetaceans’, ‘Baleen Whales’ and ‘Delphinids’ were found to occur at greater distances from the seismic source during times of full power source operation when compared to silence, which was statistically significant (Kruskal-Wallis, $p<0.05$), with the mean differences shown in Figure 3-7. The same pattern can be seen in Figure 3-8 during soft-start source operation, ‘All Cetaceans’, ‘Baleen Whales’ and ‘Delphinids’ the differences were statistically significant (Kruskal-Wallis, $p<0.05$). The sample sizes for reduced power operation were lower than 5 for all species groups, these results have been excluded from the analysis.

Figure 3-8 shows the distribution of the data for distance of sightings in West Africa. The proportion of sightings of all cetaceans within a given range of airgun arrays was reduced during periods when airgun activity was firing at full power, however Soft-start had a higher percentage of sighting distances from 500m to 4.5km.

Table 3-5: Kruskal-Wallis analysis of variance results for the closest approach to the seismic source.

	Species Group	*Count*	*Firing Median*	*Silent Median*	*H*	*p- value*
Full Power vs. Silent	**All Cetaceans**	4087	1000	600	89.54	0.000
	Baleen Whales	957	1000	700	21.71	0.000
	Delphinids	2658	1000	600	51.45	0.000
	Sperm Whales	179	1800	1500	2.25	0.134
	Turtles	180	45	50	1.44	0.229
Soft-start vs. Silent	**All Cetaceans**	2580	1000	600	13.40	0.000

	Baleen Whales	571	1000	700	4.36	0.037
	Delphinids	1689	1000	600	5.41	0.020
	Sperm Whales	120	1650	1500	0.46	0.499
	Turtles	122	170	50	0.17	0.679

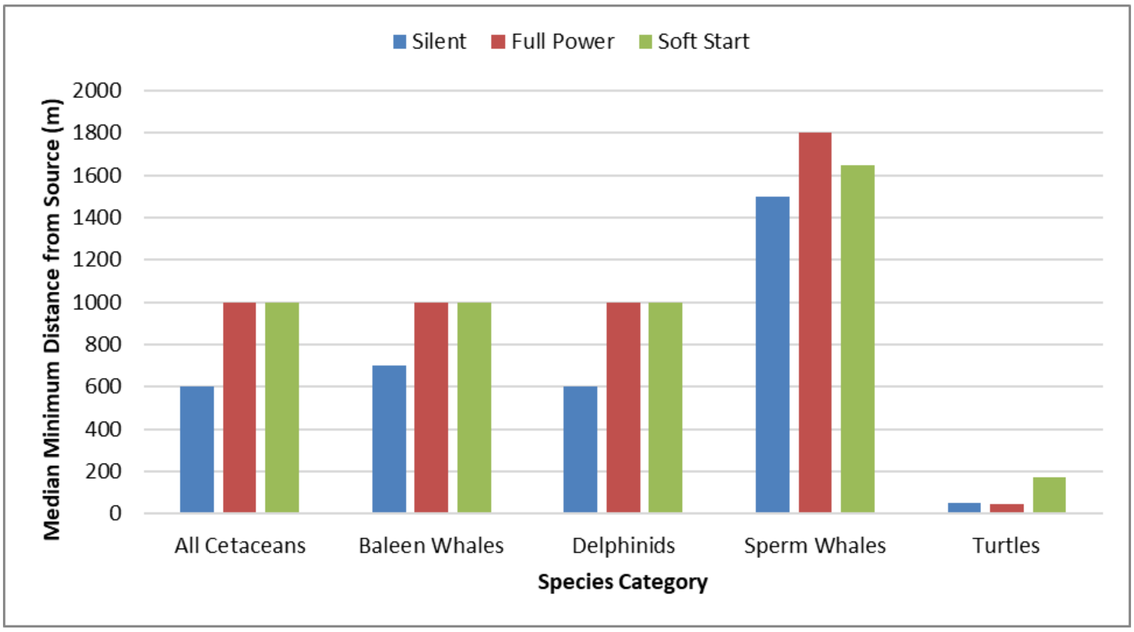

Figure 3-7: Comparison of the Distance to the Seismic Source during Full Power, Soft-start and Silence in West Africa.

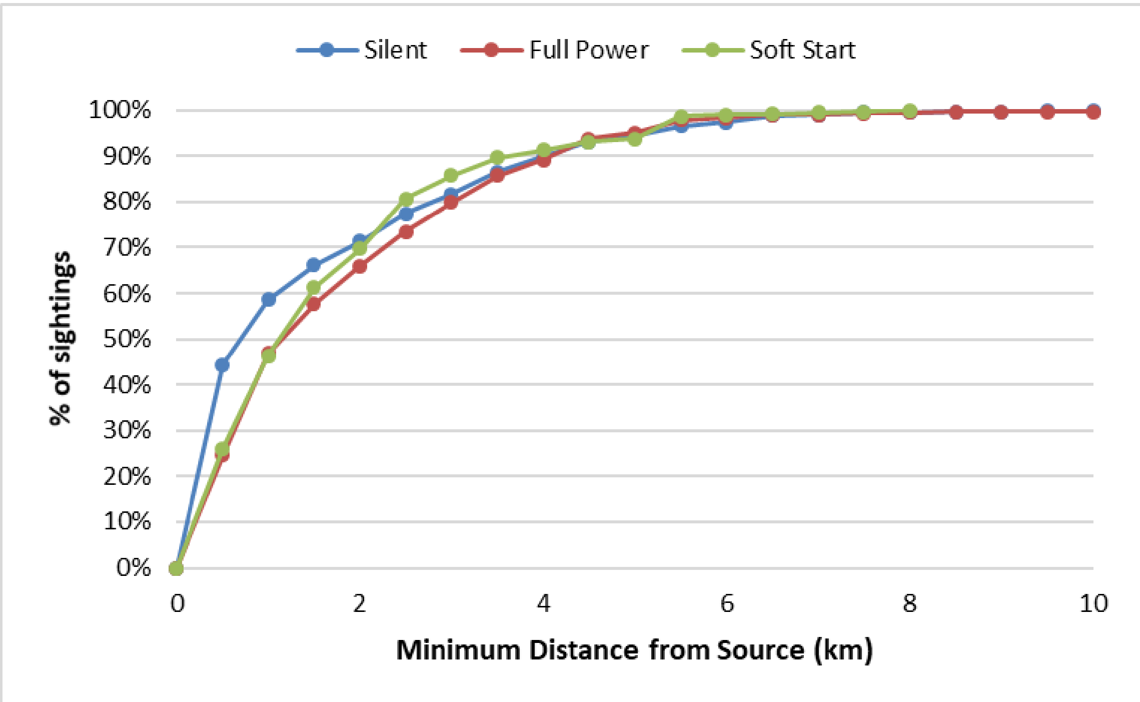

Figure 3-8: Proportion of sightings occurring within specified distances of airgun arrays, in relation to airgun activity, in the West Africa.

Australia

Closest approach to the source was not recorded from the provided observation data and therefore no statistical analysis could be performed. Distances in the datasets were only recorded as initial range to animal, with no recorded closest approach to the vessel or source. All other datasets utilized for this study recorded distances as initial range and closest approach, and the closest approach was utilized for the analyses for other regions, so the initial range data were not used for this analysis for consistency.

3.4.2 Sightings by source activity – Duration of sighting

Gulf of Mexico

The median sighting duration for each seismic source was compared between active seismic source conditions and silence. Table 3-6 summarises the Kruskal-Wallis analysis of variance results. ‘All Cetaceans’, ‘Delphinids’, ‘Sperm Whales’ and ‘Turtles’ were observed for shorter durations during times of full power source operation when compared to silence, which were statistically significant (Kruskal-Wallis, p<0.05), with the mean differences shown in Figure 3-9. Sighting duration was significantly (Kruskal-Wallis, p<0.05) longer for mitigation than for silence for ‘All Cetaceans’. When ramp-up is active, sighting durations are significantly shorter for ‘All Cetaceans’ and ‘Delphinids’ (Kruskal-Wallis, p<0.05). The difference in sighting duration for ‘All Cetaceans’ was greatest between Mitigation Firing vs. Silent mode, see Figure 3-9.

Figure 3-10 shows the distribution of the data for duration of sightings in Gulf of Mexico. The proportion of sighting durations for all cetaceans within a given range of airgun arrays was increased during periods when airgun activity was firing at full power or ramp-up when compared to silent, however mitigation firing had a lower percentage of sighting durations at all distances (Figure 3-10).

Table 3-6 :Kruskal-Wallis Analysis of Variance Results for Sighting Duration in the Gulf of Mexico.

	Species Group	*Count*	*Firing Median*	*Silent Median*	*H*	*p- value*
Full Power vs. Silent	**All Cetaceans**	19811	6	7	51.56	0.00
	Baleen Whales	44	5	6	0.03	0.86
	Delphinids	15290	7	9	75.85	0.00
	Sperm Whales	2084	9	11	20.07	0.00
	Turtles	2281	1	1	42.01	0.00
	Beaked Whales	48	11	5	1.73	0.19
Mitigation Firing vs. Silent	**All Cetaceans**	7810	10	7	16.72	0.00
	Delphinids	5670	11	9	2.88	0.09
	Sperm Whales	1056	16	11	2.05	0.15
	Turtles	1007	2	1	3.14	0.08
Ramp-up vs. Silent	**All Cetaceans**	7742	5	7	13.96	0.00
	Baleen Whales	16*	6	6	0.01	0.91
	Delphinids	5603	6	9	23.81	0.00
	Sperm Whales	1038	10	11	0.04	0.84

	Turtles	1023	1	1	1.24	0.27

*Sample number less than 5 for Ramp-up

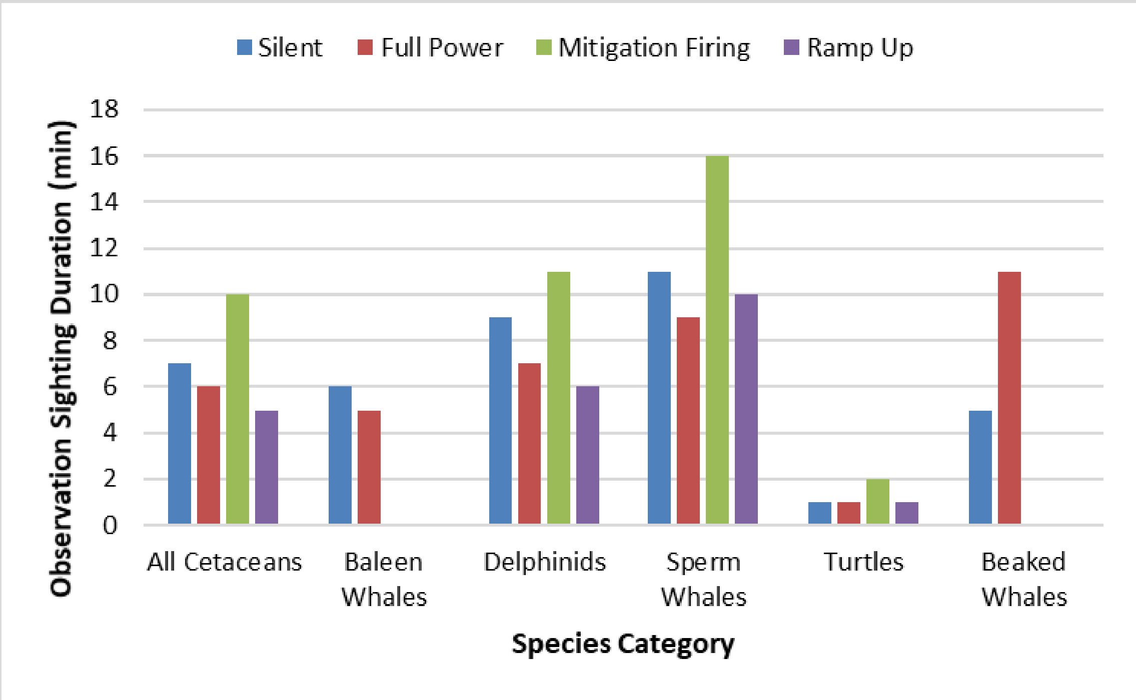

Figure 3-9: Comparison of Median Sighting Duration during Full Power, Mitigation, Ramp-up and Silence in the Gulf of Mexico.

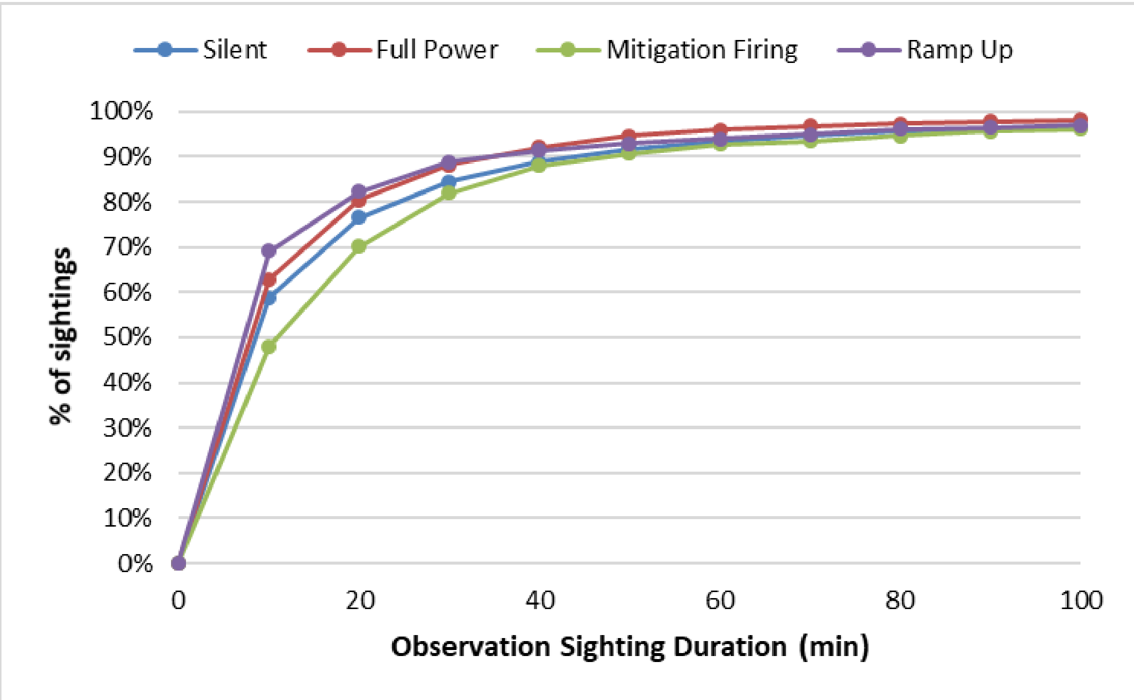

Figure 3-10: Proportion of sightings occurring within specified sighting durations, in relation to airgun activity, in the Gulf of Mexico.

West Africa

Table 3-7 summarises the Kruskal-Wallis analysis of variance results for sighting duration in West Africa. Comparing the median sighting duration for each active seismic source condition against silence showed sighting duration for the 'Baleen Whales' species group to be significantly longer and 'Delphinids' to be significantly shorter during full power than silence (Kruskal-Wallis, $p<0.05$), as summarized in Table 3-7, and illustrated in Figure 3-11. Sighting duration was significantly shorter for Reduced Power compared to silence for 'All Cetaceans' and 'Delphinids'. 'Baleen Whale' couldn't be analysed due to limited sample size (**Error! Reference source not found.**). There was no r elationship found for any species category between Soft-start vs. Silent mode, see Figure 3-11.

Figure 3-12 shows the distribution of the data for duration of sightings in West Africa. The proportion of sighting durations for all cetaceans within a given range of airgun arrays was increased during periods when airgun activity was firing at mitigation when compared to silent, however firing at full power or soft-start had the same or lower percentage of sighting durations respectively. Soft-start exhibited the highest percentage of sighting durations at 100 minutes (Figure 3-12).

Table 3-7: Kruskal-Wallis Analysis of Variance Results for Sighting Duration in West Africa

	Species Group	*Count*	*Firing Median*	*Silent Median*	*H*	*p- value*
Full Power vs. Silent	**All Cetaceans**	3134	11	12	0.50	0.48
	Baleen Whales	939	25	18	15.40	0.00
	Delphinids	1678	10	13	23.13	0.00
	Sperm Whales	160	14	16	0.13	0.72
	Turtles	186	1	2	0.41	0.52
Reduced Power vs. Silent	**All Cetaceans**	1613	5	12	3.80	0.05
	Baleen Whales	488*	26.5	18	0.10	0.76
	Delphinids	825	5	13	6.32	0.01
Soft-start vs. Silent	**All Cetaceans**	1752	13	12	0.29	0.59
	Baleen Whales	540	26.5	18	1.56	0.21
	Delphinids	899	11	13	1.32	0.25
	Sperm Whales	101*	7	16	0.45	0.50
	Turtles	115*	2	2	0.27	0.60

**Sample number less than 5 for firing mode*

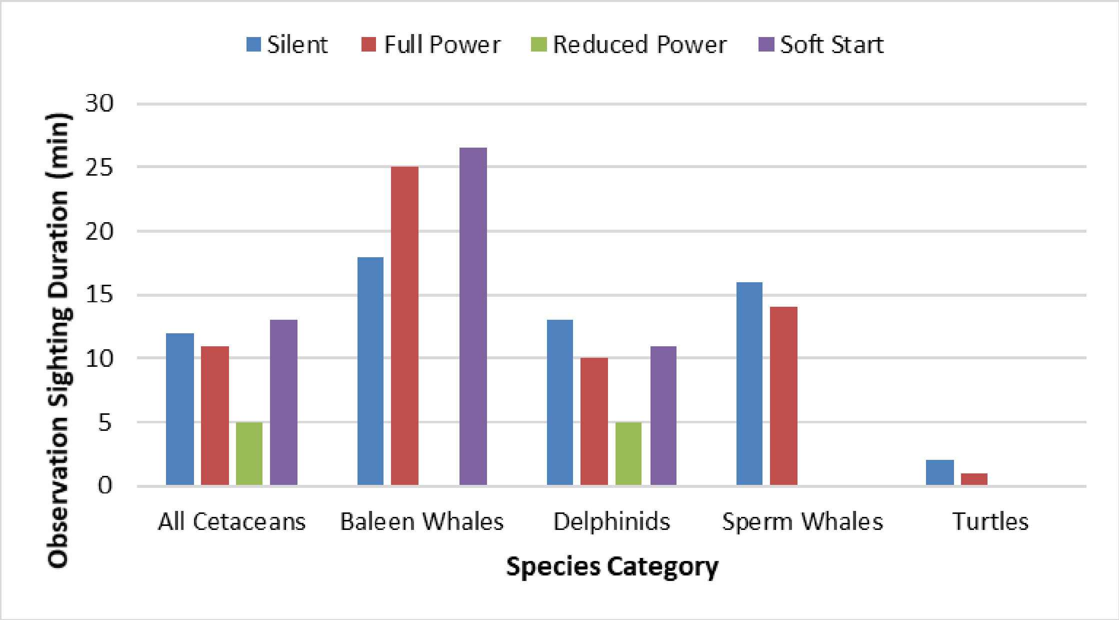

Figure 3-11: Comparison of Median Sighting Duration during Full Power, Reduced Power, Soft-start and Silence in West Africa.

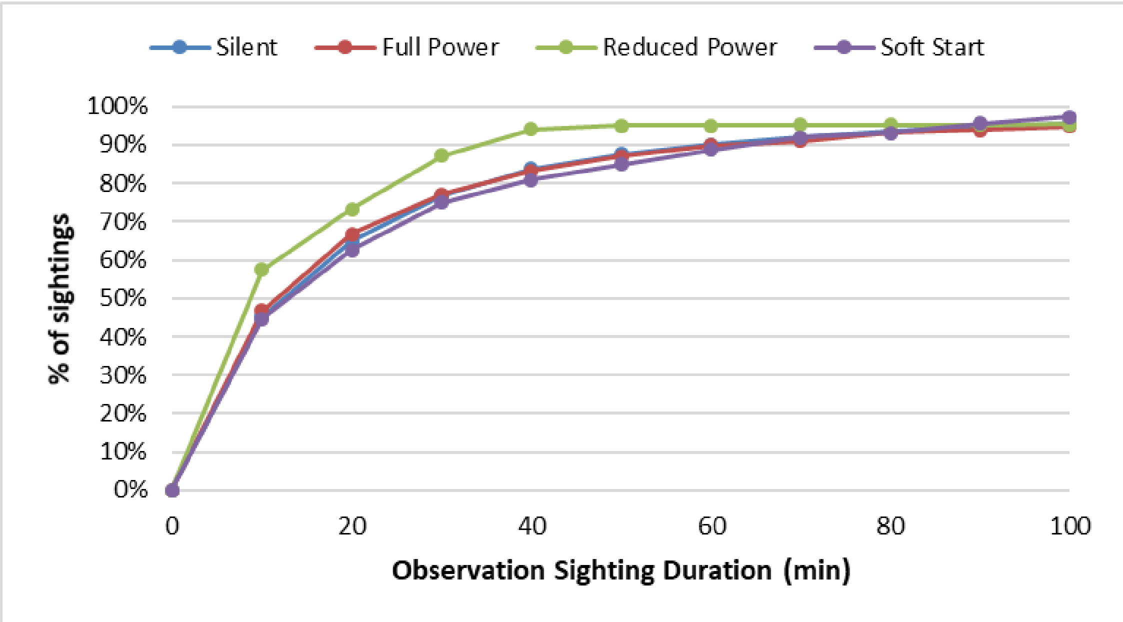

Figure 3-12: Proportion of sightings occurring within specified sighting durations, in relation to airgun activity, in the West Africa.

Australia

There were insufficient sample data to complete any analysis for 'Full Power', 'Soft-start' or 'Reduced Power' categories and therefore no statistical analysis could be performed.

3.4.3 Sightings by source activity – Sighting Rate

Gulf of Mexico

For each region, sighting rates for each Project ID were calculated from the number of sightings of a species in a project over the unit effort (1000 hours of observations) spent in a project. The sighting rate was calculated for both firing and silent seismic source conditions by grouping both the number of sightings and the effort by the source condition. The effort data had the limitation that only duration of firing and not firing were recorded, and therefore for this analysis airgun activities, Full Power, Mitigation and Ramp-up, were grouped as "Firing".

Table 3-8 summarizes Kruskal-Wallis analysis of variance results. The results for all species groups show a statistically significant variation in sighting rate, with a lower sighting rate during firing than silence (Kruskal-Wallis, $p<0.05$), as shown in Table 3-8 and Figure 3-13. Observation time was approximately more than double when not firing (silent) for all species groups apart from 'Baleen Whales', which had a low sample size.

Figure 3-14 shows the distribution of the data for sighting rates in Gulf of Mexico. The proportion of sighting rates for all cetaceans within a given range of airgun arrays was increased during periods when airgun activity was firing when compared to silent at all specified rates.

Table 3-8 Kruskal-Wallis Analysis of Variance Results for Sighting Rate/1,000 Hours in the Gulf of Mexico

	Species Group	*Count*	*Firing Median*	*Silent Median*	*H*	*p- value*
Firing vs. Silent	**All Cetaceans**	3463	13.4	28.3	363.29	0.00
	Baleen Whales	22	4.4	7.4	6.38	0.01
	Delphinids	1819	21.3	40.4	163.64	0.00
	Sperm Whales	779	10.2	19.9	128.03	0.00
	Turtles	770	7.9	19.5	172.13	0.00
	Beaked Whales	35	5.0	10.7	10.78	0.00

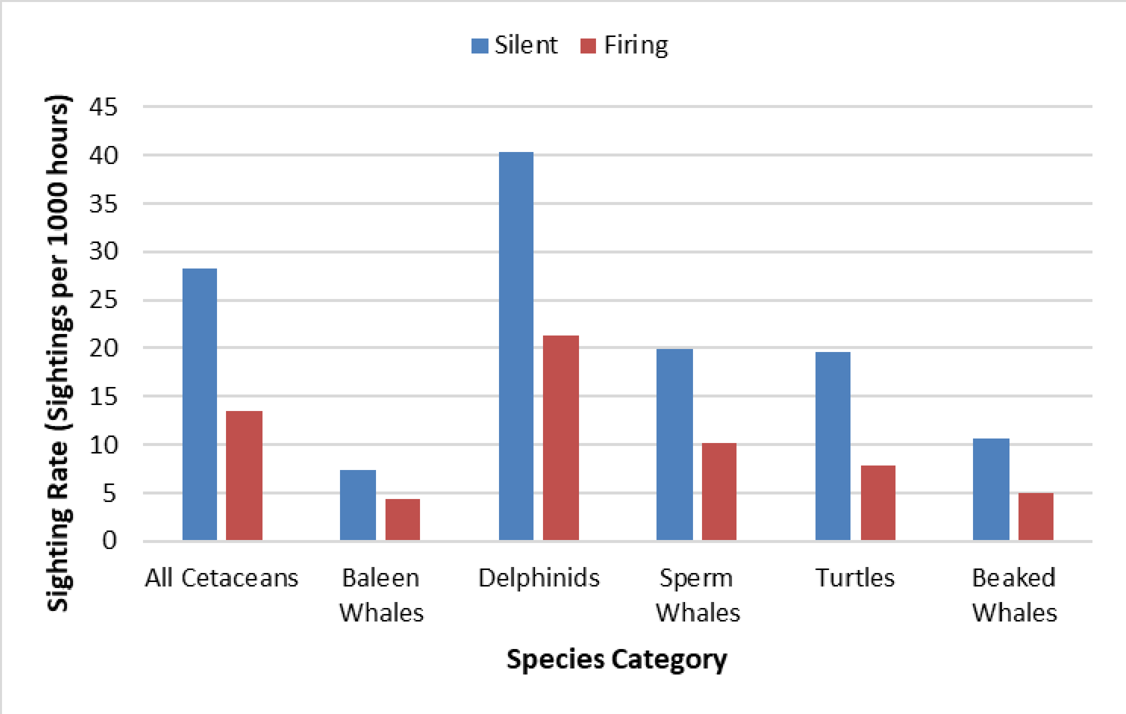

Figure 3-13: Comparison of Median Sighting Rate during Firing and Silence in the Gulf of Mexico.

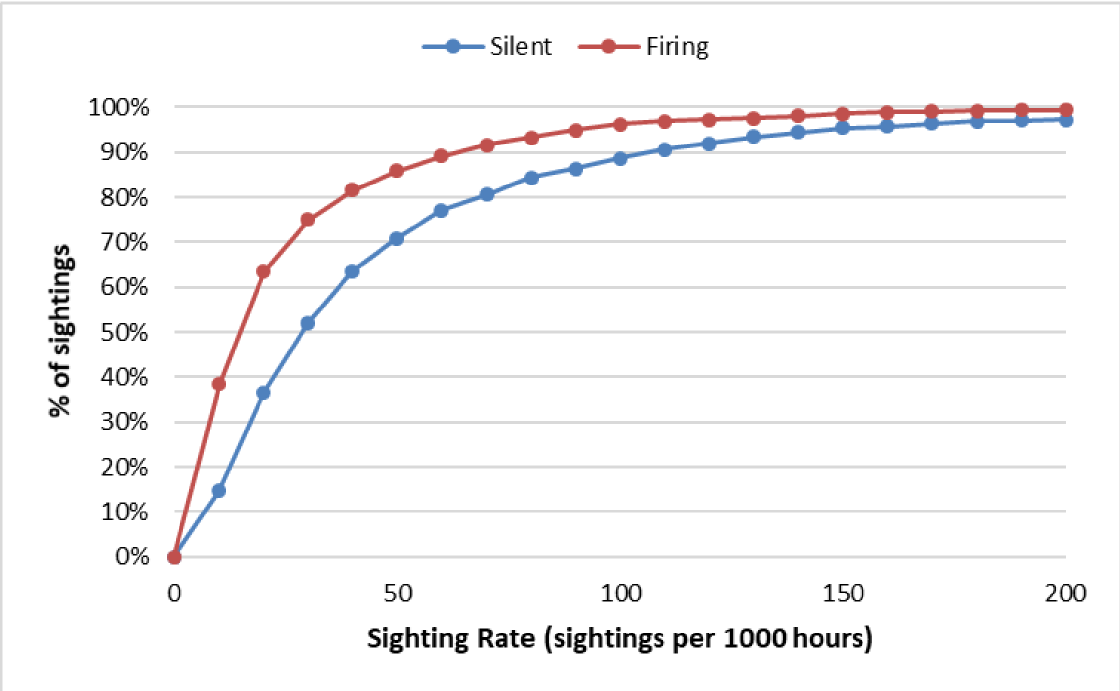

Figure 3-14 Proportion of sightings occurring within specified sighting rates, in relation to airgun activity, in the Gulf of Mexico.

West Africa

Comparing the median sighting rate for firing against silence found a significant relationship for delphinids with very high medians values compared to the other species categories which all found no relationship, as summarised in Table 3-9, and illustrated in Figure 3-15.

Figure 3-16 shows the distribution of the data for sighting rates in West Africa. The proportion of sighting rates for all cetaceans within a given range of airgun arrays is less from 40 to 200 sightings per 1000 hours during periods when airgun activity was firing when compared to silent.

Table 3-9 Kruskal-Wallis Analysis of Variance Results for Sighting Rate/1,000 Hours in West Africa.

	Species Group	*Count*	*Firing Median*	*Silent Median*	*H*	*p- value*
Firing vs. Silent	**All Cetaceans**	171	51.7	44.4	0.00	0.96
	Baleen Whales	47	35.2	46.0	2.95	0.23
	Delphinids	62	427.1	2011.6	5.34	0.02
	Sperm Whales	22	15.5	25.7	2.30	0.13
	Turtles	14	5.0	6.1	0.04	0.84

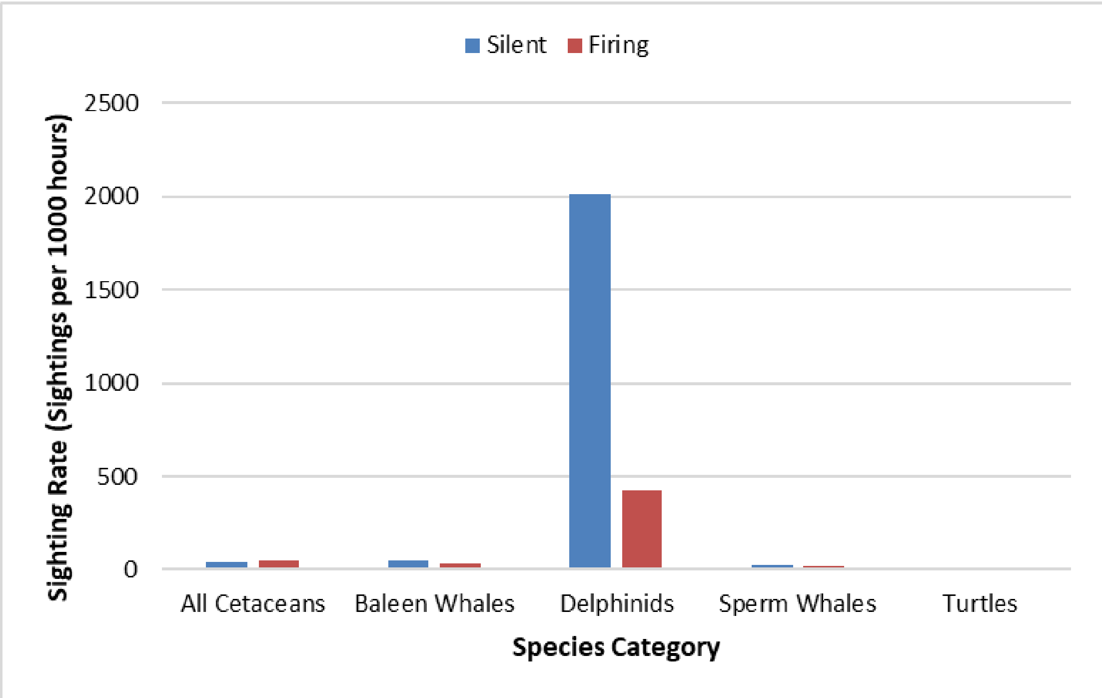

Figure 3-15: Comparison of Median Sighting Rate per 1000 hours during Firing and Silence in West Africa.

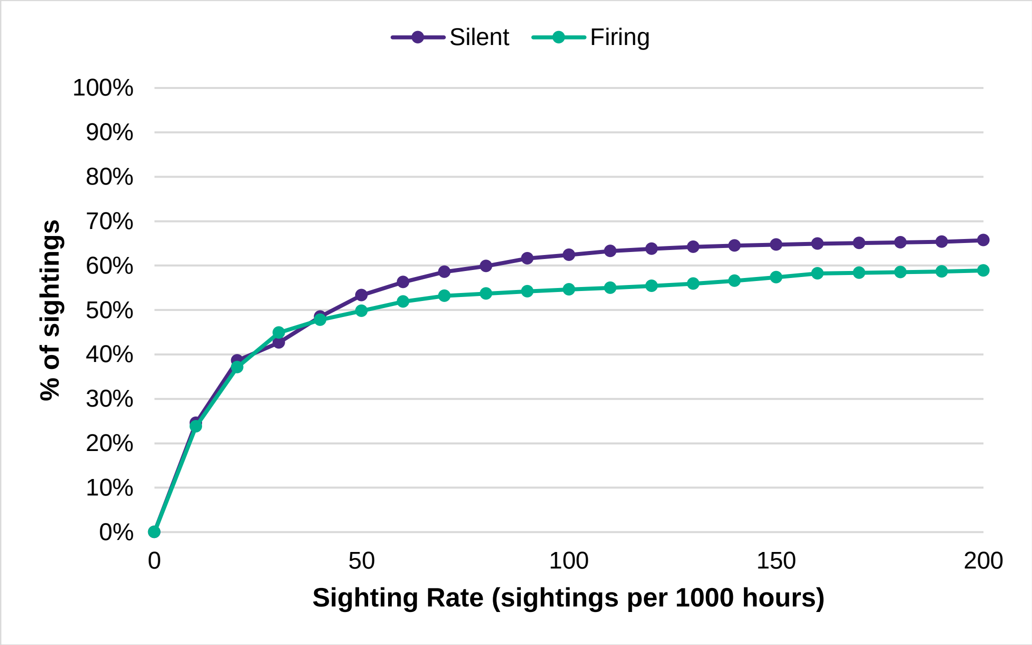

Figure 3-16: Proportion of sightings occurring within specified sighting rates, in relation to airgun activity, in West Africa.

Australia

The median sighting rate per 1,000 hours was compared between active seismic source condition and silence. Table 3-10 summarises the Kruskal-Wallis analysis of variance results. Sighting rate during silent conditions were significantly (Kruskal-Wallis, $p<0.05$) higher than firing for ‘All Cetaceans’, ‘Baleen Whales’ and ‘Sperm Whales’ (Figure 3-17).

Figure 3-18 shows the distribution of the data for sighting rates in Australia. The proportion of sighting rates for all cetaceans within a given range of airgun arrays was higher during periods when airgun activity was firing when compared to silent.

Table 3-10: Kruskal-Wallis Analysis of Variance Results for Sighting Rate/1,000 Hours in Australia

	Species Group	***Count***	***Firing Median***	***Silent Median***	***H***	***p- value***
Firing vs. Silent	**All Cetaceans**	339	9.2	14.9	9.64	0.00
	Baleen Whales	74	9.6	24.8	4.32	0.04
	Delphinids	116	21.8	34.6	3.16	0.08
	Sperm Whales	44	4.3	7.0	4.29	0.04

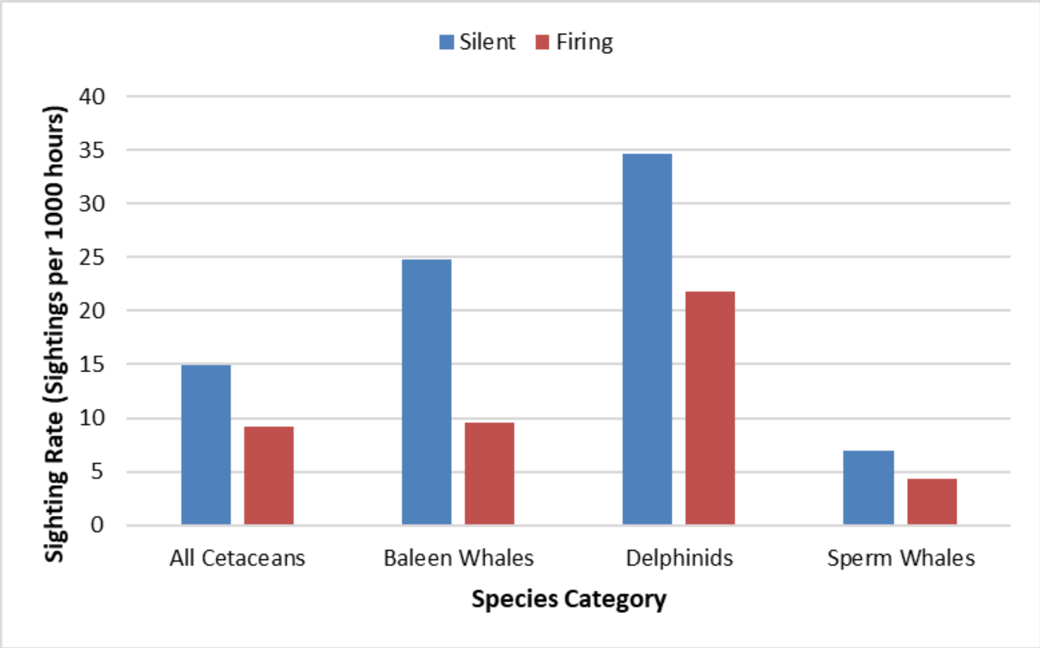

Figure 3-17: Comparison of Median Sighting Rate per 1000 hours during Firing and Silence in Australia.

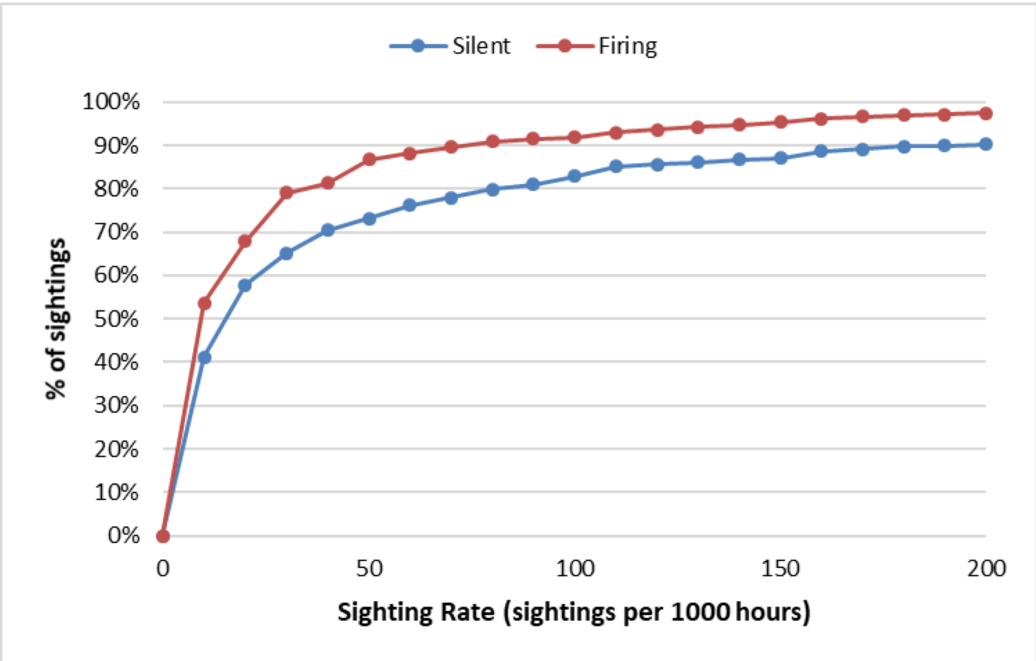

Figure 3-18: Proportion of sightings occurring within specified sighting rates, in relation to airgun activity, in Australia.

3.5 Analyses of behaviour observations relative to airgun status

3.5.1 Grouped Behavioural Observation

Tables in this section detail all species categories that were analysed in this study. For illustrative purposes the 'All Cetaceans' group was used as an example in figures for all seismic source activities.

Gulf of Mexico

A lack of consistent recording of behaviour categorisation limited the sample size for species groups and for behaviour types. By initially assessing all the behaviours in whether there was a difference in response, rather than a specific type of response, it was possible to establish that there were statistically significant differences in behaviour between times when the seismic source was active compared with when it was silent (Table 3-11 and 3-12). Baleen Whales and Beaked Whales were excluded from all behavioural analyses apart from full power which also had limited sample size (N≤60). However, for full power source activity, the two species categories were included to show the insignificant relationships identified in the dataset. Where multiple behaviours were recorded for a single observation, the observation was used for each of the recorded behaviours.

Table 3-11 and Table 3-12 summarise the chi-squared behavioural analysis. Ramp-up versus silence did not have significant statistical relationships with the behaviour demonstrated. However, the relationships identified when comparing full power with silence and mitigation versus silence were significant (P<0.01) for some species groups.

When comparing full power source operations with silence for the 'All Cetaceans' species group, there were statistically significant differences between the behaviours observed for all species groups (Table 3-11). This can be seen in behaviours such as bow riding, diving and logging, which were more prevalent when the seismic source was silent (Figure 3-19). Conversely, blowing, breaching and surfacing were found to be more prevalent during full power.

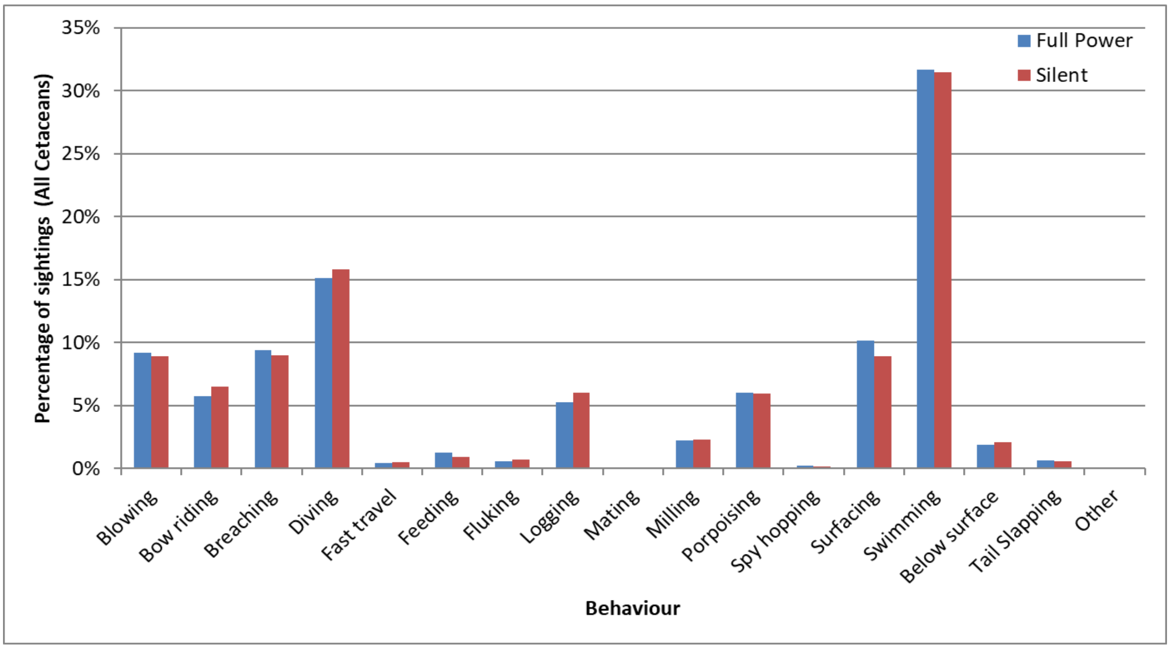

Figure 3-19: Comparative behavioural responses of the "All Cetaceans" group during full power and silence in the Gulf of Mexico.

When comparing the behaviour for the 'All Cetaceans' species group between silence and mitigation (Figure 3-20), blowing, breaching, surfacing and logging are more common behaviours during mitigation whereas bow riding, diving, porpoising, and swimming were more frequently displayed during silent periods.

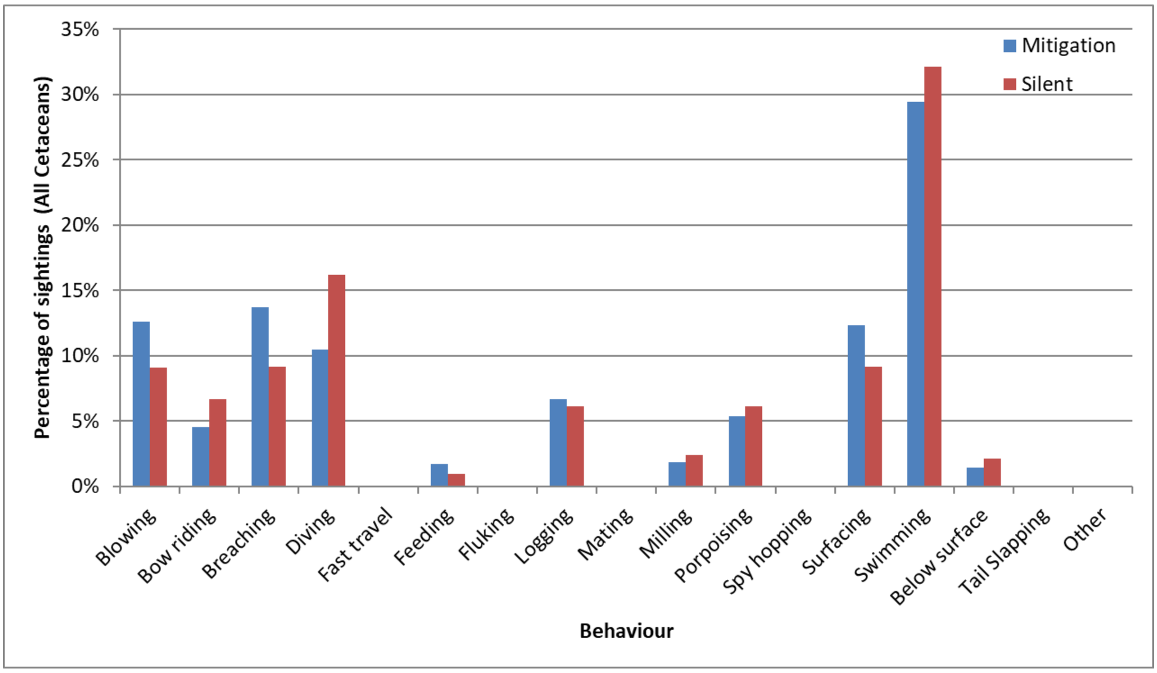

Figure 3-20: Comparative behavioural responses of the "All Cetaceans" group during mitigation and silence in the Gulf of Mexico.

Although not statistically significant (Table 3-12), when comparing the behaviour for the 'All Cetaceans' species group between silence and ramp-up (Figure 3-21), logging, porpoising, surfacing and swimming were more commonly observed behaviours during ramp-up whereas bow riding, breaching, diving and milling were more frequently observed during silent periods.

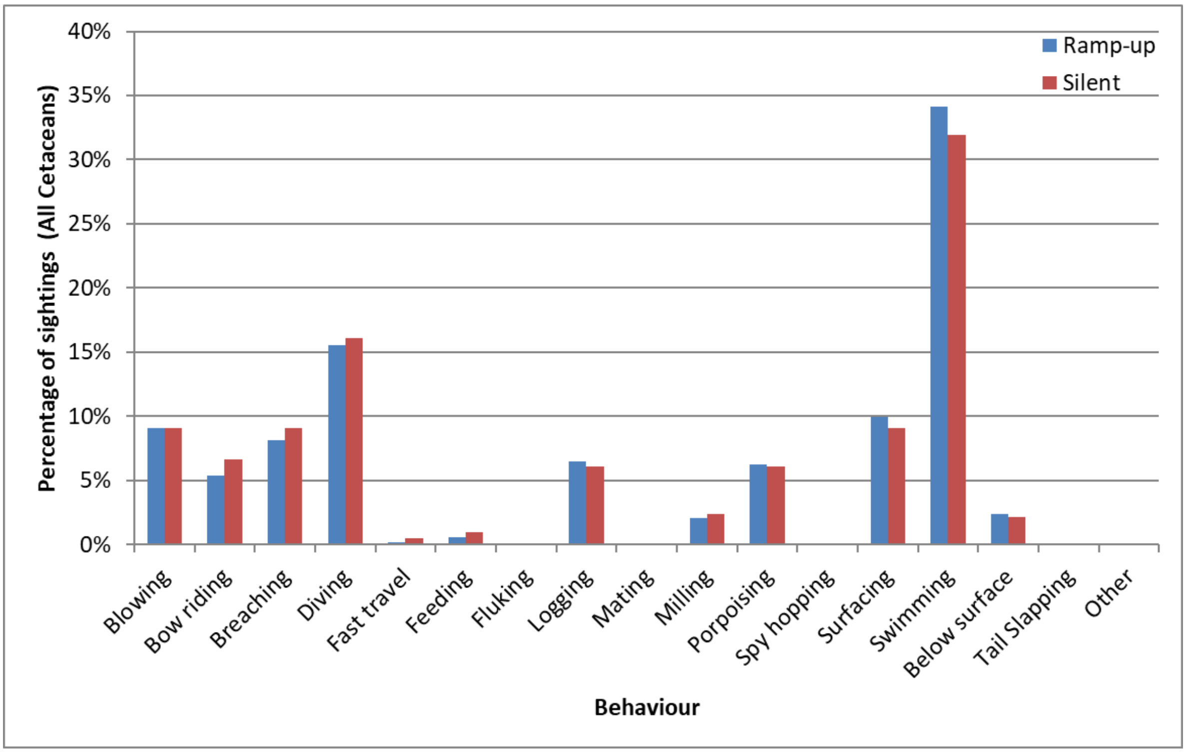

Figure 3-21: Comparative behavioural responses of the "All Cetaceans" group during ramp-up and silence in the Gulf of Mexico.

Table 3-11: Chi-squared results for Grouped Behaviours by Full Power CA Source Status in the Gulf of Mexico (Greyed areas not included within analysis due to low sample size)

	Full Power vs. Silent											
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**		**Beaked Whales**	
CA Source	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**
Blowing	9%	9%	36%	32%	4%	4%	33%	30%	0%	1%	33%	28%
Bow riding	6%	6%	0%	0%	9%	11%	0%	0%	0%	0%	0%	0%
Breaching	9%	9%	5%	6%	14%	14%	1%	1%	0%	1%	7%	9%
Diving	15%	16%	19%	23%	11%	12%	21%	21%	25%	24%	19%	13%
Fast travel	0%	1%	0%	0%	1%	1%	0%	0%	0%	1%	0%	1%
Feeding	1%	1%	1%	0%	2%	1%	0%	0%	1%	1%	0%	0%
Fluking	1%	1%	1%	0%	0%	0%	3%	3%	0%	0%	0%	1%
Logging	5%	6%	7%	0%	2%	2%	11%	12%	11%	12%	5%	1%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Milling	2%	2%	0%	3%	3%	3%	1%	1%	1%	1%	0%	1%
Porpoising	6%	6%	0%	3%	9%	10%	0%	0%	0%	0%	0%	1%
Spy hopping	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Surfacing	10%	9%	11%	13%	10%	9%	9%	9%	12%	9%	19%	16%
Swimming	32%	31%	18%	19%	32%	31%	21%	21%	43%	44%	17%	26%
Below surface	2%	2%	1%	0%	1%	2%	0%	0%	7%	6%	0%	0%
Tail Slapping	1%	1%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ϰ2	115.274		1.17419		116.498		20.8207		33.411		3.00369	
n	15244		62		9918		2729		2355		37	
d.f.	16		3		16		8		10		3	

	Full Power vs. Silent											
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**		**Beaked Whales**	
CA Source	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**
p	0.000		0.759		0.000		0.008		0.000		0.391	

Table 3-12: Chi-squared results for Grouped Behaviours by Mitigation and Ramp-up CA Source Status (Greyed areas not included within analysis due to low sample size)

	Mitigation vs. Silent								Ramp-up vs. Silent							
Species Group	All Cetaceans		Delphinids		Sperm Whales		Turtles		All Cetaceans		Delphinids		Sperm Whales		Turtles	
CA Source	Mitigation	Silent	Mitigation	Silent	Mitigation	Silent	Mitigation	Silent	Ramp-up	Silent	Ramp-up	Silent	Ramp-up	Silent	Ramp-up	Silent
Blowing	13%	9%	5%	4%	36%	30%	0%	1%	9%	9%	3%	4%	31%	30%	1%	1%
Bow riding	5%	7%	6%	11%	0%	0%	0%	0%	5%	7%	8%	11%	0%	0%	0%	0%
Breaching	14%	9%	18%	14%	2%	1%	0%	1%	8%	9%	12%	14%	1%	1%	3%	1%
Diving	10%	16%	7%	12%	19%	21%	18%	24%	15%	16%	11%	12%	23%	21%	24%	24%
Fast travel	0%	0%	0%	1%	1%	0%	0%	1%	0%	1%	0%	1%	0%	0%	0%	1%
Feeding	2%	1%	2%	1%	0%	0%	0%	1%	1%	1%	1%	1%	0%	0%	0%	1%
Fluking	0%	0%	0%	0%	2%	3%	0%	0%	0%	0%	1%	0%	2%	3%	0%	0%
Logging	7%	6%	5%	2%	12%	12%	5%	12%	6%	6%	4%	2%	10%	12%	8%	12%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Milling	2%	2%	2%	3%	1%	1%	3%	1%	2%	2%	2%	3%	2%	1%	1%	1%
Porpoising	5%	6%	7%	10%	0%	0%	0%	0%	6%	6%	10%	10%	0%	0%	0%	0%
Spy hopping	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Surfacing	12%	9%	12%	9%	12%	9%	10%	9%	10%	9%	9%	9%	10%	9%	12%	9%
Swimming	29%	32%	31%	31%	15%	21%	54%	44%	34%	32%	36%	31%	21%	21%	42%	44%
Below surface	1%	2%	1%	2%	0%	0%	10%	6%	2%	2%	2%	2%	0%	0%	9%	6%
Tail Slapping	0%	0%	1%	1%	2%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ϰ2	61.8421		59.9281		6.12202		1.40291		3.79255		14.9815		0.463434		1.5994	
n	707		499		160		28		538		342		110		65	

	Mitigation vs. Silent								Ramp-up vs. Silent							
Species Group	**All Cetaceans**		**Delphinids**		**Sperm Whales**		**Turtles**		**All Cetaceans**		**Delphinids**		**Sperm Whales**		**Turtles**	
CA Source	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**
d.f.	10		10		4		1		9		9		4		3	
p	0.000		0.000		0.19		0.236		0.925		0.091		0.977		0.660	

West Africa

Table 3-13 and Table 3-14 below show a summary of the chi-squared behavioural analysis. Ramp-up versus silent and mitigation versus silent mode did not have significant statistical relationships with the behaviour demonstrated, with sample sizes insufficient for inclusion of some species categories (Table 3-14). However, the relationships identified when comparing full power with silent were significant (P<0.05) when considering the 'All Cetaceans', 'Baleen Whales' and 'Delphinids' species categories (Table 3-13). Sperm whales were excluded from this analysis due to insufficient sample size.

Table 3-13: Chi-squared results for Grouped Behaviours by Full Power CA Source Status for the West Africa Region (Greyed areas not included within analysis due to low sample size)

	Full Power vs. Silent									
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**	
CA Source	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**
Below surface	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Blowing	16%	14%	38%	33%	1%	1%	58%	51%	0%	0%
Bow riding	1%	3%	0%	0%	2%	5%	0%	0%	0%	0%
Breaching	20%	18%	10%	16%	27%	24%	2%	0%	2%	0%
Diving	3%	3%	1%	2%	1%	1%	10%	11%	12%	10%
Fast travel	8%	8%	2%	3%	13%	12%	0%	1%	0%	2%
Feeding	3%	2%	2%	2%	5%	3%	0%	0%	0%	0%
Fluking	1%	1%	3%	1%	1%	0%	2%	6%	0%	0%
Logging	8%	8%	3%	1%	5%	5%	0%	6%	60%	57%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Milling	1%	1%	0%	1%	2%	2%	2%	0%	5%	2%
Porpoising	4%	5%	0%	0%	8%	9%	0%	0%	0%	0%
Spy hopping	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%
Surfacing	4%	4%	2%	2%	4%	3%	2%	2%	3%	3%
Swimming	26%	28%	29%	28%	28%	31%	13%	19%	12%	19%
Tail Slapping	2%	3%	8%	13%	0%	1%	0%	0%	0%	0%
Other	3%	2%	0%	0%	3%	2%	10%	1%	6%	7%
ϰ2	29.9339		10.3852		16.9796		1.68899		2.19091	
n	991		195		562		39		55	
d.f.	12		4		10		2		2	
p	0.003		0.034		0.075		0.43		0.334	

Table 3-14: Chi-squared results for Grouped Behaviours by Reduced Power and Soft-start CA Source Status for the West Africa Region (Greyed areas not included within analysis due to low sample size)

	Reduced Power vs. Silent				Soft-start vs. Silent					
Species Group	**All Cetaceans**		**Delphinids**		**All Cetaceans**		**Baleen Whales**		**Delphinids**	
CA Source	**Reduced Power**	**Silent**	**Reduced Power**	**Silent**	**Soft-start**	**Silent**	**Soft-start**	**Silent**	**Soft-start**	**Silent**
Below surface	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Blowing	24%	14%	0%	1%	18%	14%	33%	43%	1%	1%
Bow riding	0%	3%	0%	5%	1%	3%	0%	0%	5%	1%
Breaching	16%	19%	27%	24%	21%	19%	15%	14%	24%	28%
Diving	8%	3%	7%	1%	1%	3%	2%	0%	1%	0%
Fast travel	8%	8%	0%	12%	10%	8%	3%	5%	12%	13%
Feeding	0%	2%	0%	3%	4%	2%	2%	0%	3%	5%
Fluking	0%	1%	0%	0%	0%	1%	1%	0%	0%	0%
Logging	4%	8%	7%	5%	5%	8%	1%	0%	5%	5%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Milling	0%	1%	0%	2%	2%	1%	1%	0%	2%	3%
Porpoising	8%	5%	13%	9%	5%	5%	0%	0%	9%	8%
Spy hopping	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Surfacing	4%	4%	7%	3%	3%	4%	2%	5%	4%	3%
Swimming	20%	28%	27%	31%	28%	28%	28%	24%	31%	32%
Tail Slapping	0%	3%	0%	1%	1%	3%	13%	5%	1%	0%
Other	8%	2%	13%	2%	2%	2%	0%	5%	2%	1%
ϰ2	2.33838		0.112989		1.96672		6.61308		3.2609	
n	11		8		99		214		669	
d.f.	1		1		4		1		3	
p	0.126		0.737		0.742		0.003		0.353	

For species groups ‘All Cetacean’ and ‘Baleen Whales’, when comparing full power source operations with silence, there were statistically significant differences between the responses of those groups. This can be seen in behaviours for the ‘All Cetaceans’ species group such as blowing, breaching, fast travel and feeding, which were more prevalent when the seismic source was at full power (Figure 3-22). Bow riding, diving, logging, porpoising, swimming and tail slapping were more prevalent during silence.

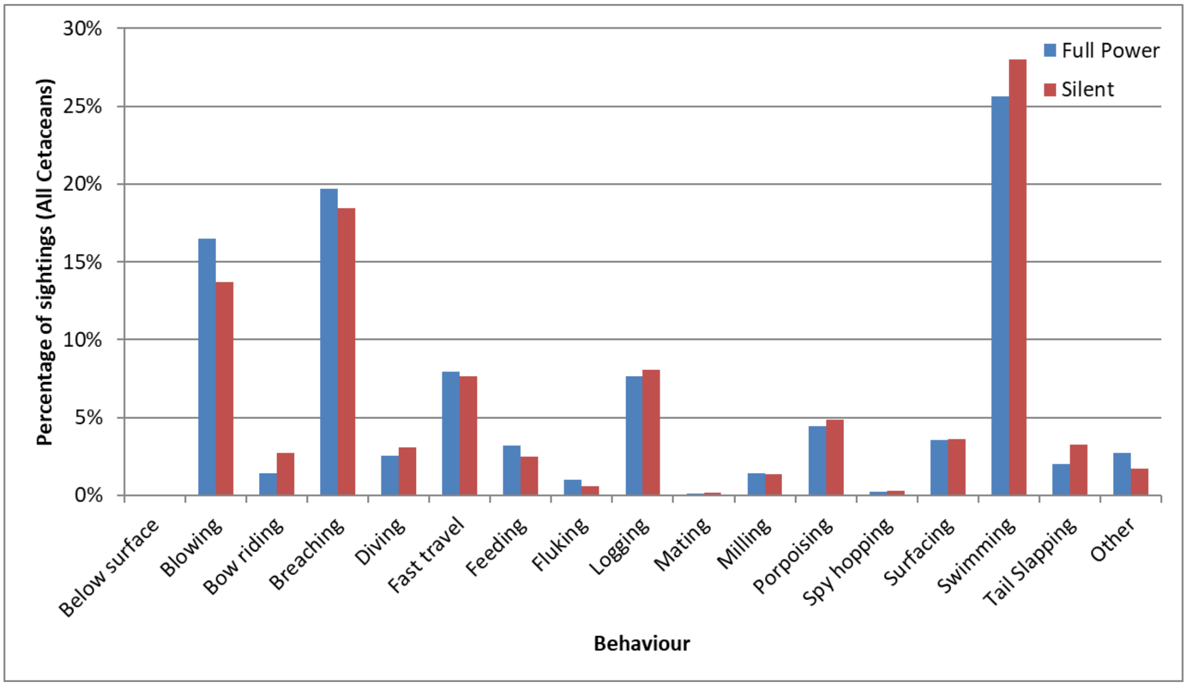

Figure 3-22: Comparative behavioural responses of the “All Cetaceans” group during full power and silence for the West African Region

For soft-start source activity comparison with silent periods, there were no statistically significant differences between the observed behaviours for those groups, seen in behaviours for the ‘All Cetaceans’ species group such as blowing, breaching, fast travel, feeding, and porpoising (Table 3-14, Figure 3-23Figure 3-23: Comparative behavioural responses of the ‘All Cetaceans’ group during soft-start and silence for the West African Region.). Similarly, for reduced power firing comparison with silence, there were no statistically significant differences between the observed behaviours for the ‘All Cetaceans’ species group, seen in behaviours such as blowing, diving, logging, porpoising, swimming and other behaviours, (Figure 3-24).

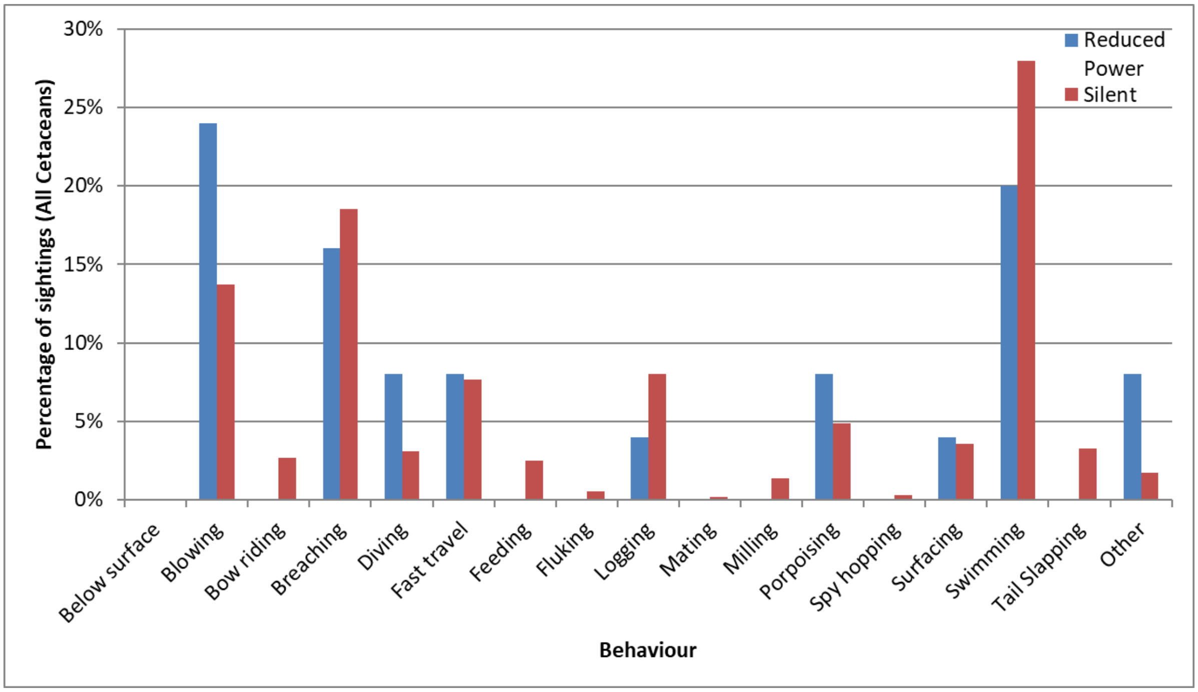

Figure 3-23: Comparative behavioural responses of the 'All Cetaceans' group during soft-start and silence for the West African Region.

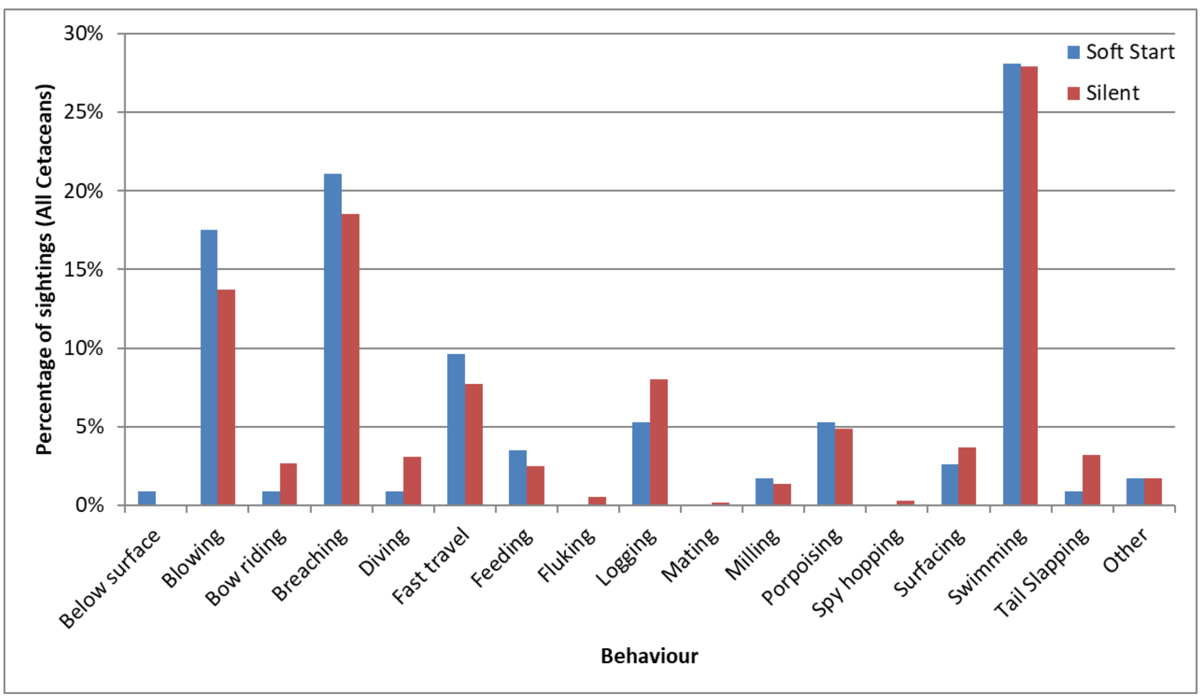

Figure 3-24: Comparative behavioural responses of the 'All Cetaceans' group during reduced power and silence for the West African Region

Australia

Table 3-15 below shows a summary of the chi-squared behavioural analysis. For full power versus silence operating modes, 'All Cetaceans' and 'Delphinid' groups show significant behavioural relationships to the firing mode (P>0.05). Sample sizes were insufficient to perform the analysis for the 'Sperm Whale' and 'Turtle' species groups. Soft-start versus silent failed to meet the requirements of sufficient sample size or the relationships were not found to be significant. No relationships were identified when comparing reduced power with silent when considering the 'All Cetaceans' species category.

Behaviours for the 'All Cetaceans' species group such as blowing, bow riding, breaching, diving, fast travel, feeding and surfacing were recorded more when the seismic source was at full power than during silence from the acoustic survey operation (Figure 3-25). Logging, milling, porpoising and swimming were more prevalent during silence.

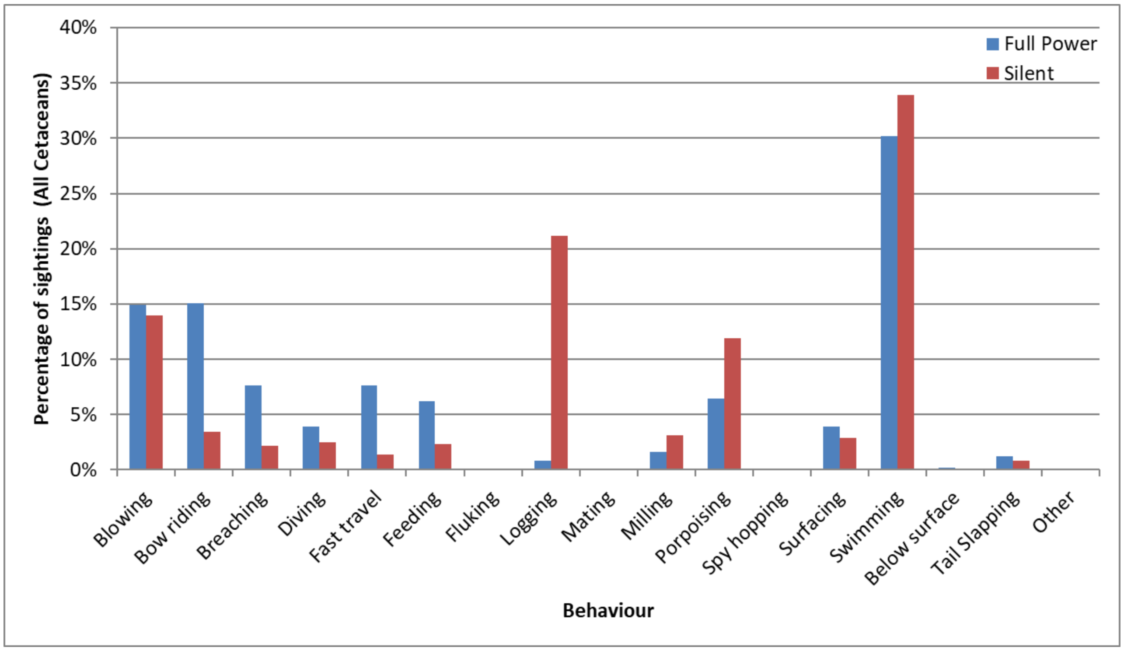

Figure 3-25: Comparative behavioural responses of the 'All Cetaceans' group during full power and silence

Table 3-15: Chi-squared results for Grouped Behaviours by CA Source Status for the Australia Region (Greyed areas not included within analysis due to low sample size)

			Percentage												
	Species Group	Airgun Activity	Below surface	Blowing	Bow riding	Feeding	Logging	Porpoising	Surfacing	Swimming	Other	2	n	d.f.	p
Full Power vs. Silent	All Cetaceans	Full Power	0%	15%	15%	6%	1%	6%	4%	30%	22%	224.213	478	6	0.000
		Silent	0%	14%	3%	2%	21%	12%	3%	34%	10%				
	Baleen Whales	Full Power	0%	52%	0%	1%	0%	0%	6%	23%	18%	8.10183	66	2	0.017
		Silent	0%	42%	0%	3%	5%	0%	10%	31%	9%				
	Delphinids	Full Power	0%	1%	21%	8%	1%	9%	4%	34%	23%	150.253	340	5	0.000
		Silent	0%	2%	7%	4%	18%	16%	0%	44%	10%				
	Sperm Whales	Full Power	0%	45%	0%	0%	18%	0%	18%	18%	0%	0	0	0	0.000
		Silent	0%	40%	0%	0%	18%	0%	12%	25%	4%				
	Turtles	Full Power	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				
Soft Start vs. Silent	All Cetaceans	Soft Start	0%	32%	7%	4%	0%	7%	7%	43%	0%	1.93676	21	1	0.164
		Silent	0%	15%	4%	3%	24%	13%	3%	38%	0%				
	Baleen Whales	Soft Start	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				
	Delphinids	Soft Start	0%	0%	15%	8%	0%	15%	8%	54%	0%	0	0	0	0.000
		Silent	0%	2%	8%	4%	20%	17%	0%	48%	0%				
	Sperm Whales	Soft Start	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				
	Turtles	Soft Start	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				
Reduced Power vs. Silent	All Cetaceans	Reduced Power	0%	17%	20%	3%	0%	9%	0%	51%	0%	12.4746	31	2	0.002
		Silent	0%	16%	4%	3%	24%	14%	0%	39%	0%				
	Baleen Whales	Reduced Power	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				
	Delphinids	Reduced Power	0%	0%	33%	5%	0%	14%	0%	48%	0%	9.59302	17	1	0.002
		Silent	0%	2%	8%	4%	20%	17%	0%	48%	0%				
	Sperm Whales	Reduced Power	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				
	Turtles	Reduced Power	0%	0%	0%	0%	0%	0%	0%	0%	0%	0	0	0	0.000
		Silent	0%	0%	0%	0%	0%	0%	0%	0%	0%				

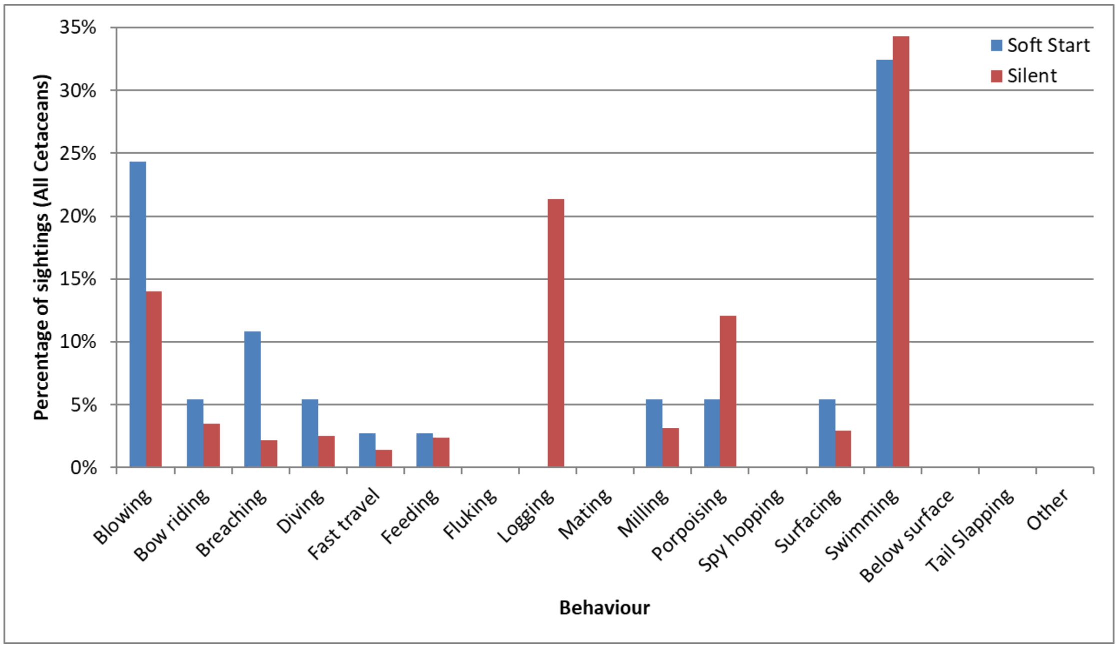

Figure 3-26: Comparative behavioural responses of the 'All Cetaceans' group during soft-start and silence in the Australia Region.

Figure 3-10 below shows that when comparing the reduced power operations with silence, the 'All Cetaceans' group demonstrated 22% more blowing, bow riding, fast travel and swimming behaviours than during silence. Porpoising and logging were more prevalent during silence.

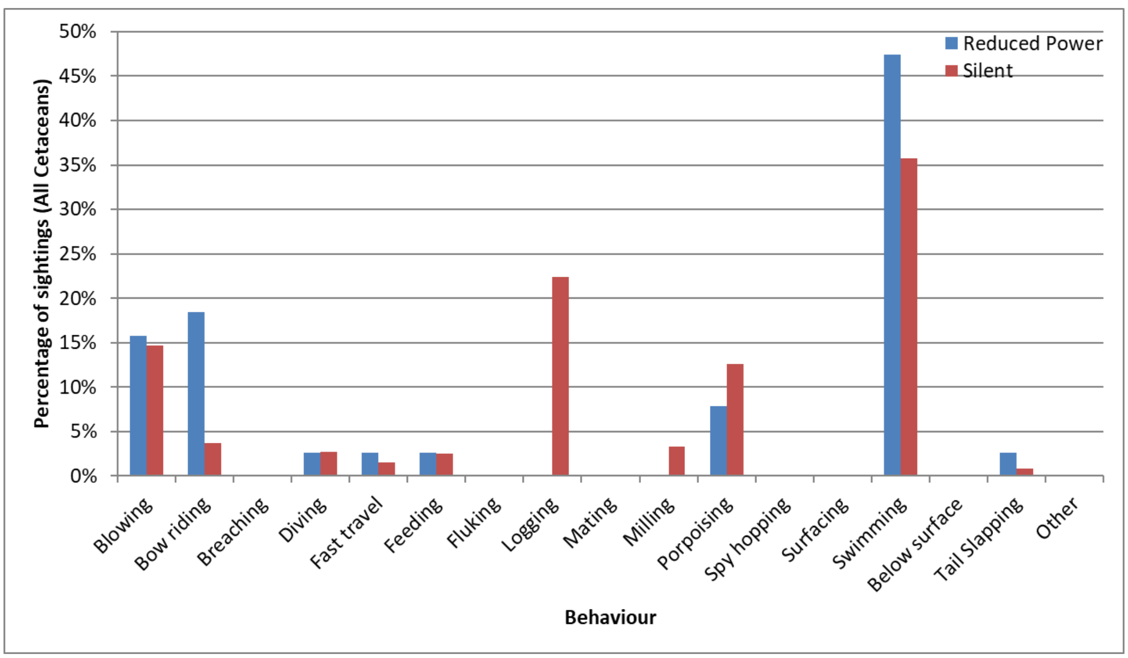

Figure 3-27: Comparative behavioural responses of the 'All Cetaceans' group during reduced power and silence in the Australia Region.

3.5.2 Individual Behavioural Analysis

Where the combined behaviour analysis (Section 3.7.1 above) identified statistically significant differences in behaviour observations between CA source activity modes (Section 3.7.1 above), a more detailed analysis was undertaken to identify the significance of the variations for individual behaviours, as detailed by region below.

Gulf of Mexico

There were significant differences in 'Delphinids' behaviours for some behaviours listed in Table 3-9 when the seismic source was active compared with silence, including greater incidences of spy hopping, surfacing, feeding and swimming, and there was a lower incidence of bow riding and swimming below the surface during full power operation.

The 'Sperm Whales' species category was observed to perform blowing activity significantly more frequently during full power compared to silence. Turtles were observed to be swimming below the surface and also surfacing significantly more frequently during full power compared to silence.

Table 3-16: Chi-squared results for individual behaviours during full power operation compared with silence in the Gulf of Mexico

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Baleen Whales	Blowing	Full Power	36.00%	1.12723	62	1	0.288
		Silent	32.26%				
	Diving	Full Power	18.67%	0.36129	62	1	0.548
		Silent	22.58%				
	Surfacing	Full Power	10.67%	0.179523	62	1	0.672
		Silent	12.90%				
	Swimming	Full Power	17.33%	0.0564516	62	1	0.812
		Silent	19.35%				
Delphinids	Blowing	Full Power	4.00%	1.96673	9918	1	0.161
		Silent	3.74%				
	Bow riding	Full Power	8.77%	39.7685	9918	1	0.000
		Silent	10.73%				
	Breaching	Full Power	14.01%	0.0010369	9918	1	0.974
		Silent	14.03%				
	Diving	Full Power	11.30%	0.941623	9918	1	0.332
		Silent	11.61%				
	Fast travel	Full Power	0.56%	0.0828236	9918	1	0.774
		Silent	0.54%				

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
	Feeding	Full Power	1.78%	12.2417	9918	1	0.000
		Silent	1.38%				
	Fluking	Full Power	0.11%	0.0528808	9918	1	0.818
		Silent	0.12%				
	Logging	Full Power	2.37%	0.029472	9918	1	0.864
		Silent	2.34%				
	Mating	Full Power	0.06%	2.84615	9918	1	0.092
		Silent	0.12%				
	Milling	Full Power	2.92%	0.449623	9918	1	0.503
		Silent	3.04%				
	Porpoising	Full Power	9.25%	3.2186	9918	1	0.073
		Silent	9.78%				
	Spy hopping	Full Power	0.36%	6.55983	9918	1	0.010
		Silent	0.24%				
	Surfacing	Full Power	10.13%	32.1676	9918	1	0.000
		Silent	8.54%				
	Swimming	Full Power	32.23%	4.67942	9918	1	0.031
		Silent	31.23%				
	Below surface	Full Power	1.08%	16.9003	9918	1	0.000
		Silent	1.60%				
	Tail Slapping	Full Power	0.97%	0.123863	9918	1	0.725
		Silent	0.93%				
Sperm Whales	Blowing	Full Power	33.27%	10.8305	2729	1	0.001
		Silent	30.43%				
	Breaching	Full Power	0.87%	3.79314	2729	1	0.051
		Silent	1.29%				
	Diving	Full Power	21.02%	0.0019015	2729	1	0.965
		Silent	21.01%				
	Fluking	Full Power	2.69%	0.890689	2729	1	0.345
		Silent	3.00%				
	Logging	Full Power	10.80%	3.10928	2729	1	0.078

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
		Silent	11.90%				
	Milling	Full Power	0.73%	2.52447	2729	1	0.112
		Silent	1.04%				
	Surfacing	Full Power	8.80%	1.00005	2729	1	0.317
		Silent	9.37%				
	Swimming	Full Power	20.58%	0.269294	2729	1	0.604
		Silent	21.01%				
	Below surface	Full Power	0.47%	2.35226	2729	1	0.125
		Silent	0.31%				
Turtles	Blowing	Full Power	0.47%	4.11875	2355	1	0.042
		Silent	0.85%				
	Breaching	Full Power	0.34%	1.35637	2355	1	0.244
		Silent	0.51%				
	Diving	Full Power	24.44%	0.0158286	2355	1	0.900
		Silent	24.32%				
	Fast travel	Full Power	0.42%	2.28914	2355	1	0.130
		Silent	0.68%				
	Feeding	Full Power	0.59%	0.324634	2355	1	0.569
		Silent	0.51%				
	Logging	Full Power	10.99%	2.63603	2355	1	0.104
		Silent	12.07%				
	Milling	Full Power	1.23%	0.965776	2355	1	0.326
		Silent	1.47%				
	Surfacing	Full Power	11.88%	17.6937	2355	1	0.000
		Silent	9.35%				
	Swimming	Full Power	42.34%	2.64252	2355	1	0.104
		Silent	43.99%				
	Below surface	Full Power	6.83%	4.73936	2355	1	0.029
		Silent	5.78%				
Beaked Whales	Blowing	Full Power	33.33%	0.337838	37	1	0.561
		Silent	27.94%				

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
	Surfacing	Full Power	19.05%	0.128245	37	1	0.720
		Silent	16.18%				
	Swimming	Full Power	16.67%	2.74463	37	1	0.098
		Silent	26.47%				

For mitigation firing, there were significant differences in observed 'Delphinids' behaviours for bow riding, logging and surfacing, shown in Table 3-10, when the seismic source was active compared with silence, including greater incidences of breaching, logging and surfacing. There was a lower incidence of bow-riding and diving during mitigation operation.

Behaviour relationships to seismic source operation were not determined to be significant for the other species categories during mitigation source levels.

Table 3-17: Chi-squared results for individual behaviours during mitigation operation compared with silence in the Gulf of Mexico

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Delphinids	Blowing	Mitigation	5.10%	2.63995	499	1	0.104
		Silent	3.74%				
	Bow riding	Mitigation	6.27%	10.4585	499	1	0.001
		Silent	10.71%				
	Breaching	Mitigation	18.43%	8.25771	499	1	0.004
		Silent	14.05%				
	Diving	Mitigation	6.67%	12.1147	499	1	0.001
		Silent	11.61%				
	Feeding	Mitigation	2.35%	3.59817	499	1	0.058
		Silent	1.38%				
	Logging	Mitigation	4.90%	14.6115	499	1	0.000
		Silent	2.35%				
	Milling	Mitigation	2.16%	1.34646	499	1	0.246
		Silent	3.04%				
	Porpoising	Mitigation	7.45%	3.13681	499	1	0.077
		Silent	9.79%				
	Surfacing	Mitigation	12.16%	8.5686	499	1	0.003

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
		Silent	8.55%				
	Swimming	Mitigation	31.18%	0.0004771	499	1	0.983
		Silent	31.19%				
	Below surface	Mitigation	1.18%	0.570888	499	1	0.450
		Silent	1.60%				
Sperm Whales	Blowing	Mitigation	36.05%	2.59303	172	1	0.107
		Silent	30.40%				
	Diving	Mitigation	18.60%	0.606999	172	1	0.436
		Silent	21.03%				
	Logging	Mitigation	11.63%	0.0061915	160	1	0.937
		Silent	11.91%				
	Surfacing	Mitigation	11.63%	1.11111	160	1	0.292
		Silent	9.37%				
	Swimming	Mitigation	15.12%	3.51312	160	1	0.061
		Silent	21.03%				
Turtles	Diving	Mitigation	17.95%	1.40291	28	1	0.236
		Silent	24.36%				
	Swimming	Mitigation	53.85%	1.40291	28	1	0.236
		Silent	43.82%				

For ramp-up, there was a significant difference in ‘Delphinids’ behaviour with a greater incidence of logging (Table 3-11) when the seismic source was active compared with silence. Relationships between other behaviours and for other species categories were not found to be statistically significant.

Table 3-18 Chi-squared results for individual behaviours during ramp-up operation compared with silence in the Gulf of Mexico

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Delphinids	Blowing	Ramp-up	2.80%	0.825617	342	1	0.364
		Silent	3.74%				
	Bow riding	Ramp-up	8.12%	2.35981	342	1	0.124
		Silent	10.71%				

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
	Breaching	Ramp-up	11.48%	1.76551	342	1	0.184
		Silent	14.03%				
	Diving	Ramp-up	10.92%	0.123073	342	1	0.726
		Silent	11.62%				
	Logging	Ramp-up	4.48%	7.30386	342	1	0.007
		Silent	2.35%				
	Milling	Ramp-up	2.24%	0.737469	342	1	0.390
		Silent	3.04%				
	Porpoising	Ramp-up	9.52%	0.0143864	342	1	0.905
		Silent	9.80%				
	Surfacing	Ramp-up	8.96%	0.107754	342	1	0.743
		Silent	8.55%				
	Swimming	Ramp-up	35.57%	3.69109	342	1	0.055
		Silent	31.19%				
	Below surface	Ramp-up	1.68%	0.0210369	342	1	0.885
		Silent	1.60%				
Sperm Whales	Blowing	Ramp-up	31.30%	0.0044081	110	1	0.947
		Silent	30.40%				
	Diving	Ramp-up	22.61%	0.0918622	110	1	0.762
		Silent	21.03%				
	Surfacing	Ramp-up	10.43%	0.10101	110	1	0.751
		Silent	9.37%				
	Swimming	Ramp-up	20.87%	0.0237374	110	1	0.878
		Silent	21.03%				
Turtles	Diving	Ramp-up	23.38%	0.0094029	65	1	0.923
		Silent	24.36%				
	Logging	Ramp-up	7.79%	1.0208	65	1	0.312
		Silent	12.12%				
	Surfacing	Ramp-up	11.69%	0.790636	65	1	0.374
		Silent	9.39%				
	Swimming	Ramp-up	41.56%	0.0036173	65	1	0.952

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
		Silent	43.82%				

West Africa

For full power operation, there were significant differences in 'Delphinids' behaviours for bow riding and logging (Table 3-12), with a lower incidence of logging. 'Baleen Whales' had significant differences in behaviours for blowing at higher incidence and breaching at a lower incidence. The relationships to other behaviours and for other species categories were not found to be statistically significant.

Table 3-19: Chi-squared results for individual behaviours during full power operation compared with silence for the West African Region.

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Delphinids	Bow riding	Full Power	2%	7.16191	562	1	0.005
		Silent	5%				
	Breaching	Full Power	27%	3.50177	562	1	0.061
		Silent	24%				
	Diving	Full Power	1%	0.006929	562	1	0.934
		Silent	1%				
	Fast travel	Full Power	13%	0.420456	562	1	0.517
		Silent	12%				
	Feeding	Full Power	5%	2.30604	562	1	0.129
		Silent	3%				
	Logging	Full Power	5%	0.00645	562	1	0.036
		Silent	5%				
	Milling	Full Power	2%	0.239818	562	1	0.624
		Silent	2%				
	Porpoising	Full Power	8%	0.754511	562	1	0.385
		Silent	9%				
	Surfacing	Full Power	4%	0.132456	562	1	0.716
		Silent	3%				
	Swimming	Full Power	28%	1.79756	562	1	0.180
		Silent	31%				
	Other	Full Power	3%	2.11779	562	1	0.146
		Silent	2%				

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Baleen Whales	Blowing	Full Power	38%	4.23752	195	1	0.040
		Silent	33%				
	Breaching	Full Power	10%	3.97167	195	1	0.046
		Silent	16%				
	Fast travel	Full Power	2%	0.365609	195	1	0.545
		Silent	3%				
	Swimming	Full Power	29%	0.810825	195	1	0.368
		Silent	28%				
	Tail Slapping	Full Power	8%	3.42718	195	1	0.064
		Silent	13%				
Sperm Whales	Blowing	Full Power	58%	1.43761	39	1	0.231
		Silent	51%				
	Diving	Full Power	10%	0.037221	39	1	0.847
		Silent	11%				
	Swimming	Full Power	13%	1.46335	39	1	0.226
		Silent	19%				
Turtles	Diving	Full Power	12%	0.656818	55	1	0.418
		Silent	9%				
	Logging	Full Power	59%	0.445455	55	1	0.505
		Silent	57%				
	Swimming	Full Power	12%	1.87532	55	1	0.171
		Silent	19%				

There were no statistically significant relationships found between individual behaviours and the seismic source operation for 'Delphinids'. However, 'baleen whales' during the soft-start operation compared with silence had significant differences for blowing (lower incidence) and a high incidence of swimming (Table 3-13).

Table 3-20: Chi-squared results for individual behaviours during soft-start operation compared with silence for the West African Region

Species Group	Behaviour Category	CA Source	Behaviour Frequency	ϰ2	n	d.f.	p
Delphinids	Breaching	Soft-start	24%	1.76174	669	1	0.184
		Silent	28%				

Species Group	Behaviour Category	CA Source	Behaviour Frequency	ϰ2	n	d.f.	p
	Fast Travel	Soft-start	12%	0.0304933	669	1	0.861
		Silent	13%				
	Porpoising	Soft-start	9%	2.11301	669	1	0.146
		Silent	8%				
	Swimming	Soft-start	31%	0.28851	669	1	0.591
		Silent	32%				
Baleen Whales	Blowing	Soft-start	33%	8.61308	214	1	0.003
		Silent	43%				
	Swimming	Soft-start	28%	8.61308	214	1	0.003
		Silent	24%				

Australia

For full power operations, the 'Delphinids' species category showed that the majority of the behaviours observed exhibited statistically significant differences. During full power operations, 'Delphinids' were more frequently observed bow riding, breaching, fast travelling, and feeding but were marginally less likely to be seen blowing, porpoising, or swimming (Table 3-14).

Table 3-21: Chi-squared results for individual behaviours during full power operation compared with silence in Australia

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Baleen Whales	Blowing	Full Power	49.33%	3.18145	53	1	0.074
		Silent	38.93%				
	Swimming	Full Power	21.33%	3.18145	53	1	0.074
		Silent	28.53%				
Delphinids	Blowing	Full Power	1.41%	0.424578	327	1	0.009
		Silent	1.60%				
	Bow riding	Full Power	20.56%	65.7697	327	1	0.000
		Silent	7.29%				
	Breaching	Full Power	9.01%	36.769	327	1	0.000
		Silent	2.80%				
	Fast travel	Full Power	8.73%	38.8475	327	1	0.000
		Silent	2.60%				

	Feeding	Full Power	7.61%	11.0747	327	1	0.001
		Silent	3.50%				
	Milling	Full Power	1.97%	1.40121	327	1	0.237
		Silent	2.60%				
	Porpoising	Full Power	8.73%	20.4556	327	1	0.000
		Silent	15.18%				
	Swimming	Full Power	34.08%	41.0869	327	1	0.000
		Silent	42.86%				

For ramp-up, there was a significant difference in 'Delphinids' behaviour with a higher incidence of spy hopping and a lower incidence of bow riding (Table 3-15) when the seismic source was active compared with silence. Relationships between other behaviours and for other species categories were not found to be statistically significant.

Table 3-22: Chi-squared results for individual behaviours during ramp-up operation compared with silence.

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Baleen Whales	Blowing	Ramp-up	40%	0.146233	4	1	0.702
		Silent	39%				
	Breaching	Ramp-up	8%	0.0249836	4	1	0.874
		Silent	8%				
	Surfacing	Ramp-up	8%	0.274438	4	1	0.600
		Silent	7%				
	Swimming	Ramp-up	21%	0.67002	4	1	0.413
		Silent	25%				
Delphinids	Below surface	Ramp-up	1%	0.0195429	474	1	0.889
		Silent	1%				
	Blowing	Ramp-up	2%	1.0347	474	1	0.309
		Silent	3%				
	Bow riding	Ramp-up	7%	5.1125	474	1	0.024
		Silent	10%				
	Breaching	Ramp-up	15%	0.801093	474	1	0.371
		Silent	14%				
	Diving	Ramp-up	8%	0.175411	474	1	0.675

Species Group	Behaviour Category	CA Source Activity	Behaviour Frequency	ϰ2	n	d.f.	p
		Silent	9%				
	Fast travel	Ramp-up	3%	1.55984	474	1	0.212
		Silent	2%				
	Feeding	Ramp-up	2%	0.0281533	474	1	0.867
		Silent	2%				
	Logging	Ramp-up	9%	0.152717	474	1	0.696
		Silent	2%				
	Milling	Ramp-up	2%	0.0226769	474	1	0.880
		Silent	1%				
	Porpoising	Ramp-up	10%	0.194506	474	1	0.659
		Silent	10%				
	Spy hopping	Ramp-up	1%	15.6913	474	1	0.000
		Silent	0%				
	Surfacing	Ramp-up	7%	0.223303	474	1	0.637
		Silent	7%				
	Swimming	Ramp-up	34%	0.689244	474	1	0.406
		Silent	33%				
	Tail Slapping	Ramp-up	1%	0.0206638	474	1	0.886
		Silent	1%				
Sperm Whales	Blowing	Ramp-up	33%	0.081326	122	1	0.776
		Silent	31%				
	Diving	Ramp-up	21%	0.107146	122	1	0.743
		Silent	19%				
	Logging	Ramp-up	9%	0.904311	122	1	0.342
		Silent	12%				
	Surfacing	Ramp-up	10%	0.127322	122	1	0.721
		Silent	9%				
	Swimming	Ramp-up	21%	0.018671	122	1	0.891
		Silent	21%				

3.6 Analyses of directional observations relative to CA Source status

3.6.1 Direction of travel

Tables in this section detail all species categories that were analyzed in this study. For illustrative purposes, the 'All Cetaceans' group was used as an example in figures for all seismic source activities.

The 'Beaked whales' species group overall had limited sample sizes and observations for all regions. Gulf of Mexico and Combined regions were the only sections in which 'Beaked whales' were recorded during more than one CA source status, and therefore this species group was only statistically analyzed in these regions.

Gulf of Mexico

Direction of travel categorization was limited due to a lack of consistent recordings for sample sizes for species groups and for direction of travel observation types. Initially, species direction of travel types was combined and assessed as to whether there was a difference in response, rather than a specific type of response. It was possible to establish that there were statistically significant differences in direction of travel between times when the seismic source was active compared with when it was silent. Baleen whales and beaked whales were excluded from analyses with mitigation and ramp-up operational status due to low sample size ($N \leq 30$). Where multiple directional types were recorded for a single observation, the observation was included in the analysis for each of the recorded direction of travel.

Table 3-11 summarizes the chi-squared direction of travel analysis. All operational status had significant statistical relationships ($p<0.05$) for all species during mitigation firing when compared with silent status except for turtles. However, the relationships identified when comparing mitigation with silence were not significant for the 'Turtle' species group.

When comparing full power source operations with silence, there were statistically significant differences between the travel directions observed for all species groups (Table 3-11). This can be seen in directions such as, 'parallel to ship in opposite direction' and 'parallel to ship in same direction' which were more prevalent when the seismic source was silent for the 'All Cetaceans' group (Figure 3-29). Conversely, 'away from ship' and 'crossing path of ship' were found to be more prevalent during full power for 'All Cetaceans'.

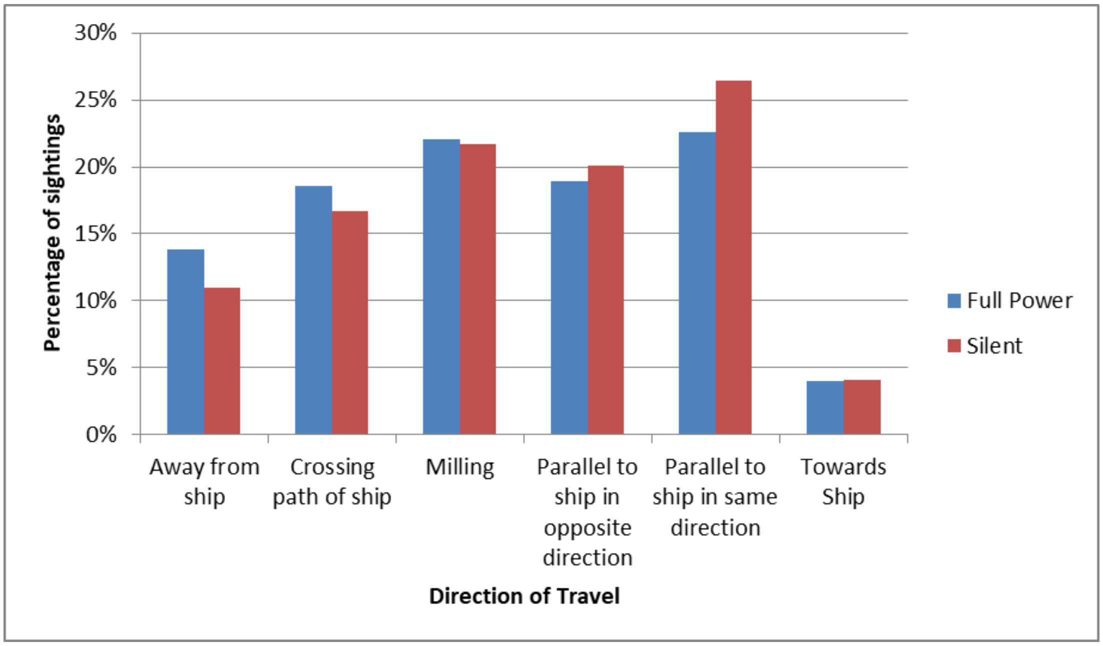

Figure 3-28: Comparative directional travel responses of the "All Cetaceans" group during full power and silence

Comparing the direction of travel between silent and mitigation for 'All Cetaceans' (Figure 3-12), 'away from ship', 'crossing path of ship' and 'towards ship' were more common directional types during mitigation whereas 'milling', 'parallel to ship in opposite direction' and 'parallel to ship in same direction' were more frequently displayed during silent periods.

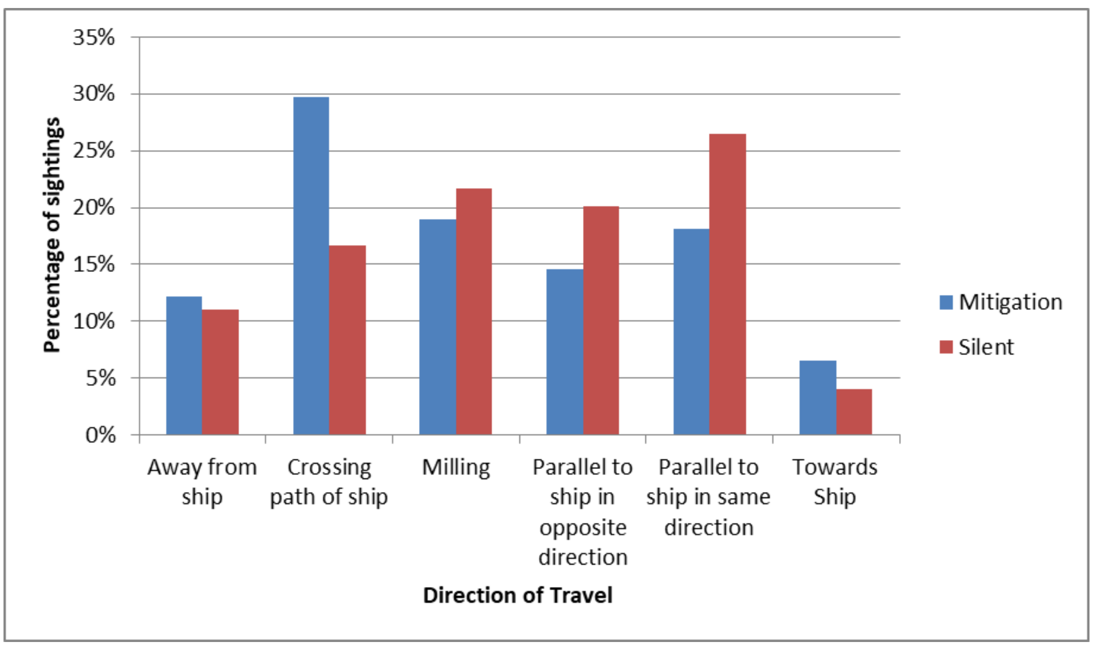

Figure 3-29: Comparative directional travel responses of the "All Cetaceans" group during mitigation and silence

When comparing the direction of travel between silent and ramp-up for 'All Cetaceans' (Figure 3-30), 'crossing path of ship', 'parallel to ship in opposite direction' and 'towards ship' were more commonly observed directional types during ramp-up whereas 'parallel to ship in same direction' was more frequently observed during silent periods. 'Milling' and 'away from ship' were observed at a similar percentage frequency between the two operational modes.

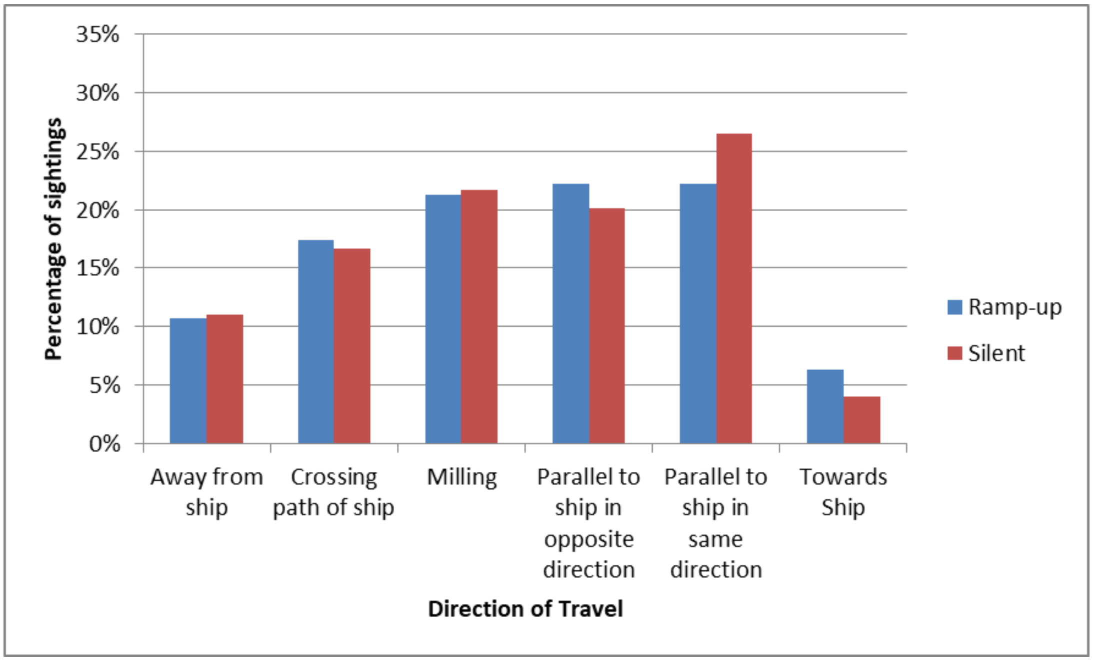

Figure 3-30: Comparative directional travel responses of the "All Cetaceans" group during ramp-up and silence

	Species Group	CA Source	Percentage: Away from ship	Crossing path of ship	Milling	Parallel to ship in opposite direction	Parallel to ship in same direction	Towards Ship	2	n	d.f.	p
Full Power vs. Silent	All Cetaceans	Full Power	14%	19%	22%	19%	23%	4%	227.278	14467	5	0.000
		Silent	11%	17%	22%	20%	26%	4%				
	Baleen Whales	Full Power	26%	12%	0%	39%	23%	0%	87.3333	66	5	0.000
		Silent	16%	35%	10%	10%	19%	10%				
	Delphinids	Full Power	7%	21%	17%	20%	30%	4%	391.116	9425	5	0.000
		Silent	6%	16%	14%	22%	38%	4%				
	Sperm Whales	Full Power	29%	23%	18%	22%	4%	4%	300.738	2573	5	0.000
		Silent	17%	27%	21%	24%	6%	5%				
	Turtles	Full Power	22%	4%	46%	10%	14%	4%	60.7534	2276	5	0.000
		Silent	21%	6%	49%	10%	10%	4%				
	Beaked Whales	Full Power	45%	17%	0%	38%	0%	0%	148.114	29	4	0.000
		Silent	4%	45%	0%	16%	8%	27%				
Mitigation vs. Silent	All Cetaceans	Mitigation	12%	30%	19%	15%	18%	7%	109.368	674	5	0.000
		Silent	11%	17%	22%	20%	26%	4%				
	Delphinids	Mitigation	8%	32%	18%	12%	24%	6%	133.33	480	5	0.000
		Silent	6%	16%	14%	22%	38%	4%				
	Sperm Whales	Mitigation	25%	28%	14%	22%	3%	8%	14.9661	152	5	0.011
		Silent	17%	27%	21%	24%	6%	5%				
	Turtles	Mitigation	22%	5%	51%	16%	0%	5%	5.21774	37	5	n.s.
		Silent	21%	6%	48%	10%	10%	4%				
Ramp-up vs. Silent	All Cetaceans	Ramp-up	11%	17%	21%	22%	22%	6%	11.4561	523	5	0.043
		Silent	11%	17%	22%	20%	26%	4%				
	Delphinids	Ramp-up	7%	19%	17%	20%	31%	5%	11.5851	332	5	0.041
		Silent	6%	16%	14%	22%	38%	4%				
	Sperm Whales	Ramp-up	19%	20%	21%	28%	0%	12%	19.3586	109	5	0.002
		Silent	17%	27%	21%	24%	6%	5%				
	Turtles	Ramp-up	12%	8%	41%	16%	20%	3%	14.2334	75	5	0.014
		Silent	21%	6%	48%	10%	10%	4%				

Table 3-23: Chi-squared results for Grouped Direction of travel by Seismic Source Status for the Gulf of Mexico (Greyed areas not included within analysis due to low sample size; n.s. = not significant)

West Africa

Table 3-16 above shows a summary of the chi-squared direction of travel analysis. Soft-start versus silent and reduced power versus silent mode did not have significant statistical relationships with the direction of travel demonstrated, with sample sizes insufficient for inclusion of most species categories apart from 'Delphinids and 'All Cetaceans' ($p<0.05$). However, the relationships identified when comparing full power with silent were significant ($P<0.05$) for 'Baleen Whales' as well as 'All Cetaceans' and 'Delphinids' species categories. Turtles were excluded from this analysis due to insufficient sample size.

For all species groups excluding 'Turtles' and 'Sperm Whales', when comparing full power source operations with silence, there were statistically significant differences between the responses of those groups. This can be seen in directional types such as 'away from ship', 'crossing path of ship' and 'parallel to ship opposite direction', which were more prevalent when the seismic source was at full power for 'All Cetaceans' (Figure 3-14). 'Milling' and 'towards ship' were more prevalent during source silence.

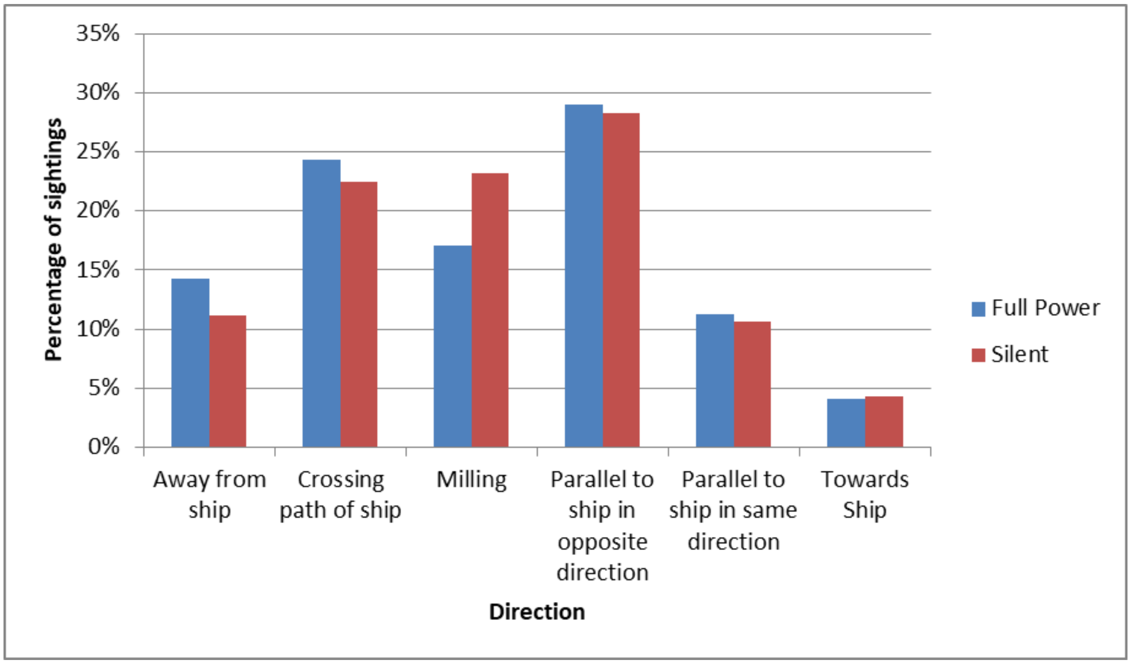

Figure 3-31: Comparative directional travel responses of the "All Cetaceans" group during full power and silence

For reduced power comparison with silent periods, there were significant differences between the observed direction of travel for the 'All Cetaceans' group, seen in directional types such as 'milling' and 'parallel to ship opposite direction' (Figure 3-32), where they were more prevalent during reduced power. 'Crossing path of ship', 'parallel to ship same direction' and 'towards ship' were more prevalent during silence. Similarly, for soft-start comparison with silence there were significant differences between the observed directions of travel. During soft-start for 'All Cetaceans', 'away from ship', 'crossing path of ship' and 'parallel to ship opposite direction' were more prevalent (Figure 3-33). At times of airgun silence, 'milling', 'parallel to ship same direction' and 'towards ship' were more common.

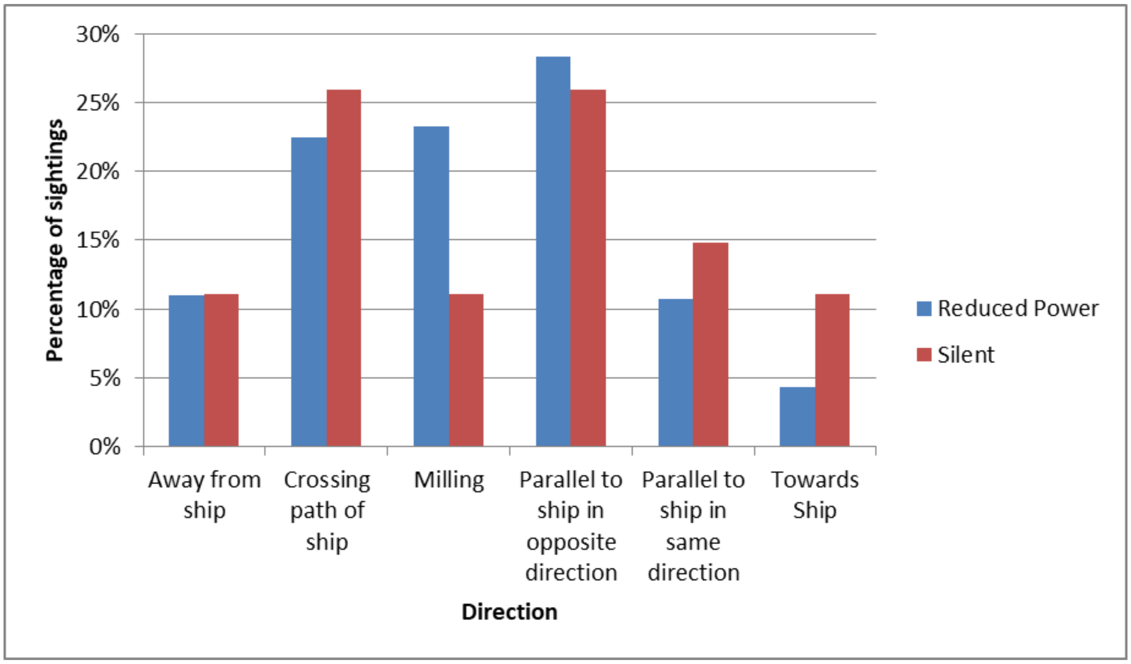

Figure 3-32: Comparative directional travel responses of the “All Cetaceans” group during reduced power and silence

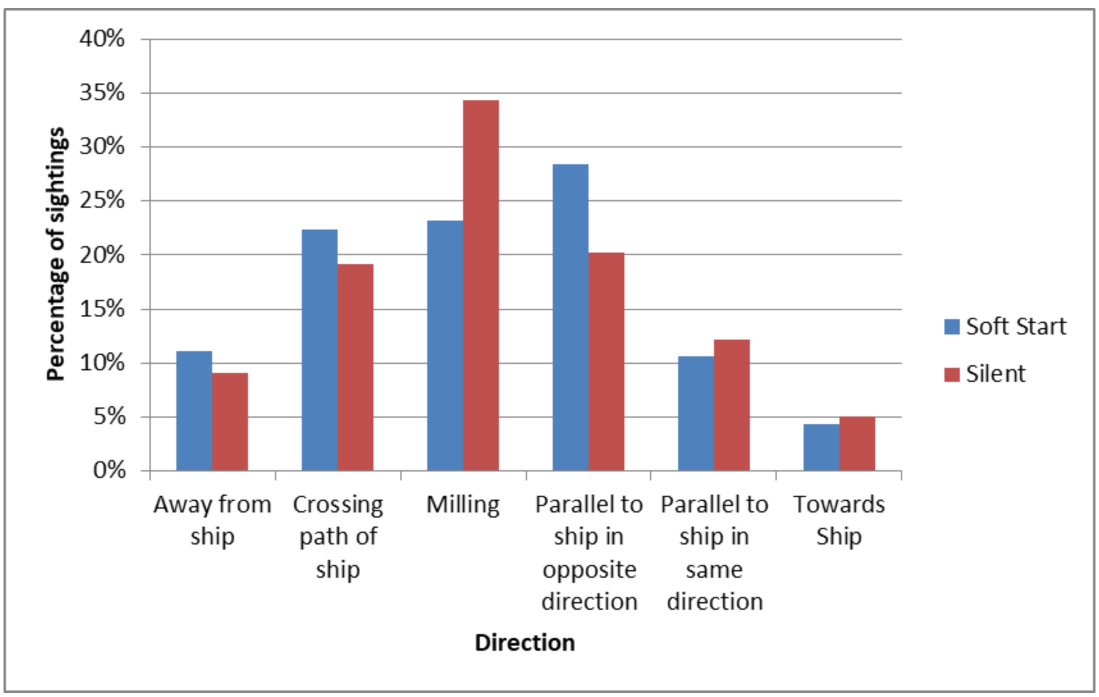

Figure 3-33: Comparative directional travel responses of the “All Cetaceans” group during soft-start and silence

Table 3-24: Chi-squared results for Grouped Direction of travel by seismic source status for the West Africa (Greyed areas not included within analysis due to low sample size)

			Percentage									
	Species Group	CA Source	Away from ship	Crossing path of ship	Milling	Parallel to ship in opposite direction	Parallel to ship in same direction	Towards Ship	2	n	d.f.	p
Full Power vs. Silent	All Cetaceans	Full Power	14%	24%	17%	29%	11%	4%	23.6034	869	5	0.000
		Silent	11%	22%	23%	28%	11%	4%				
	Baleen Whales	Full Power	26%	12%	0%	39%	23%	0%	87.3333	66	5	0.000
		Silent	16%	35%	10%	10%	19%	10%				
	Delphinids	Full Power	14%	11%	4%	26%	27%	19%	20.3967	558	5	0.001
		Silent	10%	12%	4%	24%	24%	25%				
	Sperm Whales	Full Power	18%	26%	0%	21%	21%	13%	7.11231	38	4	n.s.
		Silent	14%	14%	0%	24%	35%	13%				
	Turtles	Full Power	19%	0%	0%	19%	63%	0%	2.01389	16	2	n.s.
		Silent	30%	0%	0%	25%	45%	0%				
Soft Start vs. Silent	All Cetaceans	Soft Start	11%	22%	23%	28%	11%	4%	112.754	1379	5	0.000
		Silent	9%	19%	34%	20%	12%	5%				
	Delphinids	Soft Start	7%	8%	7%	23%	17%	38%	9.37927	71	5	n.s.
		Silent	10%	13%	4%	24%	24%	25%				
Reduced Power vs. Silent	All Cetaceans	Reduced Power	11%	22%	23%	28%	11%	4%	265.69	1375	5	0.000
		Silent	11%	26%	11%	26%	15%	11%				
	Delphinids	Reduced Power	11%	11%	11%	26%	26%	16%	2.71363	19	5	n.s.
		Silent	10%	13%	4%	25%	24%	25%				

Australia

Direction of travel was not recorded for this region and therefore no statistical analysis could be performed.

3.7 Comparison of results between regions

3.7.1 Sightings (minimum distance of approach, sightings duration, sightings rate)

A number of differences were identified between international locations, Gulf of Mexico (GoM), West Africa and Australia. Data availability for Australia was very limited with data only provided for firing CA source status for sighting rate. Mitigation firing was only recorded for GoM and therefore comparisons could not be made with the other regions.

During full power source status when compared with silence, both GoM and West Africa had sufficient data, of which ‘Sperm Whales’ showed the greatest differences in median distances for GoM and ‘Delphinids’ for West Africa ($p<0.05$). The results for the combined (global) regions analysis (Appendix A) suggest that the data more closely resembled the results for the GoM region. For ramp-up or soft start status when compared against silence, both GoM and West Africa demonstrated significant differences in distance of approach for all cetacean’s species group. GoM identified sperm whales as having the greatest mean distance difference from seismic source and delphinids had the greatest mean distance difference from the seismic source in West Africa. Overall, the combined analysis for ramp-up or soft-start closely has significant differences for all species compared to the results for the GoM and West Africa region. This indicates that the larger median distances existed within the ‘other regions’ data set and potentially also within the limited samples for the West Africa region.

The duration of sightings during full power seismic source operation when compared with silence was greatest for ‘Sperm Whales’ and ‘Delphinids for GoM, and ‘Baleen Whales’ and ‘Delphinids’ for West Africa ($p<0.05$). For GoM and West Africa, ramp-up or soft start when compared against silence showed different trends. GoM recorded ‘All Cetaceans’ and ‘Delphinids’ as having significant sighting durations, whereas in West Africa, had no significant differences but higher duration medians overall. The combined regions analysis suggested that for the ramp-up or soft start airgun status, the incorporation of data from ‘other regions’ and West Africa cause an increase in the median sighting duration for each category except for ‘Turtles’. ‘Baleen Whales’ had the highest median durations for all airgun activities ($p<0.05$).

In GoM, all species categories showed significant differences, the greatest differences for sighting rate was for ‘Delphinids’ during times of firing compared to silence ($p<0.05$). West Africa had greater differences than for GoM and Australia but no significant differences. In all regions, ‘Delphinids’ demonstrated the largest change in sightings rate of all the cetacean categories and when airgun was silent the medians were higher overall. The combined regions analysis suggested that for the ‘ramp-up’ or ‘soft start’ airgun status, the results are similar to the GoM results. All species categories have significant differences between firing and silent.

3.7.2 Behaviour observations

The GoM region had a wide range of data covering ‘Delphinids’, ‘Sperm Whales’, ‘Baleen Whales’, ‘Beaked Whales’, and ‘Turtles’. West Africa had sufficient data to analyze the behaviour of delphinids, baleen whales and turtles. However, the Australia region had limited data only available for ‘Delphinids’. Data were not available for all operation categories, so analysis was carried out on full power and ramp-up versus silence only.

During full power when compared to silence in all regions across the CA source status, the most common behaviours were swimming, diving, bow riding and blowing for the ‘All Cetaceans’ group with the exception of West Africa which also had significant records of ‘breaching’ behaviour. The grouped behaviours in the other categories were recorded in similar proportions between the Gulf of Mexico and West Africa region. The behaviours of the "All Cetaceans" group in the Australia region were much more variable.

Individual behaviours of delphinids in all regions during full power operation compared to silence had the most significant observed differences in behaviours ($p<0.05$). Gulf of Mexico had the most behavioural categories demonstrating significant differences during airgun activity, with 'Delphinid' behaviours most significantly different during airgun activity being swimming below the surface, spy hopping, bow riding, feeding, surfacing, and swimming. In West Africa, only bow riding and logging showed a significant difference for 'Delphinids'. In Australia, the behaviours bow riding, breaching, fast travel, feeding, porpoising, and swimming were the most significantly different. Generally, across all regions, the other CA source power modes showed little to no significant relationships when compared to silence. Apart from Gulf of Mexico ('Sperm Whale': blowing; and 'Turtles': swimming below surface, blowing, swimming, $p<0.05$) and West Africa (baleen whale: blowing and swimming), all other species categories showed no significant differences for CA source modes versus silence.

3.7.3 Direction of travel

The Gulf of Mexico region had the most expansive range of data covering 'Delphinids', 'Sperm Whales', 'Baleen Whales', 'Beaked Whales', and 'Turtles' for all operational activity modes. 'Beaked Whales' were only observed during more than one CA source activity mode for Gulf of Mexico and subsequently the Combined Regions with the inclusion of Gulf of Mexico and other regions. West Africa had limited sample sizes and species groups for all CA source modes apart from full power. Australia had no recorded observations for direction of travel and therefore analysis couldn't be carried out. There was a significant relationship between direction of travel when full power was compared to silent mode for all regions with the exception of 'Sperm Whales' and 'Turtles' in the West Africa region. There was a significant relationship between direction of travel when comparing mitigation source mode to silent mode for all species in the Gulf of Mexico and combined regions analysis with the exception of 'Turtles' in the Gulf of Mexico region. Soft-start compared with silent operation demonstrated significant direction of travel relationships for all cetaceans in the West Africa region. When comparing Ramp-up with silent modes there were found to be significant relationships for all species groups in the Gulf of Mexico region, and for 'All Cetaceans' in the West Africa region. For the combined regions analysis, comparing ramp-up with silence demonstrated significant relationships with direction of travel in all species groups except for 'Turtles'.

During full power when compared to silence in all regions across the CA source status for the 'All Cetaceans' group, the most common direction of travel was 'parallel to ship in opposite direction' for West Africa and 'parallel to ship same direction' for Gulf of Mexico, with 'Combined Regions' including 'towards ship' too. Data were not available for all the operation categories across each region, so comparisons were limited to full power versus silence only.

3.8 Mitigation Measures Taken

3.8.1 Gulf of Mexico

A total of 295 shutdowns occurred in the GOM from 2009-2017. These shutdowns resulted in an estimated downtime of 338 hours and 33 minutes. The longest duration downtime was due to a shutdown that was estimated to be 15 hours and 4 minutes. Acoustic detections caused 138 shutdowns while visual detections caused 159 shutdowns. One manatee, 1 unidentifiable whale, 2 pygmy sperms whales, 4 beaked whales, and 204 sperm whales in the exclusion zone resulted in shutdowns. There were 85 shutdowns for dolphins. Some of the shutdowns for dolphins were mandatory under certain permits in state waters or were mandatory due to internal operator policies. For example, in 2014, an Operator required their operations to shutdown for dolphins even though it was not a requirement in the survey area. Additionally, in some instances, communication errors resulted in shutdowns for dolphins. For example, operations were shutdown for pilot whales which are classified as dolphins per the NTL but because the term "whale" was mentioned, it caused confusion. There were also voluntary shutdowns for dolphins because operations were not actively collecting seismic data while the CA sources were firing such as during a line turn, and the crew opted to go silent due to the presence of dolphins.

There were 798 delays caused by mitigation actions for protected species. These delays resulted in an estimated downtime of 413 hours and 39 minutes. The longest estimated downtime due to a delay was 14 hours and 13 minutes. Acoustic detections resulted in 447 delays while visual detections resulted in 351 delays There were 39 whales, 67 sea turtles, and 692 dolphin detections that resulted in delays to operations. Of the 692 dolphins that caused delays, 113 of them were reported to have approached the vessel during their direction of travel.

There were 629 voluntary shot pauses for sea turtles as many operators in this region have adopted this mitigation measure. The total downtime from these voluntary pauses was estimated to be 27 hours and 22 minutes. Voluntary shot pauses were typically around 3 minutes. There were three instances where a voluntary shot paused resulted more than 20 minutes of downtime. These instances were due to a pause followed by a delay for dolphins, a pause followed by a 20-minute ramp-up, and a pause due to a miscommunication on gun operations.

3.8.2 West Africa

There are no formal regulatory requirements for seismic operations in relation to marine mammals or sea turtles in West Africa, but it was common practice for this region to adopt JNCC guidelines which requires delays for marine mammals but does not require shutdowns.

West Africa had 69 delays caused by leatherback sea turtles (n=4), Dolphins, (n=40), one beaked whale, one sperm whale and 23 baleen whales. Most of the delays were from acoustic detections (n=40).

A total of 58 shutdowns were recorded due to 27 baleen whales, 26 dolphins, one sperm whale, and four shutdowns for sea turtles. Of those shutdowns, 40 were correlated with PAM detections, 16 visual detections and 2 concurrent PAM and visual detections.

There were 3 shot pauses for sea turtles lasting 8 to 10 shots. In scanning the data, there was one detection recorded of a sea turtle caught in fishing nets. A work boat was deployed, and the sea turtle was freed. Although this was not a mitigation action, it does demonstrate the altruistic actions taken by industry personnel. Several other reports in this region, although not included in the dataset for this report, have shown instances where workboats have been deployed to help sea turtles caught in fishing gear.

3.8.3 Australia

The Australia region recorded 28 delays, 117 shutdowns, and 19 power-downs, all from visual detections. The estimated production downtime due to mitigation actions was not included in the dataset provided. The delays were caused by 2 sperm whales and 26 baleen whales/unidentified whales/cetaceans. Sea turtles (n=11), dolphins, (n=21), baleen whales (n=75) and sperm whales (n=10) were observed in the 500m exclusion zone and resulted in 117 shutdowns. Sperm whales (n=4), unidentifiable whales/cetaceans (n=4), and baleen whales (n=11) resulted in power-reductions of the acoustic source. No turtle pauses were recorded in our dataset for Australia.

4 DISCUSSION

4.1 Data Management

4.1.1 Data collection

The data conversion and QC for this study was completed with a large amount of manual user intervention to sort out the recording errors. Data utility would be greatly improved by greater consistency and quality of data during the recording and initial reporting stages. To facilitate better analysis in the future, PSO data collection training should be more thorough or repeated, additional QC procedures should be put in place, and industry and PSO providers should work toward a standard format that is compatible for most regions and can be more easily exchanged and loaded for analysis.

For the most commonly-used data formats, the provision of data viewing capabilities needs to be improved such as providing a dashboard to check for unusual data or providing nearby calculations with conditional formatting to highlight potential errors, so that those persons submitting data for post-survey archiving can be sure that the data they submit is correctly recorded.

4.1.2 Data exchange

To facilitate the exchange and archiving of recorded marine mammal data, a definition of a common exchange format should be described and promoted. Industry would not be forced to use a single database structure, but rather it would define a method of exporting and importing the data recorded, regardless of the software, database or spreadsheet used to record the data in the field. The use of a single, fully defined format allows data to be properly checked when submitted for post-survey archiving and to be freely exchanged between post-survey analysis systems.

4.1.3 Data storage and access

In some cases, PSO reports and the associated PSO data were difficult to locate within certain companies. A global database of PSO data has been sought (Barton et al., 2008) but it would be beneficial to also keep a report repository linked to the associated data. Oil and Gas companies could submit the reports and data to a centralized database and explicitly state if the data is open access or restricted. Government and industry could both examine ways to make PSO data easier to access and available to researchers.

4.2 Potential effects of seismic exploration upon marine mammals

4.2.1 Source activity

Average closest distance of approach of animals to airguns

In the GOM region, the data indicates that cetaceans are observed farther away when the source is active than when it is silent. At full power the All Cetaceans group, Delphinids, and Sperm whales were observed farther away from the source at statistically significant distances: . During mitigation firing the All Cetaceans group, Delphinid group and Sperm whale groups were farther away and at ramp-up, All Cetacean and Dolphins were farther away. The results are consistent with Barkaszi et al. (2012) which found all species groups to occur at greater distances from the seismic source during full power with similar patterns during reduced power and ramp-up. The analysis of the West African region revealed similar trends with the All Cetaceans group, Delphinids and Baleen Whales being observed farther away during full power than silent. Similar results occurred for soft-start.

Overall the broad results were consistent with the previous PSO data studies by Barkaszi et al. (2012), Compton (2013), and Stone (2015) with cetaceans generally being detected at further distances when the large array acoustic source is active than when it is silent which suggests a lateral spatial avoidance.

Compton (2013) and Stone (2015) also examined if animals moved toward or away from a vessel during firing and found that cetaceans generally moved away from the vessel during active firing. Our results suggested that animals are generally traveling parallel to a vessel. The directionality can have potential inaccuracies depending on the timing and angle of the detection. For example, a vessel may approach an animal traveling in a direct line and if the animal is detected early it could be perceived as approaching the vessel, but the animal is not detected until later then it could be perceived as moving away from the vessel.

It is important to note that the results are suggestive of a spatial avoidance, but the degree of avoidance is not known as PSO observations only provide data during operations as baseline and follow-up studies are not typically included and are not practical with the current data collection. However, there is a need to determine if avoidance has any long-term implications or impacts to population levels or if it is a harmless disturbance (NRC, 2005). For example, Thompson (2013) found that harbour porpoises demonstrated a spatial avoidance to a commercial seismic survey but returned to the area shortly after the survey. It should also be noted that the data is of animals observed, which may not be equal to the animals present, as the size and surface behaviour of animals can impact their detectability.

Average sighting duration

In general, sighting durations for cetaceans were shorter during active operations than when the CA sources were silent, except for Baleen Whales which were observed longer during full power in West Africa and the All Cetaceans group which was observed longer during mitigation firing in the Gulf of Mexico. It is possible that due to animals being at greater distances during operations (as described above) that they would be observed for a shorter duration due to the distance. For example, an animal sighted father away could be observed for less time due to the observer losing sight of the animal where as an animal detected nearby might be observed longer due to the proximity.

While the average sighting duration is a straightforward metric to record, precaution should be taken as the current forms do not allow easy identification of anomalies from a large dataset. For example, some sightings could have been shortened due to darkness or inclement weather. Furthermore, the platform type, vessel speed, and the length of the survey lines are other factors that can cause increased sighting durations. For example, animal sighting durations may be observed longer on a stationary platform or may be observed for shorter periods if the animal was detected during transit when the vessel would travel at a faster speed.

Sightings frequency

The results generally showed that animals are detected more frequently during periods of silence. The sighting rates were lowest during full power compared to silence . Our results are similar to Stone 2015 where species were generally observed more often during periods of silence. Overall, the results indicated that there were fewer sightings when CA sources were active. This does not necessarily indicate that animals were present at lower rates. Some studies that have shown that seismic activities impacted diving behaviours making whales less visible at the surface (Robertson, 2014) thus it is possible that more whales were present during active operations but were undetected due to surface behaviours.

The analysis of sighting rate did not examine the effect of using supplementary detection methods (camera systems, advanced optical systems such as big eyes) which may impact sighting rates by PSOs. Furthermore, under current data practices, the effort recorded is for periods of watch and does not consider the number of PSOs conducting the watch (i.e., if two PSOs conducted a watch for two hours it would be recorded as two hours of effort and if one PSO conducted a watch for two hours it would also be recorded as two hours of effort). In some regions, it is not a requirement to watch during periods of downtime or silence except for pre-watch periods. Therefore, sometimes one PSO could have conducted a voluntary watch during periods of silence whereas typical watches during active operations require more than one PSO on watch.

4.2.2 Behaviour

All behaviour results should be reviewed with caution due to the subjective nature of scoring behaviour to a given category and the inconsistency within and between observers in assigning behaviours to a given category. And most PSO training programs include only a very brief component of behavior identification, if the topic is covered at all. In addition, even when a statistical difference is observed, there is difficulty in determining whether the behaviour change was influenced by the acoustic source, the vessel, or some other unobserved or unreported factor. Another caveat of the behavioural analysis in this study, is that the data were not collected blind. With PSOs being on the same ship as the CA source, they were aware of the operational mode of the CA source which could influence their description of behaviours. Behavioural analyses using PSO data are also complicated because there is no background data to compare. There have been suggestions that behavioural data be eliminated from PSO forms (Childerhouse et al., 2016) as current PSO practices and variations of personnel capabilities and training make it unreliable for scientific analysis. However, using CA source silence or inactivity as a control, large sample sizes, statistical tests for significance, and comparisons to other PSO data analyses may enable PSO-reported behavioural data to indicate trends and impacts to some degree. Furthermore, recording behaviour may provide insight on rare instances of animals behaving in a unique way that has little or no documentation.

In each of the three regions there were statistically significant differences in behaviour between times when the seismic source was at full power compared to when it was silent for some species groups. The statistically significant differences in behaviour observations in the delphinid group suggested trend towards more surface-active behaviours when the full volume source was active and lower incidences of bow-riding. Baleen whales exhibited diving and fast traveling behaviors more frequently when the source was on full volume as opposed to all other source activity levels..

Generally, across all regions, the other CA source operation levels showed little to no significant relationships when compared to silence, which could be related to the smaller sound source output levels present in the other operation states (mitigation source, ramp-up).

4.3 Mitigation Measures

Shutdowns, delays, reducing power, and turtle pauses can provide some indication of the budgetary impacts and risks that Seismic Operators may incur from implementing mitigation measures, but they do not provide an accurate assessment of the true downtime caused by marine species. The estimated downtime provided on standard forms is currently unreliable due to the variety of data entry with several fields left blank (i.e., unable to determine if a blank entry indicated that the time was zero, unknown, or not applicable). Furthermore, many data forms indicated the downtime as a unit of time instead of a unit of distance and without the vessel speed, it is difficult to have an accurate conversion. This could be due to the ease of PSOs providing a time estimate over a distance estimate due to the known time stamps of seismic operations. Furthermore, a potentially substantial amount of effort could be required by seismic companies to fill in the lost survey data after the initial survey tracks are complete (Gisiner, 2016). Current analyses of downtime using PSO data excludes the amount of infill required due to mitigation.

The effectiveness of voluntary turtle pauses has not been investigated (Nelms et al., 2016) but it is thought that pausing for sea turtles could possibly prevent the source from being at full volume as the sound source passes by. This procedure requires PSOs to time and call for the pause correctly so that the CA sources are inactive during the time when the sea turtle is passing closest to the source. Nelms et al. (2016) advised against the use of turtle pauses due to difficulty required to properly implement a pause and due to the possibility of CA sources being restarted at full volume while the sea turtle is nearby. However, the procedure has potential to benefit the sea turtle if the pause is calculated correctly and effective communication procedures are implemented to allow the correct timing of the pause. The voluntary turtle pauses in the GOM region demonstrated good intentions by operators; however, further studies should examine the feasibility of consistently and accurately implementing these pauses and assess the effectiveness and impacts of this procedure. It would also be useful to understand the potential physical impacts that could result from close range exposure to an active CA source.

In the GOM and West African regions, acoustic detections were responsible for more or similar numbers of mitigation actions when compared to visual detections. This could be due PAM operators calling for mitigation upon detections due to the difficulties associated with localizing vocalizing species.

This report indicated that several companies are voluntarily conducting mitigation measures such as pausing operations for sea turtles, implementing shutdowns for species in West Africa, and utilizing workboats to untangle sea turtles from fishing gear. There could be a variety of reasons for companies to implement voluntary mitigation measures such as corporate policies, public relations, or a misunderstanding of the mitigation requirements by the operator. It would be helpful to record the use of voluntary mitigation measures in the data forms in order to determine if they should be adopted as a best practice approach or to show a track record of common practices with in the various regions.

5 RECOMMENDATIONS

5.1 Data Collection Recommendations

5.1.1 Standardization of Terms

There are several areas of reporting that would benefit from having standardized terminology. A list of official terminology for recording parameters should be built, maintained, and published so that regardless of the system used to record the data, there would be consistency in terminology. Notable parameters that need increased standardization include:

- Species nomenclature - It is recommended that a list of official species names (presumably with associated Binomial name and aliases where required) be created specifically for PSO reporting. These lists can be created from lists that are already available, but it should be widely known which list will be used as the standard. For example, the Committee on Taxonomy from the Society of Marine Mammalogy (https://www.marinemammalscience.org/species-information/list-marine-mammal-species-subspecies/) keeps an updated list or the Census of Marine Life from Global Biodiversity Information Facility (https://www.gbif.org/darwin-core) keeps a list of species. Additionally, the species list should contain a standard broad level classification as well. For example, the U.S. and Australian regulations have different definitions for what species are considered a whale and an official list could help efforts toward unifying PSO data collected as well as provide consistent categories for future analyses of PSO data.
- Behaviour - In compiling a global dataset, there was a lack of consistent recording of behaviours. Behaviour events and states need to be clearly defined and categorized for PSO reporting.
- Source activity - It is recommended that a list of consistent nomenclature for source activity levels be developed and updated as necessary for PSO data collection to enable more effective comparison of source activity levels across regions without the need for assumptions and interpretations during analysis to group listed activity levels into categories.

5.1.2 Additional data to help future analysis of PSO data

Other areas of data collection that could benefit future analyses of PSO data include:

- Details of Mitigation Measures- It would be beneficial if all reporting forms or applications indicated the regulations (including year and version) any specific mitigation measures conducted on the project in order assess the effectiveness of the measures on a global scale and to provide a record of what has been conducted in areas with no formal requirements. Including the mitigation measures could also provide insight into how often the suggested IAGC data forms and mitigation measures are being used and if any modifications to those standards have been commonly practiced in an area.
- Infill time or distance due to mitigation for marine animals-In order to better assess the operational costs of mitigation for marine mammals, the infill related to protected species should be recorded and potentially assigned to a detection.
- Survey track line-The seismic survey track line is a visual that can be coupled with PSO detection and effort data to check for correct geographical entry. The ship track would need to be provided to the PSO by the seismic operator in a Geographical Information System (GIS) format.
- Initial and final behaviour-Studies show that changes in behaviour may be dependent on the behaviour they were already engaged in (Robertson, 2014; Southall, 2017); therefore, if methods of collecting behavioural data are to be used to provide further insight into the context of the behaviours, the current JNCC forms could consider altering the forms so that the initial behaviour observed is more apparent and subsequent behaviours can be assessed for a degree of change.

The New Zealand Excel-based reporting forms provide an example for gathering information on the initial and final behaviours.

- CA source amplitude during detections-It would be beneficial if detections included the source amplitude at the time of detection, as some detections occurred during testing or reduced power which could have a wide range of amplitude exposures.
- Duplicate detection information- As multi-vessel surveys become a standard practice (Barkaszi, 2012), PSOs should be encouraged to communicate across the fleet about detections and to record if the detection was recorded by another PSO on a different vessel. Having a standardized field of entry for duplicates can help reduce assumptions of duplicates based on time stamps, coordinates, and species identification made during post analysis.

5.1.3 Improving behavioural data collection

Dedicated behavioural studies for assessing the impacts of anthropogenic sound on marine life should be curated by experts (Compton, 2013; DOC (Ed), 2016; Gordon et al., 2004); however, better coordination between academics and industry could facilitate research goals by symbiotically utilizing PSOs. PSOs provide an opportunity to routinely collect large volumes of marine fauna data during real field conditions under seismic operations, but PSO data has been underutilized due to the lack of consistent methods, data collection, quality of data, as well as the lack of dissemination and sharing of collected data. Further coordination with academics could help develop standardized methods for distribution and behavioural assessments while maintaining mitigation and compliance as a priority. PSOs can provide high-quality data when the data are collected in a uniform method via trained and experienced observers (Gordon et al., 2004), which could potentially be used to fill some research needs of professionals conducting complex behavioural and impact studies. However, it is important to note that ultimately the role of the PSO is to monitor, implement mitigation and report and that other additional data collection potential would need to be coordinated such that it did not negatively impact the ability of the PSO to fulfill these primary duties.

It is evident that current data collection practices for behavioural fields lack consistency within and across regions and may lack scientific validity. However, despite behaviour being largely subjective and collected on an ancillary basis, it can provide an indication if there was disturbance and is worth examining on a large scale to assess impacts. Therefore, to make this area of data collection more useful to an international analysis, behaviours need to be clearly defined and categorized, the methods for objectively recording and quantifying behaviours need to be standardized and tailored to PSOs, and there needs to be more focus on training regarding identifying and recording behaviours.

5.2 Improved training

There is a need to improve and standardize training of all PSOs or those functioning as a PSO (von Luders and Gill 2008; Parente and Araújo 2011). In some cases, a PSO may not be available and a crew member may need to undertake some of their duties. Therefore, it is encouraged that some crew members undergo, at a minimum, a basic level of PSO training. Adequate training which includes training on data collection and reporting is required to help the reliability of the data. Along with more intensive training, awareness and collaboration of standardized terminology and procedures needs to be advocated and promoted through industry, organizations, and regulators.

PSO training programs may consider emulating the training conducted for dedicated behavioural studies to help improve their behavioural data. During the BRAHSS (Behavioural Response of Australian Humpback whales to Seismic Surveys) project, Kavanagh et al. (2016) examined implications of experience and native language of observers on behavioural data collection. Kavanagh et al. stated that adequate training of observers is necessary to bring everyone to the same level of competency for the sake of data collection. The study found no significant differences in data quality from experienced vs. inexperienced and native vs. non-native speakers, and suggested it was due to appropriate training. The reliability and validity training employed in the Kavanagh et al. study had participants watch videos of animal behaviours and record the behaviours observed. Their results were compared to a baseline that was determined by an expert who viewed the same videos and recorded the behaviours observed. They recommended regular training for reliability and validity of behavioural data collection and suggested further studies to develop a broader ethogram that could be used to further improve reliability. Current PSO practices could benefit from a list of clearly defined cetacean behaviours and a standardized data collection method that allows for quantification, both of which would be included in training that aims to increase the reliability and validity of data collection.

PSO training programs may also consider techniques to test and make PSOs aware of their biases during data collection. For example, marine mammal observers on the MOPs (Monitoring of Porpoise Stocks) and STAR (Stenella Abundance Research) cruises conducted by NOAA for cetacean abundance research utilized a program called GroupSize to help train observers on estimating group sizes (Kinzey, Olson, & Gerrodette, 2000). Estimating group sizes of cetaceans is subject to bias due to a variety of factors such as the difficulty in estimating large groups, the groups or individuals are in constant motion, and the propensity for cetaceans to go underwater where they may not be visible to an observer (Gerrodette et al. 2002). The GroupSize program was used as a tool for training but also served to generate a bias for each observer so that data analysis could be run against the observer sightings and adjusted with the bias. Current abundance estimation surveys have other tools at their disposal such as aerial surveys to help calibrate for group size (Gerrodette et al., 2002) and no longer use the GroupSize program, however, programs similar to GroupSize could be useful to PSOs whom are solely responsible for data collection of the marine fauna encountered during a seismic survey.

5.3 Considerations for automations of PSO data collection and management

With mitigation as a primary duty and a need for increased quality and detail in data collection, it may be worth looking into automations to make the current standard PSO forms (JNCC forms) or current data software programs relieve some of the workload desired or demanded from PSOs. In the past there were concerns about costs or the reliability of using computers for data collection. However, with technological advancements it has become more appealing and practical. As technology becomes more affordable, portable, powerful, reliable, and prevalent, it could be used to help PSOs 1.) record, 2.) review, and 3.) process the large amounts of data related to sightings.

1. Automation to help record data

Current standard practices should consider integrating information streams to optimize data collection processes and resources. Linking various onboard systems and automating data collection processes could help increase and standardize data while allowing the PSO to spend more time on observations. For example, some of the weather data could automatically be recorded by linking the PSO data forms to the ship or platform's weather station which could potentially allow the PSO to focus more on observations instead of recording parameters that are already being recorded or collected elsewhere. Another example includes linking data to the vessel’s global positioning system so that effort, operations, and detection information automatically have a georeferenced tag. In some cases, the seismic survey data could also be linked to PSO data using an appropriate program. Moreover, there is potential for a centralized station that could be available to PSOs that streams information from other detection sources such as PAM, aerial surveys, or HD or IR cameras and alerts them to detections. Additional data that may be relevant to sightings such as sea surface temperature or chlorophyll concentrations (Shaffer and Costa, 2006) could also be pulled from an external source and provided to the PSO to assist detections or be included in the PSO dataset or database without placing additional burdens on PSOs to collect more information.

2. Automation to help review data

Implementing automation may create efficiencies and provide an additional means of quality control resulting in improved data. To reduce errors during data entry, immediate and more frequent reviews of the data need to take place before archival and storage. Data are best corrected when done immediately by the onboard PSO. In order to assist the onboard PSO in the immediate correction of data, visuals such as automatic filled data, formulas, charts, graphs, dashboards, or data summaries can be placed near data entry fields and can help PSOs detect potential errors as they enter the data into a spreadsheet or application. For example, the current JNCC forms record the time soft-start or Ramp-up began and the time of full power, which is the end time of soft-start/ Ramp-up. However, the forms do not show the duration of the soft-start/Ramp-up. If a nearby automatic calculation of the duration of soft-start or Ramp-up was included, the PSO would have another indicator that the data they entered was correct due the typical constraints of the soft-start/Ramp-up times being 20 to 40 minutes. If the value was out of the expected range, the cell could be conditioned to highlight red or orange to draw attention to the data. Having formulas to show the duration can also be used to check other data fields related to monitoring times or seismic survey durations. Even if formatting is restricted, numerical fields are prone to human error and automatic formulas and other visuals provide an additional review available to the PSO which may help reduce errors and allow them to be corrected by the PSO. However, adding formulas, conditions and comments to cells, charts, and graphs to a spreadsheet may not always be appropriate and can make the file size difficult to manage or may create errors if a formula is incorrect. Therefore, a separate quality control application, similar to the MMO Import Tool used in this project, could be developed and utilized as an additional or alternate check of the data by the PSO. A standalone downloadable program could upload a standard dataset such as the JNCC forms and run through a series of checks and flag potential errors in data entry for the PSO to review prior to submission to the government, client, or PSO provider. Using a quality control tool to review the data before submission can provide the PSO with immediate feedback on their data and can help prevent the reoccurrence of the error by having the PSO correct it.

3. Automation to help process data

PSOs can collect large amounts of data and in some cases, automation may be appropriate to help process the data. Automation can reduce the workload related to data processing, however the system storing the data needs be able to interpret the various streams of information.

A rudimentary automation solution that is already in place with some of the data collection applications is to generate a Word document from the PSO data that automatically fills in the basic data required in reports and provides a standard format. The Word template would allow editing if additional or alternate information was needed and would could potentially reduce the time spent formatting and copying over data. While a generated report may not be necessary for every project, it can provide an optional standard to follow and potentially reduce the PSO workload.

Another area with potential is using technology to help process photos and videos of marine mammals. Current data practices sometimes do not include photos or videos because of the challenges associated with these file types. Photos and videos are a good resource to support and confirm the detection data; however, sometimes they are not shared due to the size of the file or due to the work required to analyze the files and link each photo or video to a detection. In some cases, it might not be reasonable to review long videos or several pictures, in which case automation could assist. Progress has been made to use photos and videos to automatically record behaviours or distinguish species or individuals which could provide another way to confirm and record data (Adams et al., 2006; Karnowski et al., 2016). Automatic analysis of photo and video data could help capture more data and integrate the data from those files into a PSO database, which would increase the value in capturing photos or videos.

5.3.1 Toward a global database

The system for collecting and storing PSO data needs to have flexibility to account for adaptive management and unique project needs whether it be including a requirement for additional marine fauna data collection such as including sharks or seabirds or for incorporating alternative or supplemental monitoring techniques such as aerial monitoring, PAM, Active Acoustic Monitoring (AAM), thermal Infra-red (IR), RADAR, telemetry, High definition (HD) cameras or drone use. A centralized web-based database that can account for the various data collection methods (i.e., Excel forms or software) and data collection requirements should be encouraged and maintained. The database could allow sufficient collation, quality control, processing/analysis, archival, and sharing of PSO data. Historical data could be included in the database via a similar method employed in this report such as the MMO Import Tool used for uploading data into the PSOMap database. The significant effort needed to amass data in a central location after the fact, as evidenced during the data collection phase of this study, highlights the importance of this initiative being advanced.

Recommendations have been made in the past toward making a global database of the data collected by PSOs (Barton et al., 2008; Compton, 2013; Erbe et al., 2016; Nelms et al., 2016); however, the various data requirements imposed by different regions, the need for more standardization, and the proprietary nature of some of the data collected have made it challenging to realize this goal. This study demonstrates that a global database can be achieved despite some of the challenges; however further coordination between academics, industry, regulators, PSO providers, and associations is needed to remove the current roadblocks toward a global sharing and archiving of PSO data for the betterment of science-based regulation and the marine environment.

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Appendix A

PSO Standardized Data Format

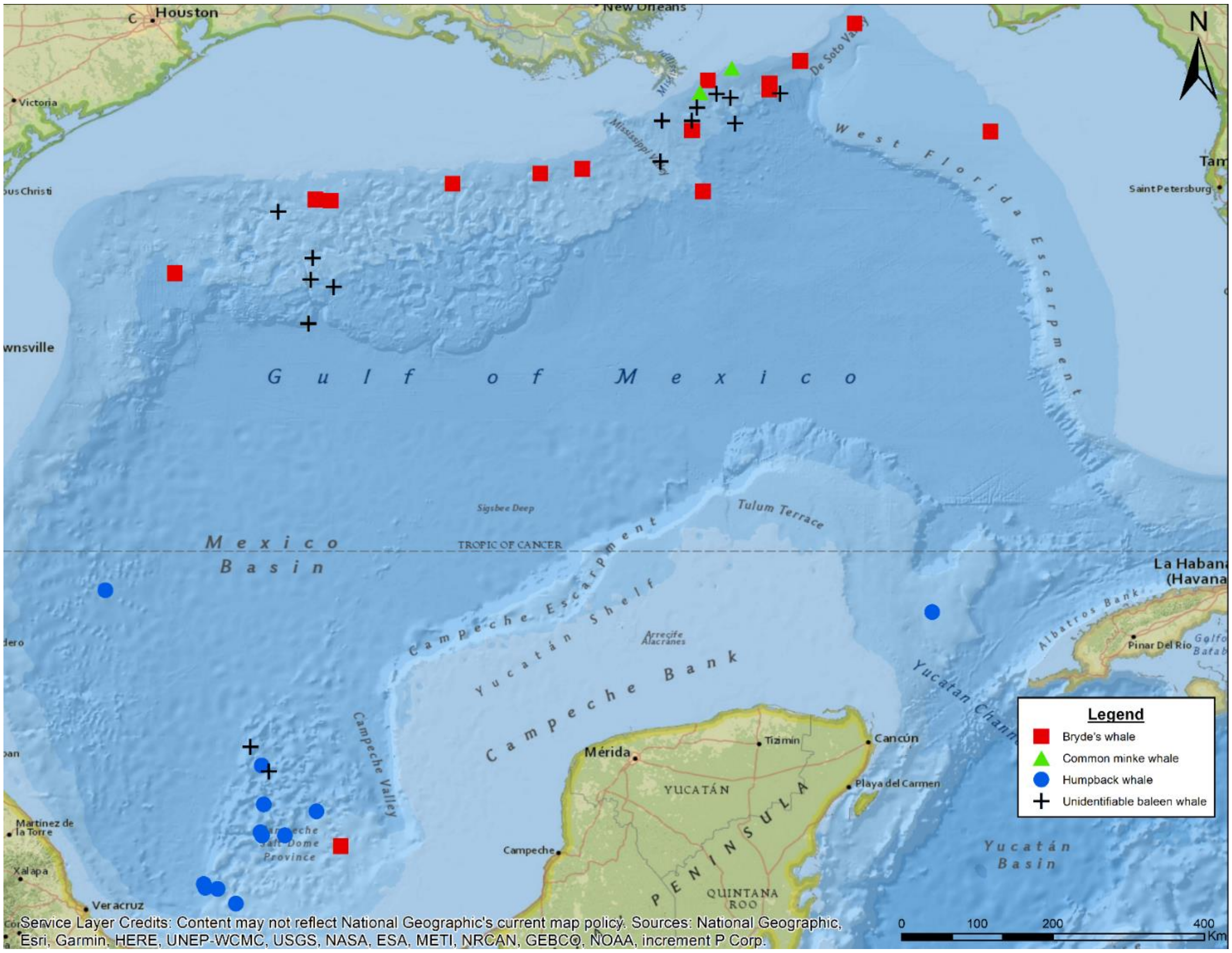
Appendix B

PSO Data Request Contact List

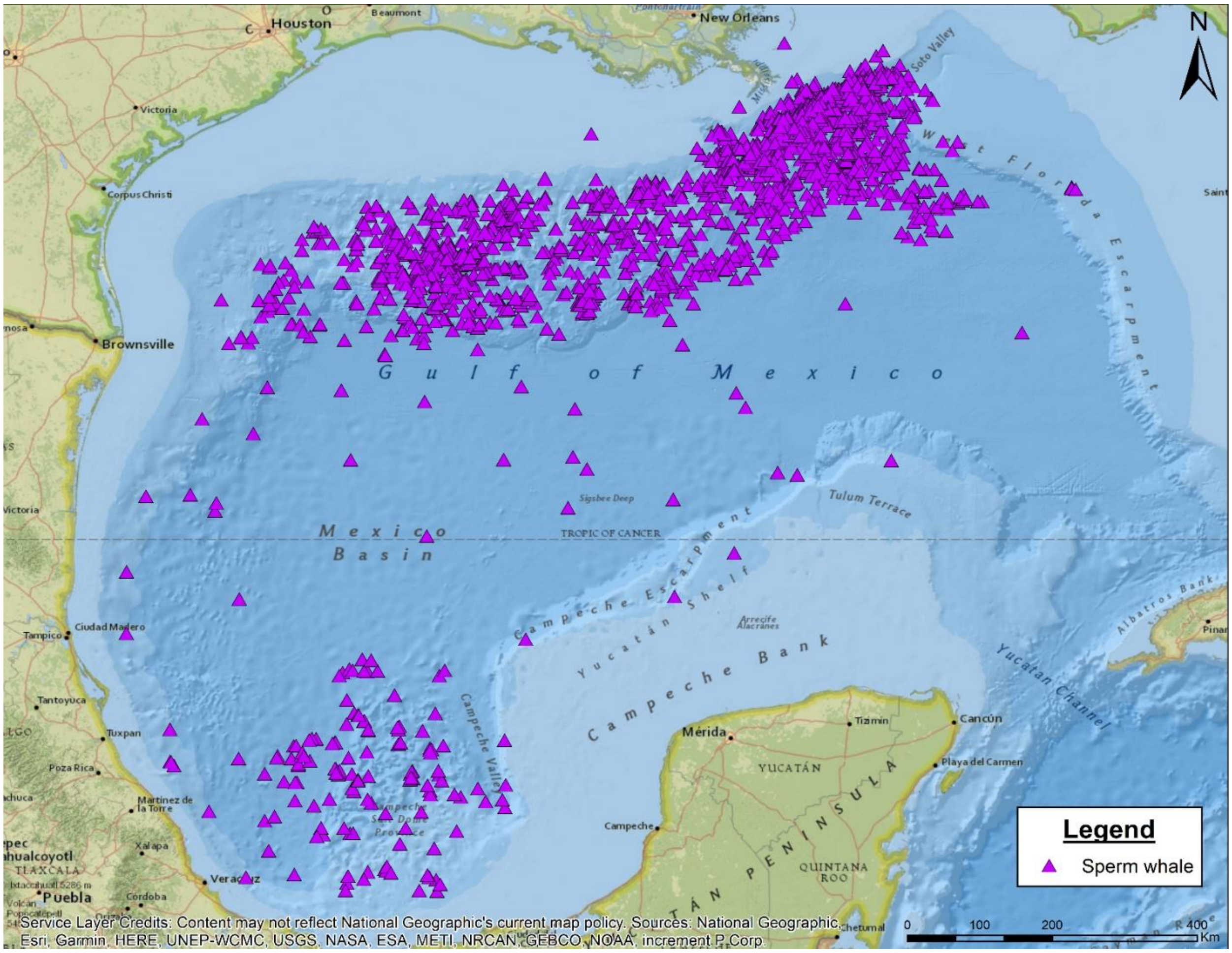
Appendix C

Detailed Detection Map

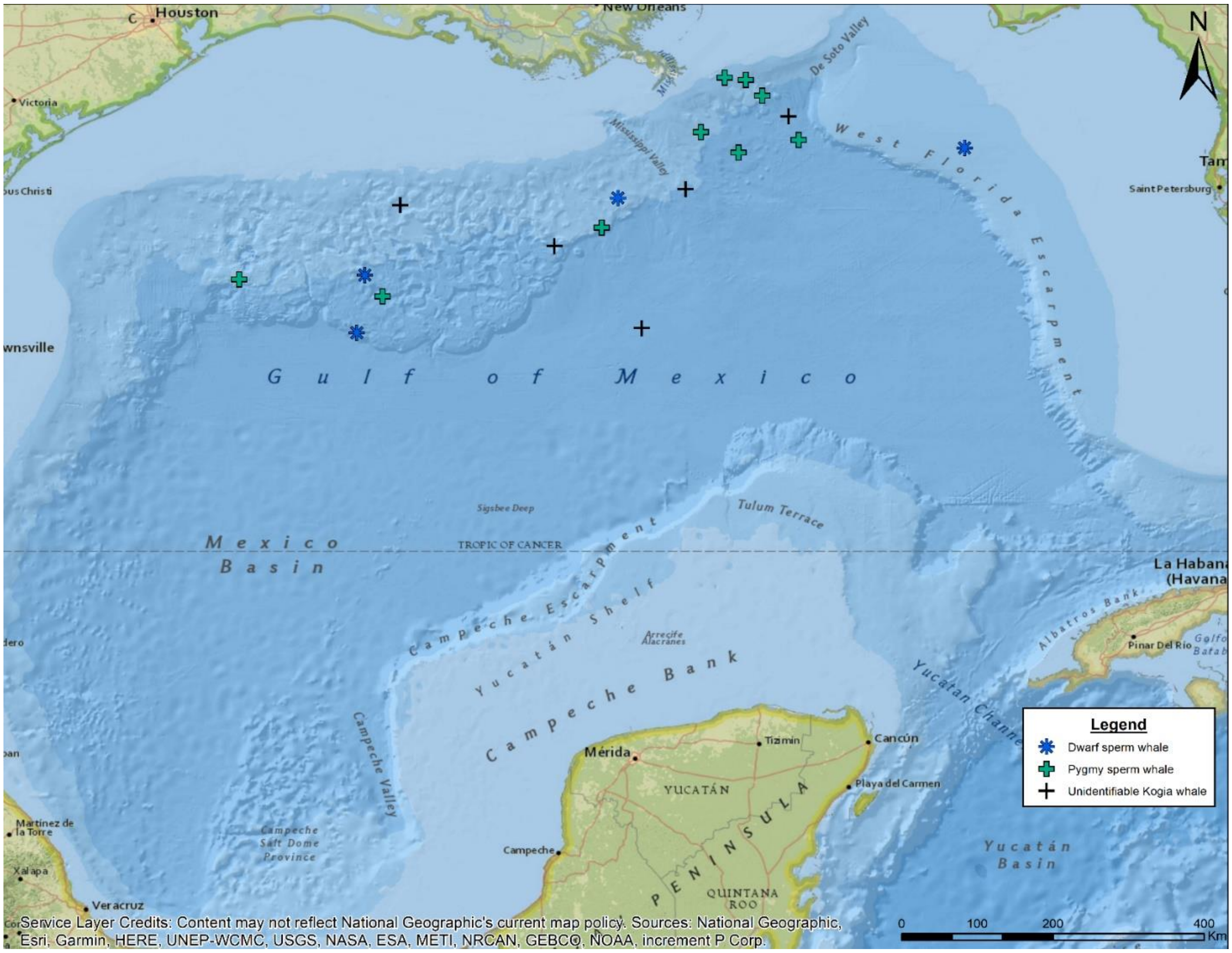
Gulf of Mexico



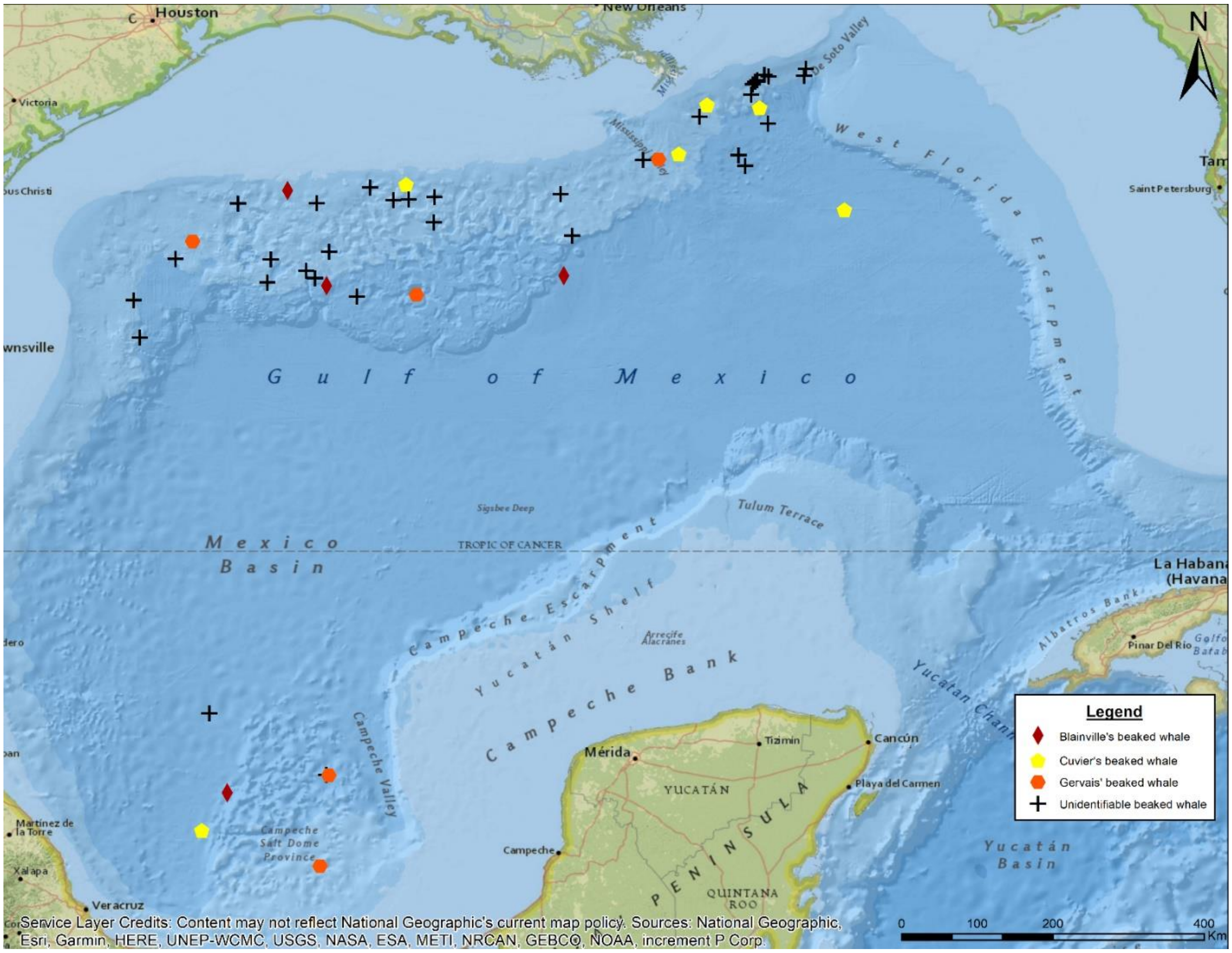
Gulf of Mexico baleen whale detections



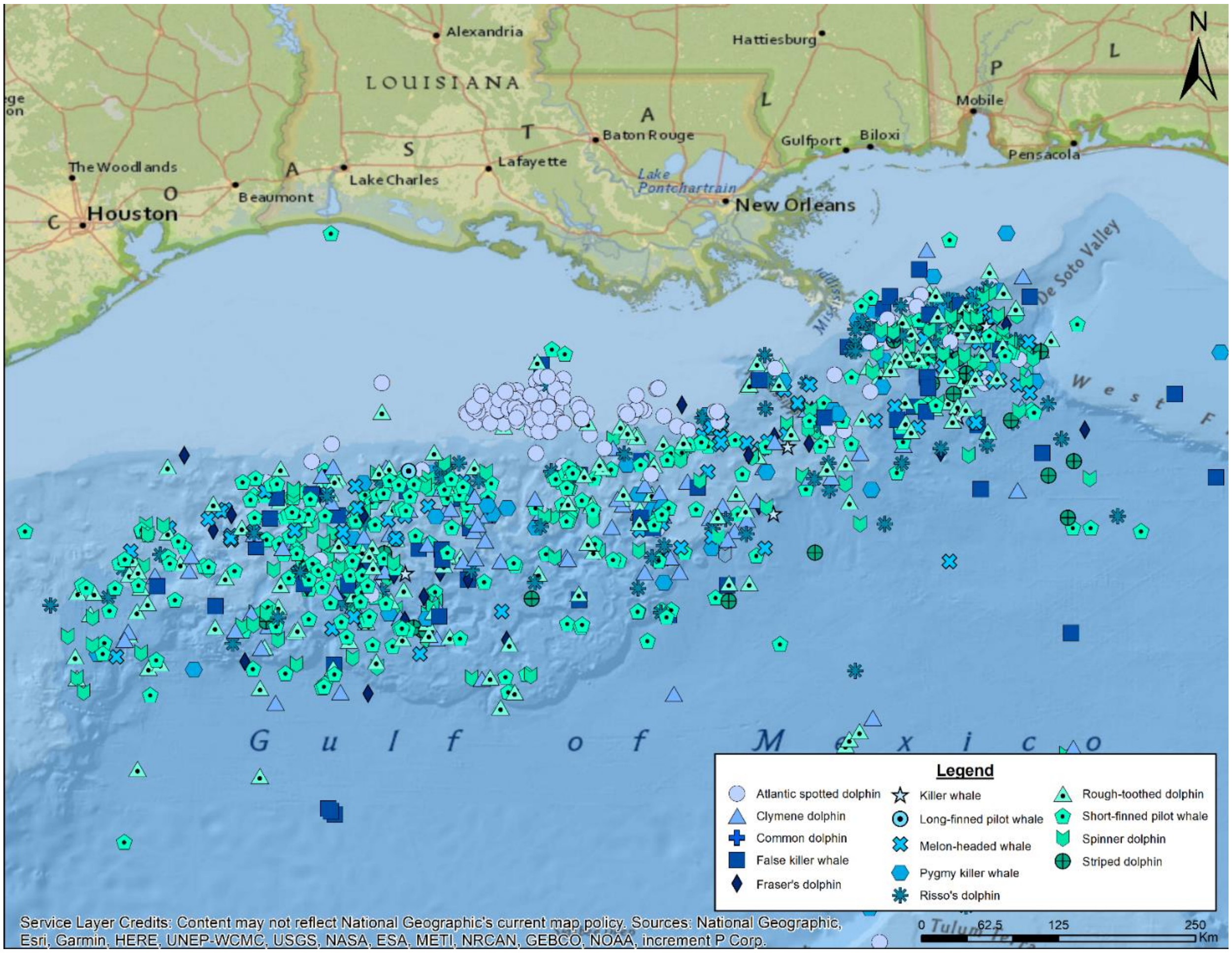
Gulf of Mexico sperm whale detections



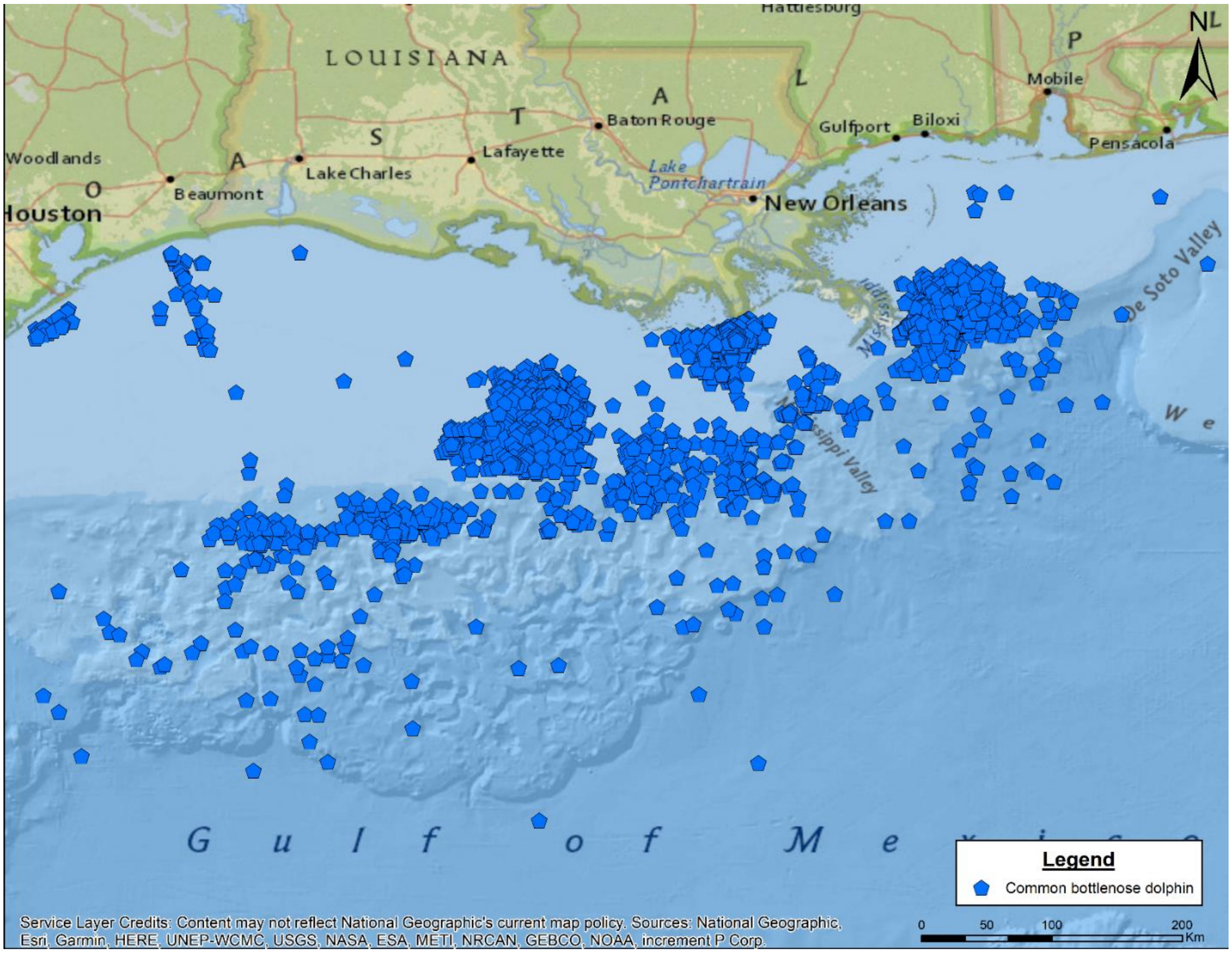
Gulf of Mexico Kogia species detections



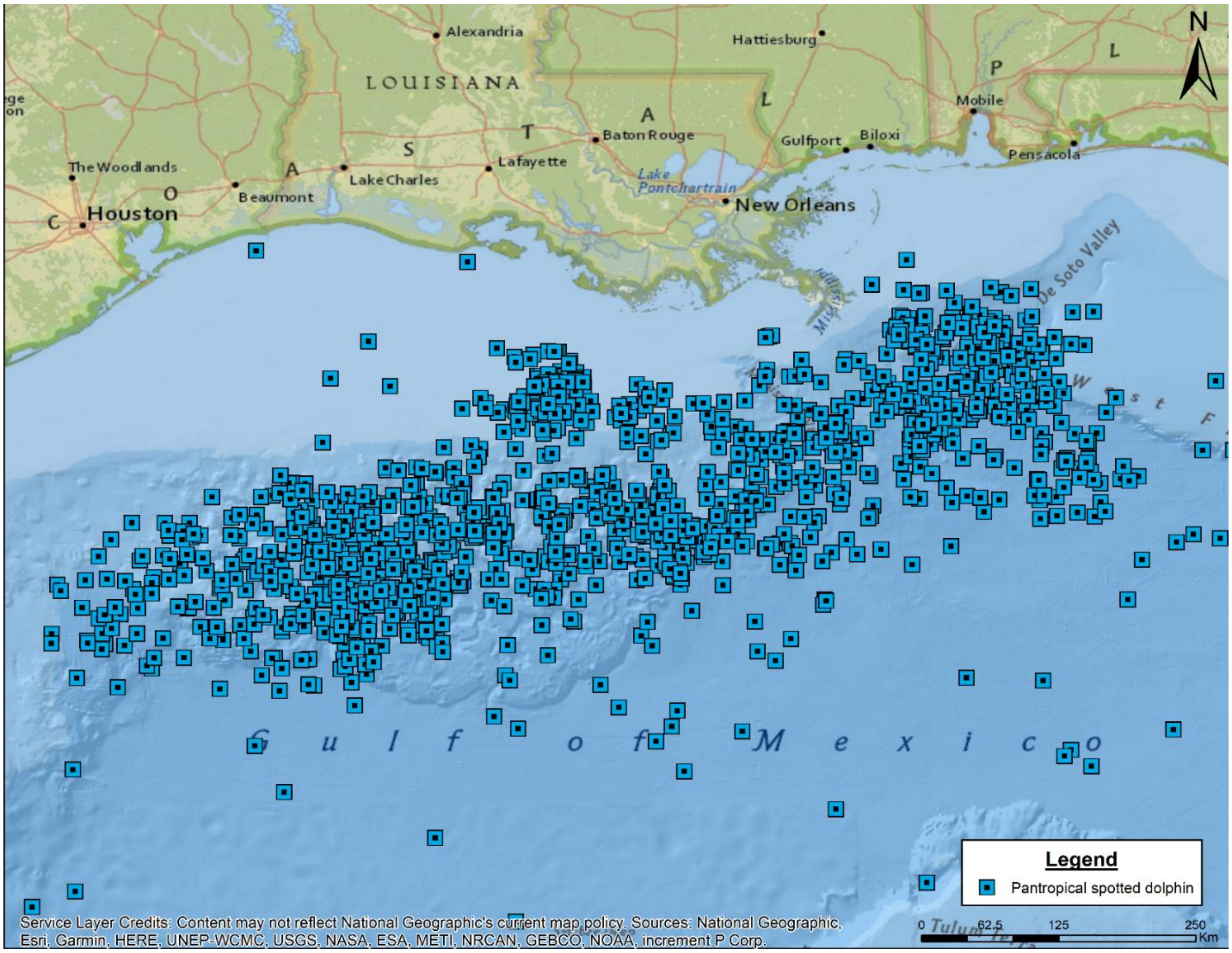
Gulf of Mexico beaked whale detections



Gulf of Mexico dolphin detections (minus common bottlenose dolphins and pantropical spotted dolphins)

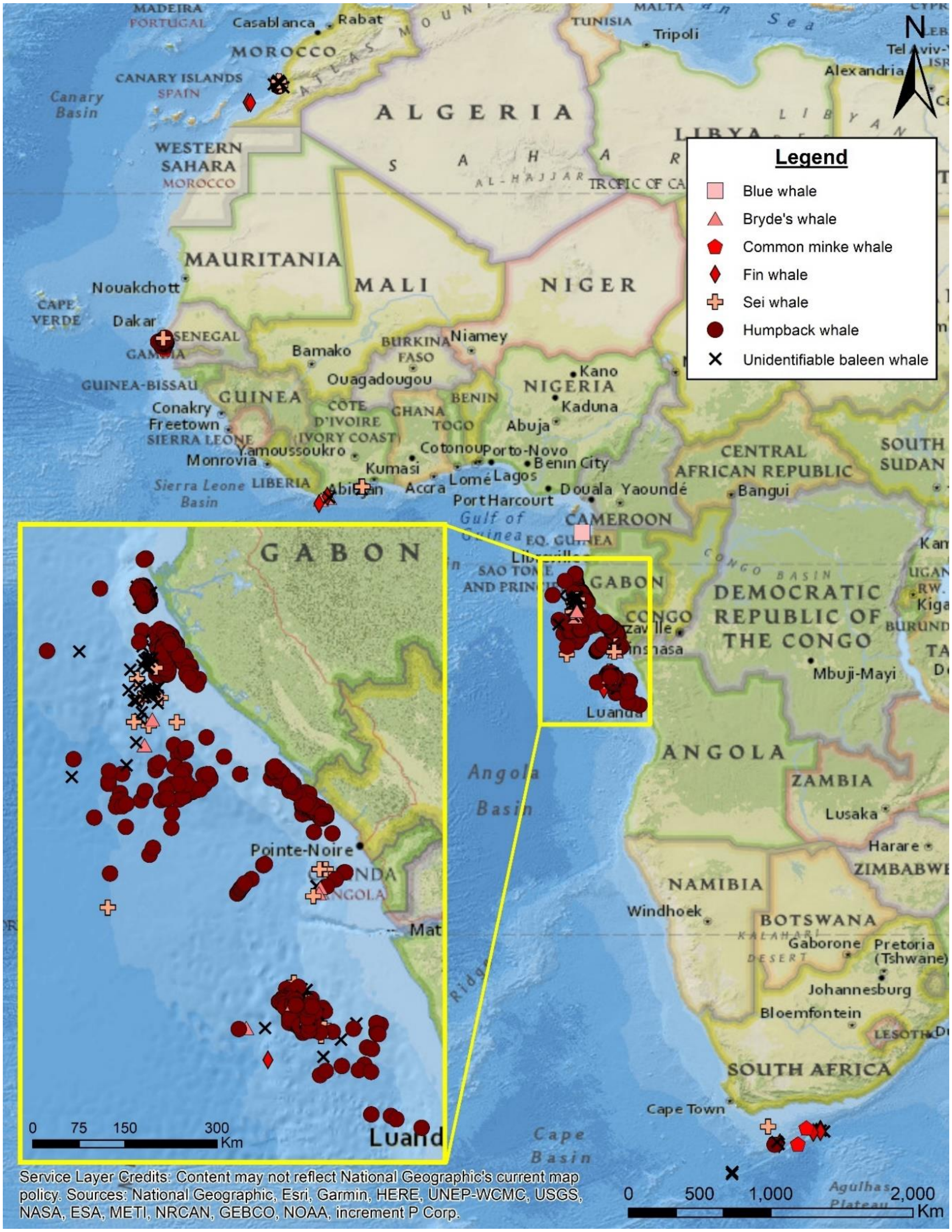


Gulf of Mexico common bottlenose dolphin detections

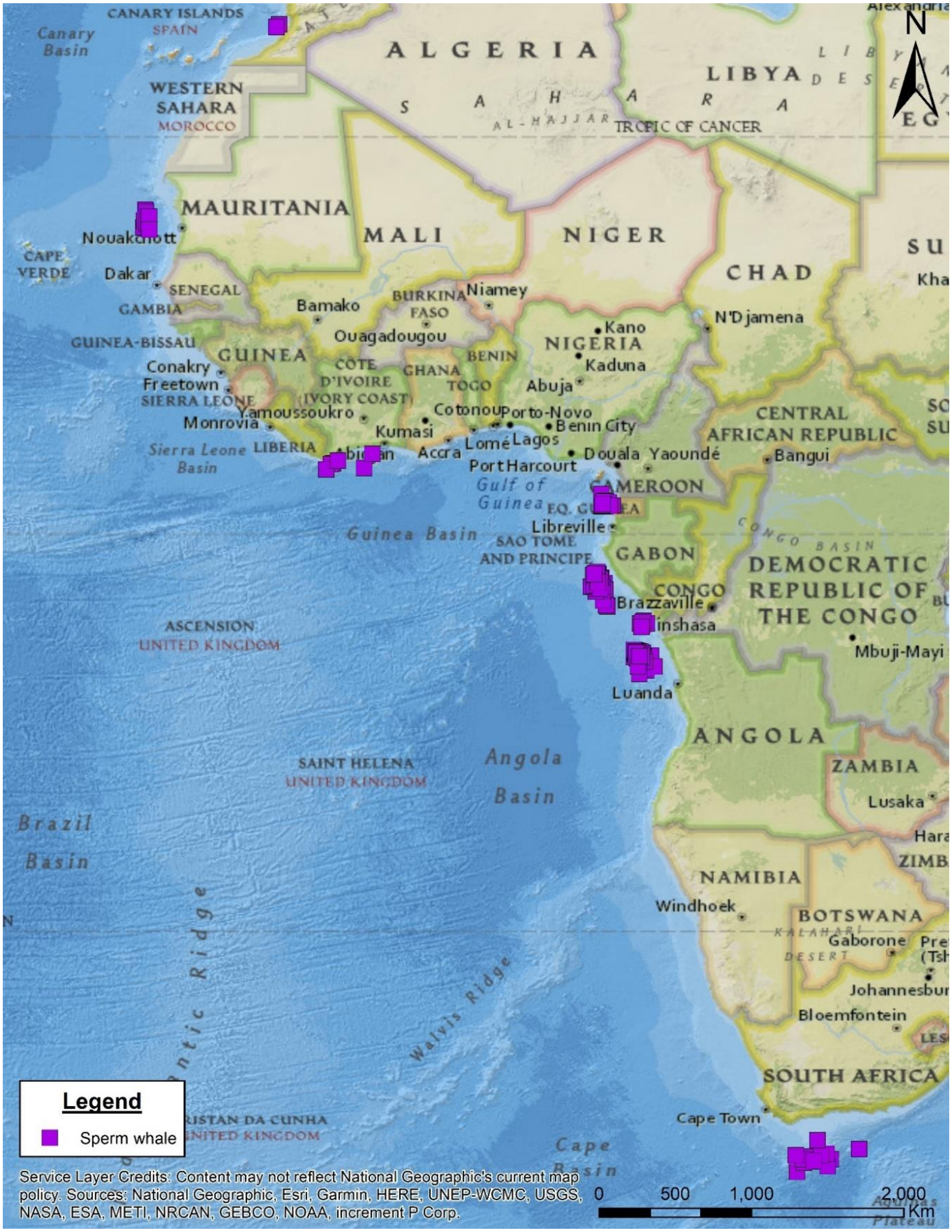


Gulf of Mexico pantropical spotted dolphin detections

West Africa



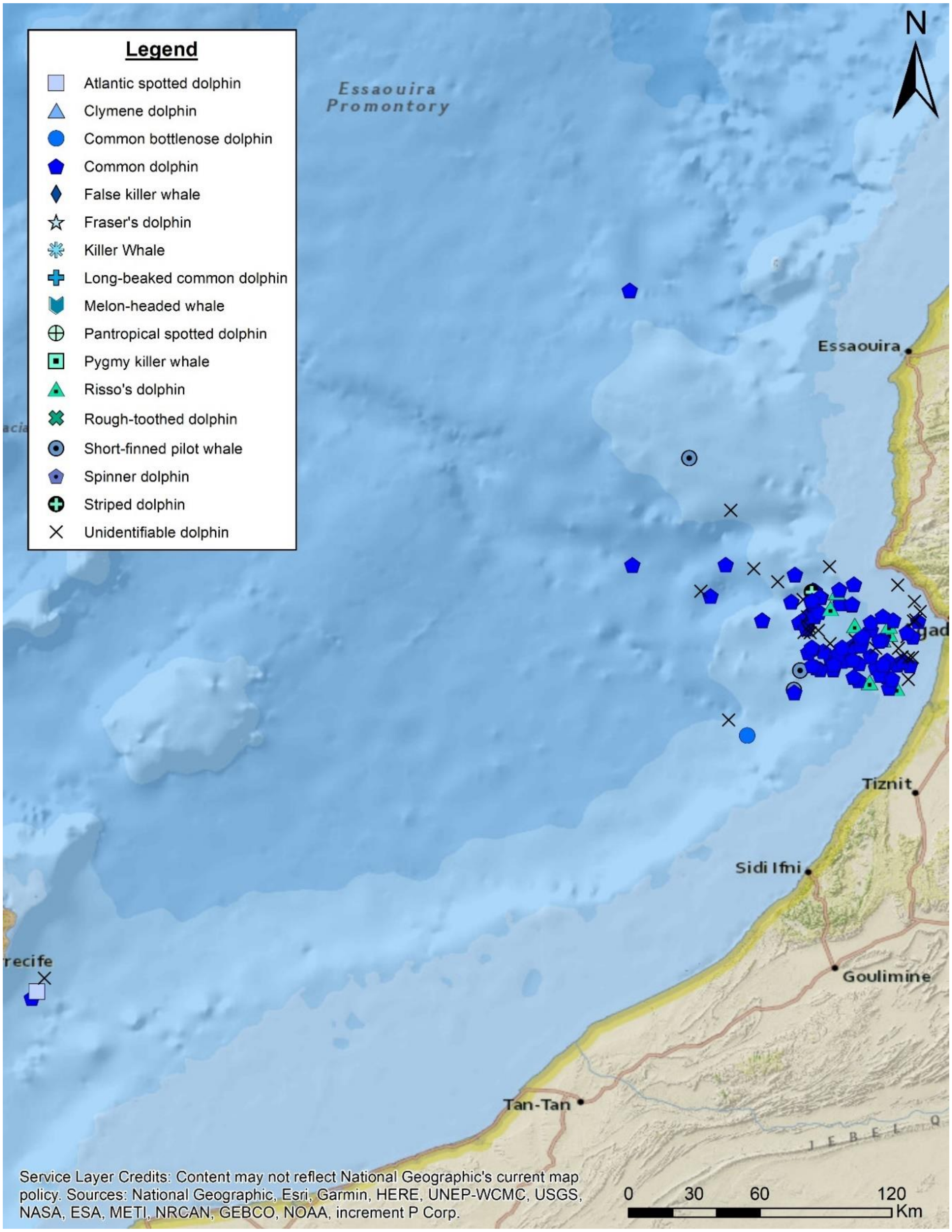
West Africa baleen whale detections



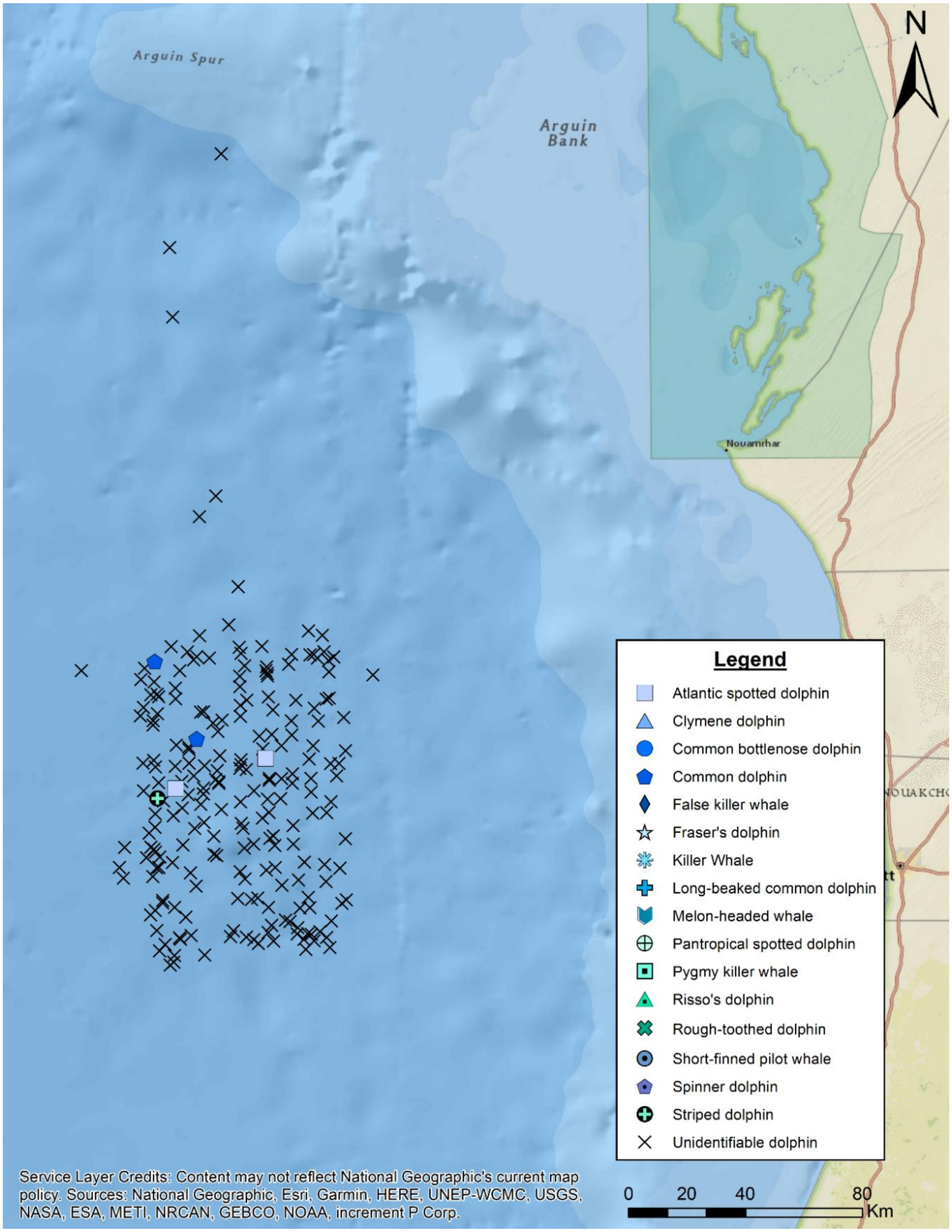
West Africa sperm whale detections

West Africa Kogia species detections

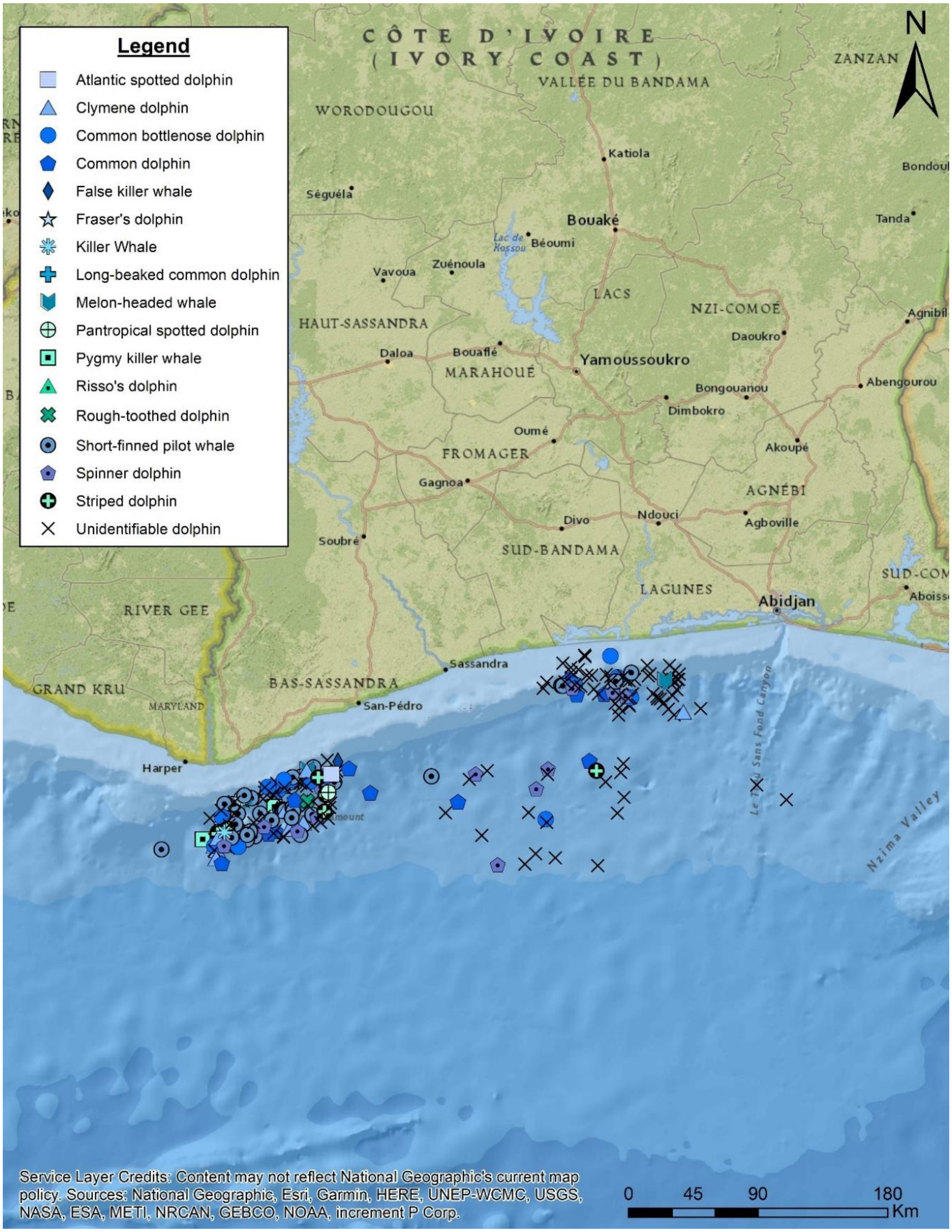
West Africa beaked whale detections



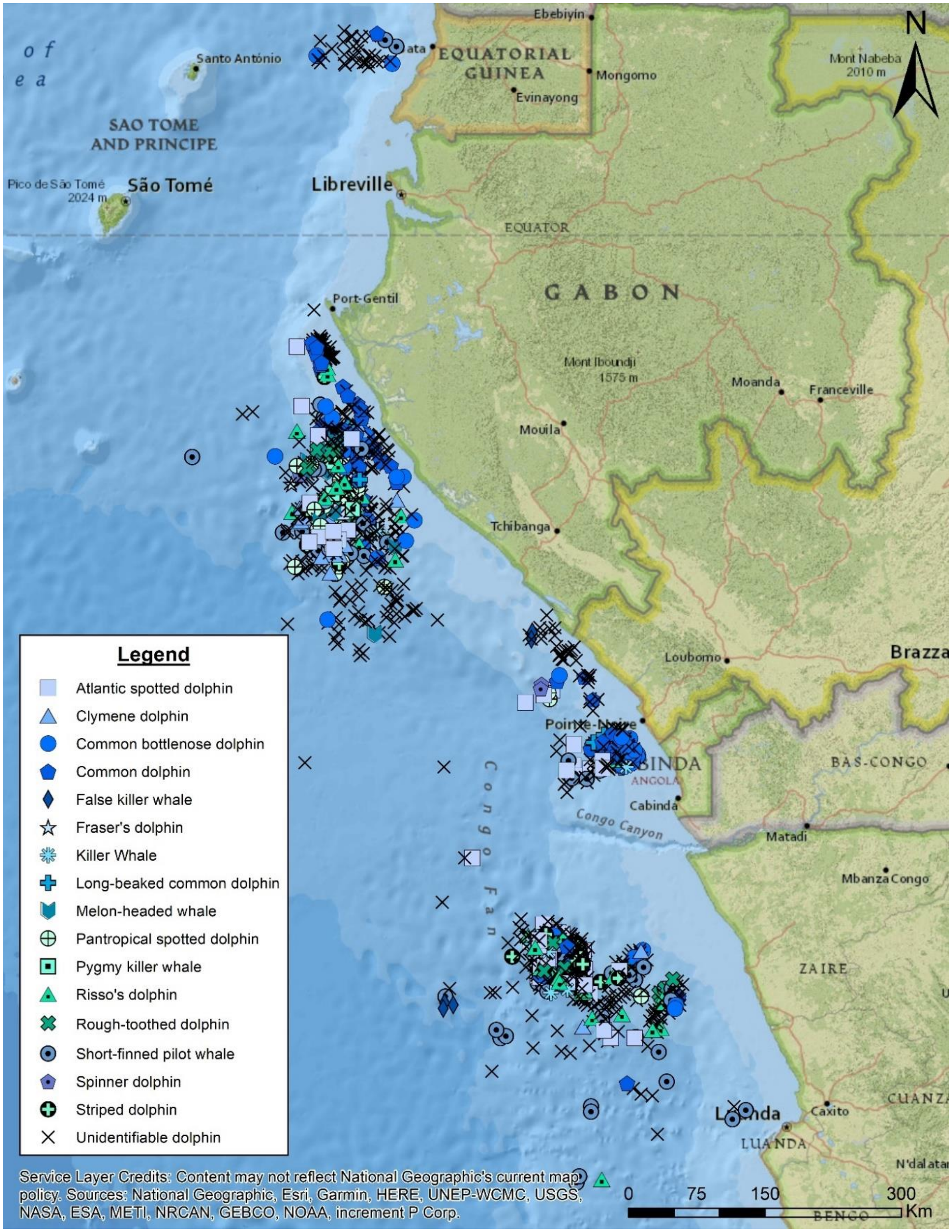
West Africa – Morocco/Canary Islands dolphin detections



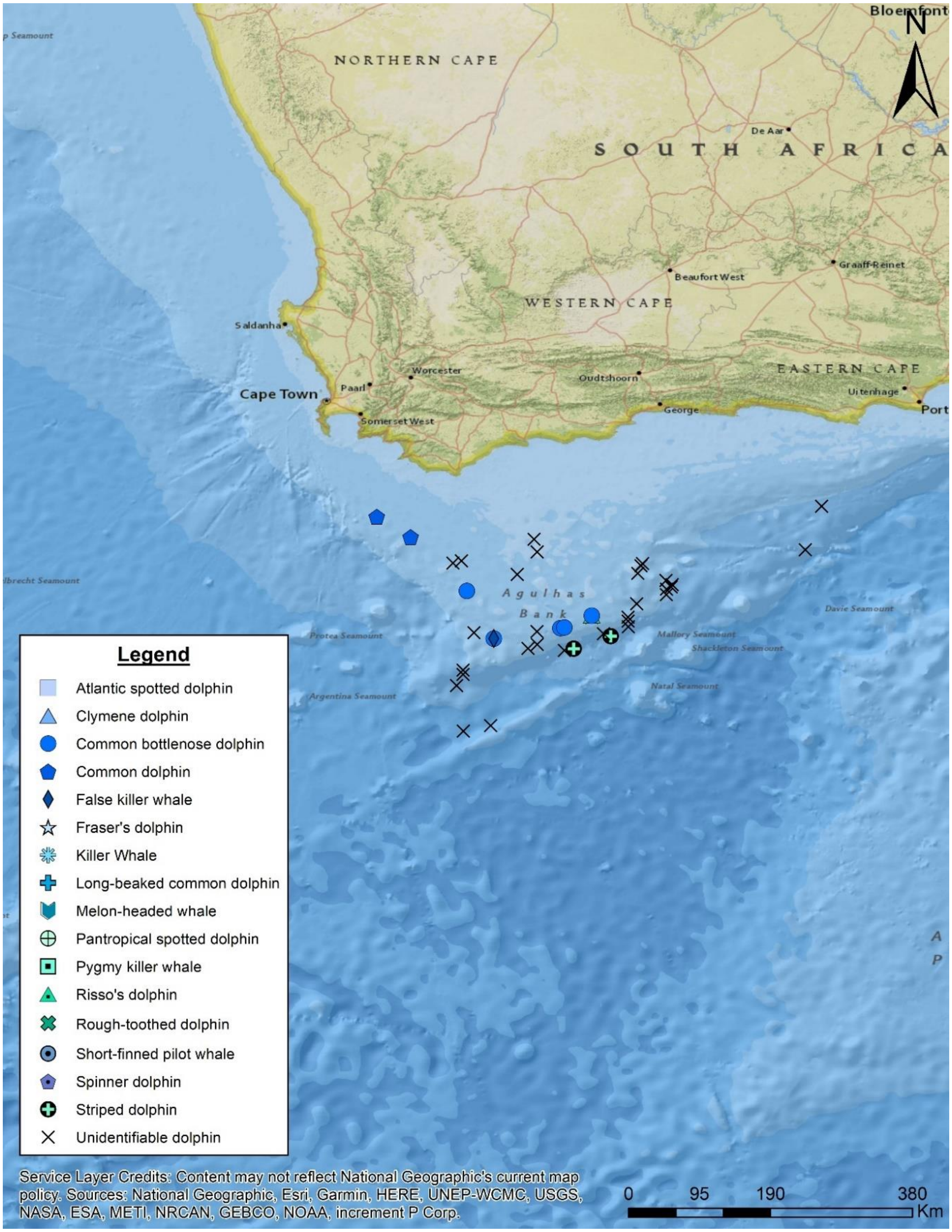
West Africa – Mauritania dolphin detections



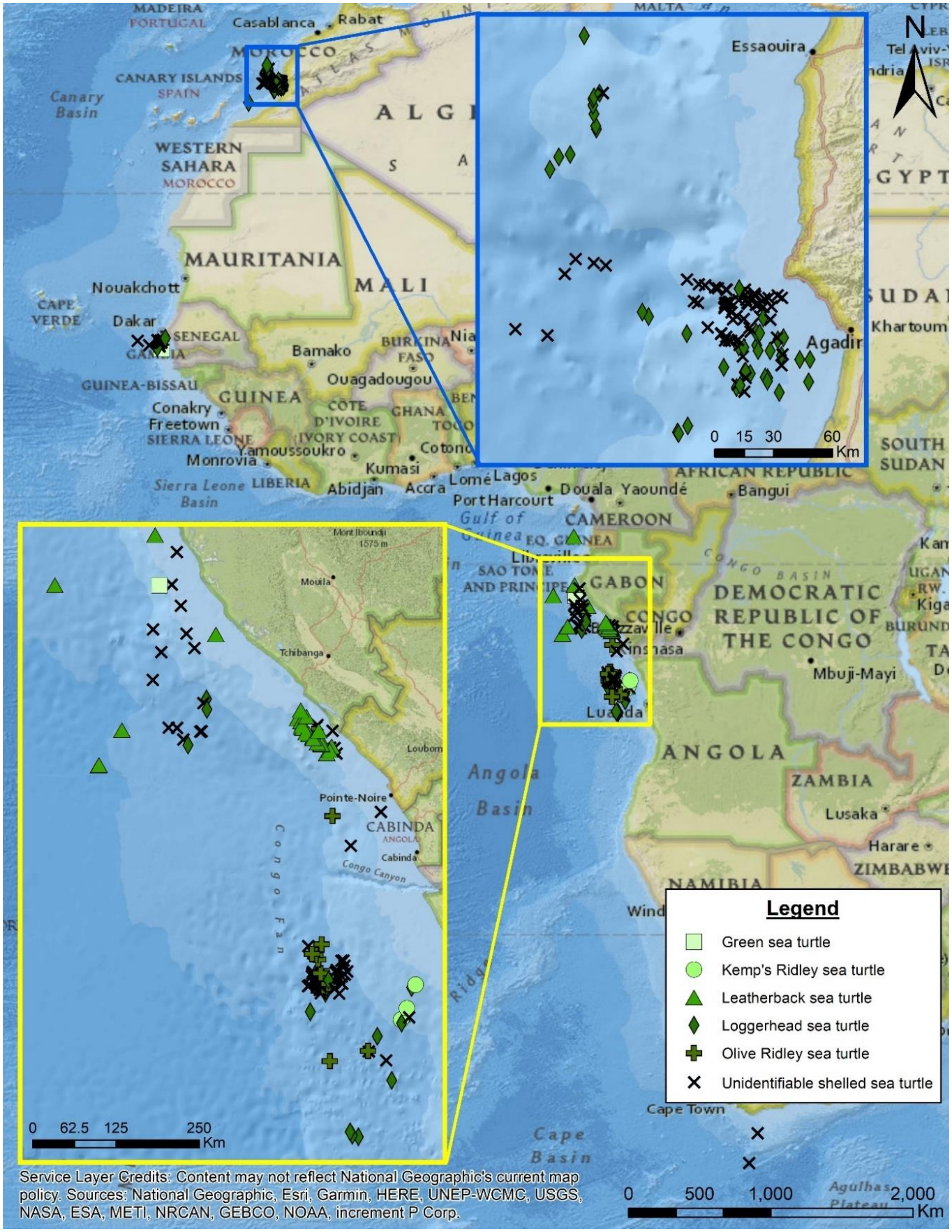
West Africa – Cote d'Ivoire dolphin detections



West Africa – Gabon, Congo, Angola dolphin detections

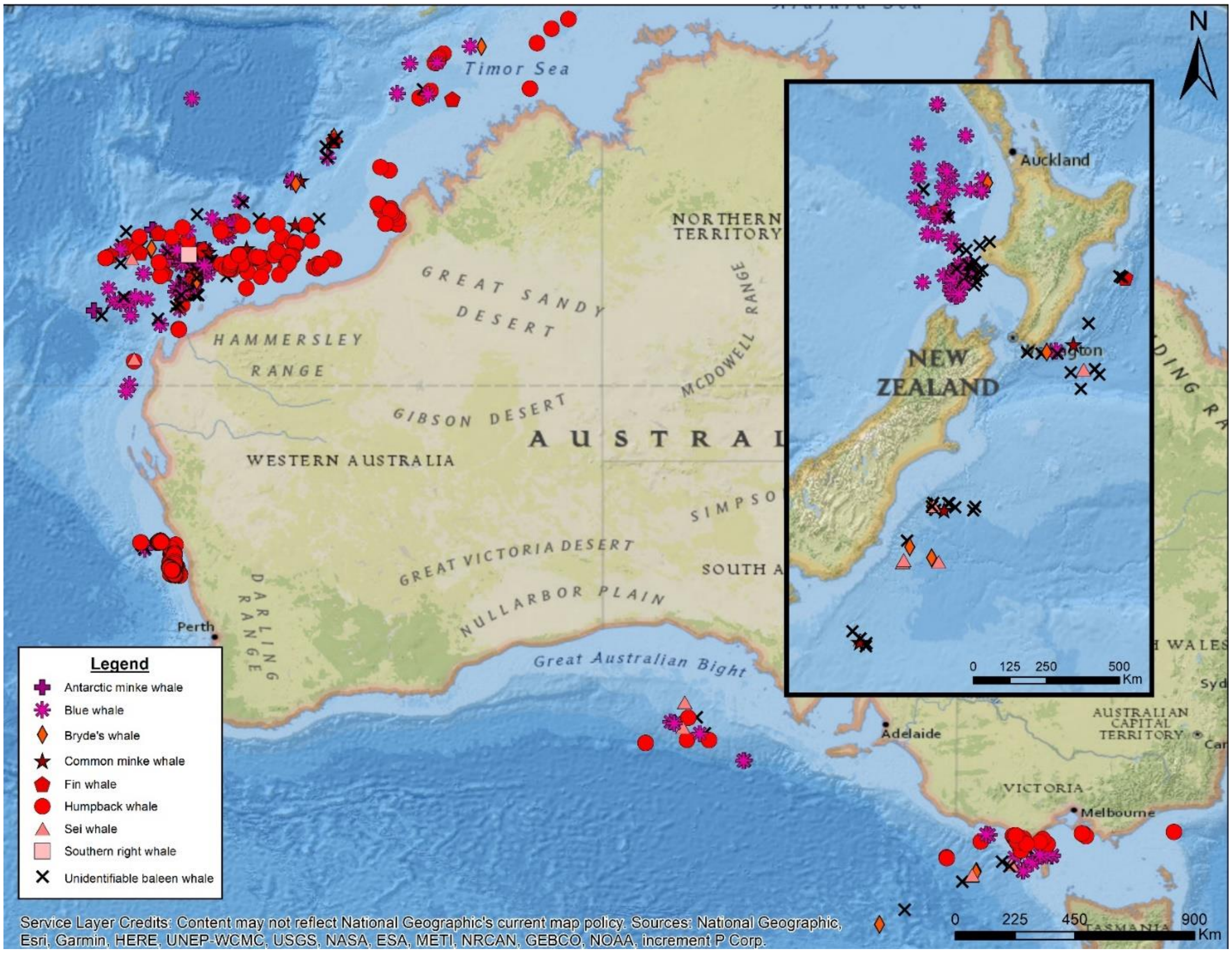


West Africa – South Africa dolphin detections

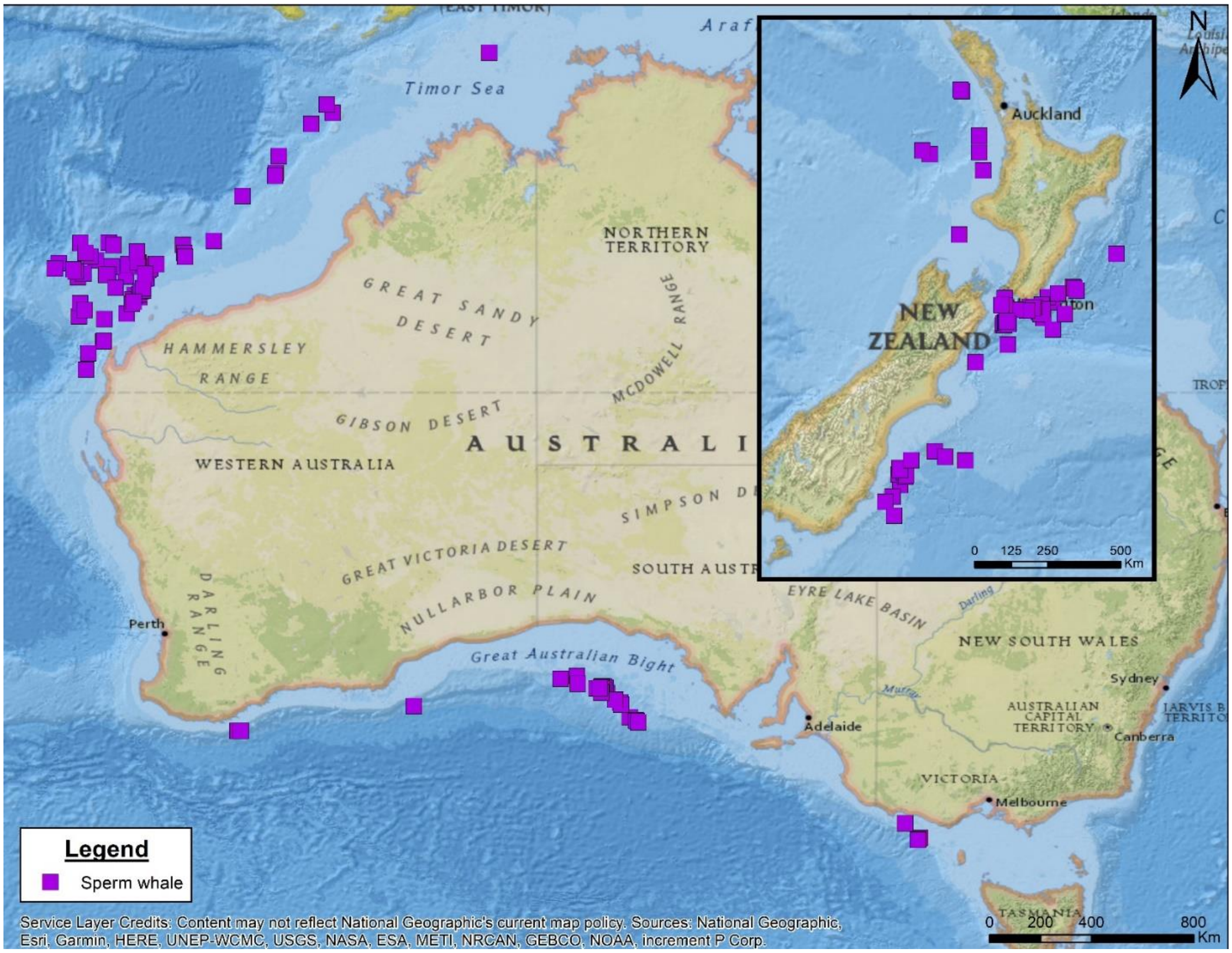


West Africa sea turtle detections

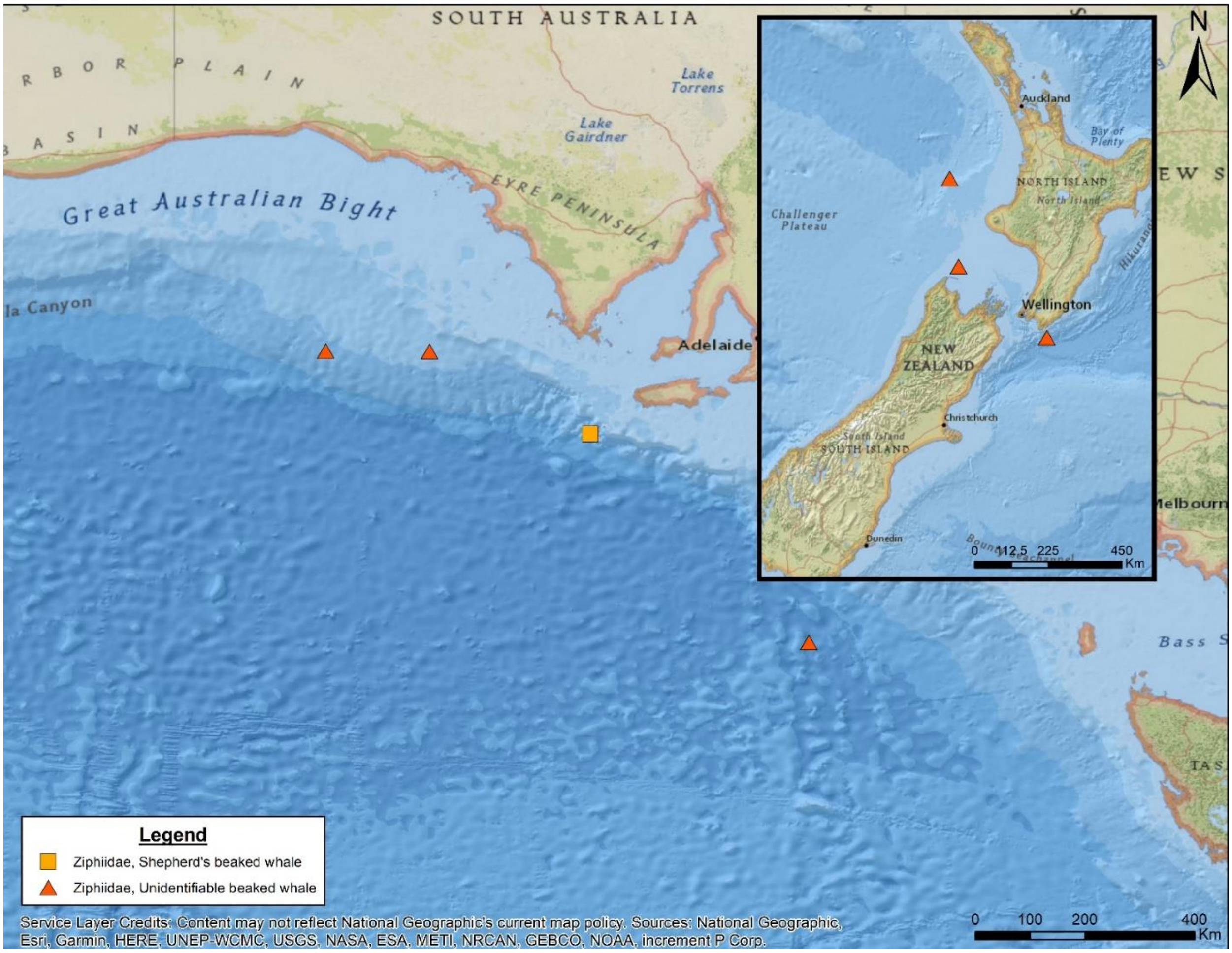
Australia



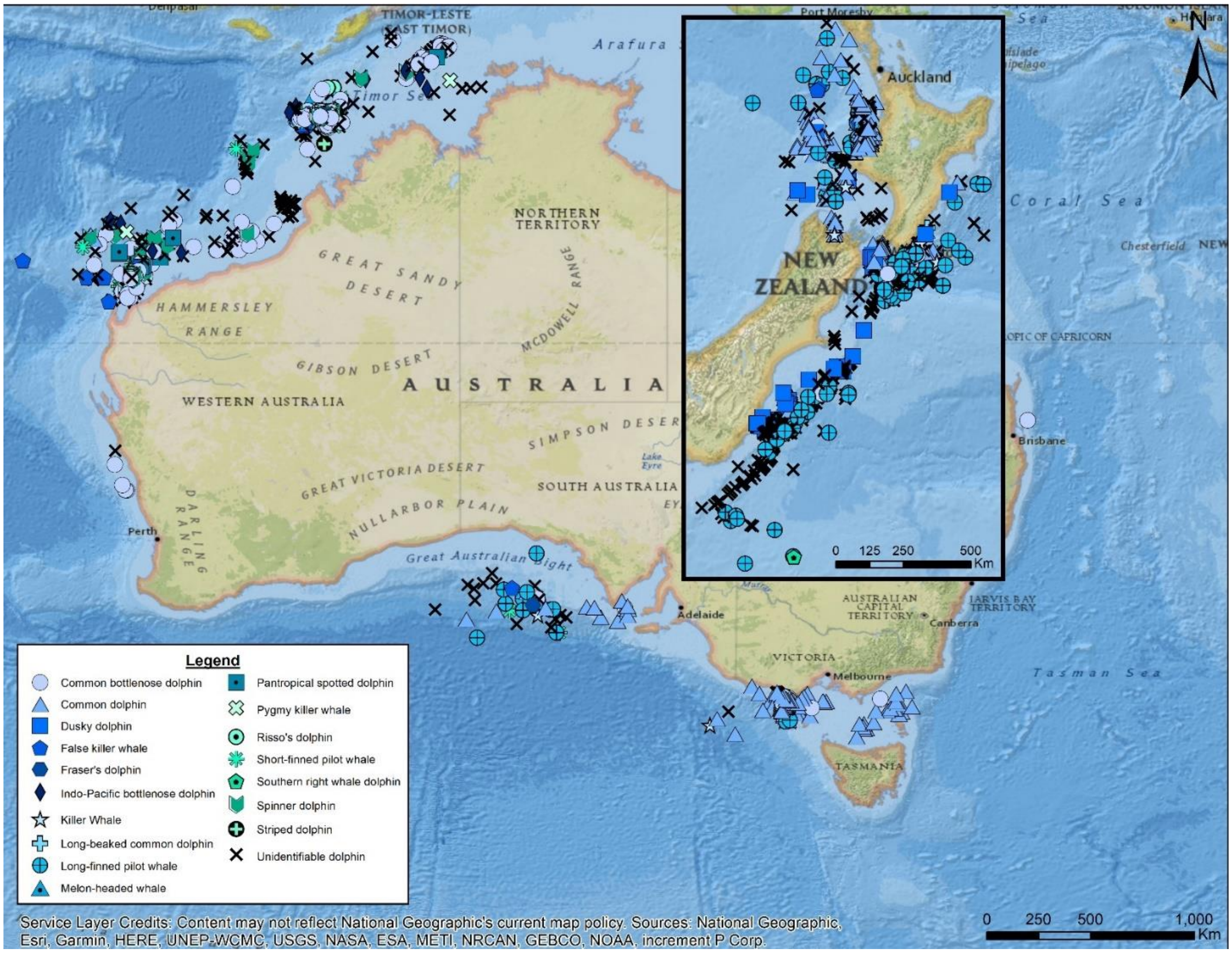
Australia baleen whale detections



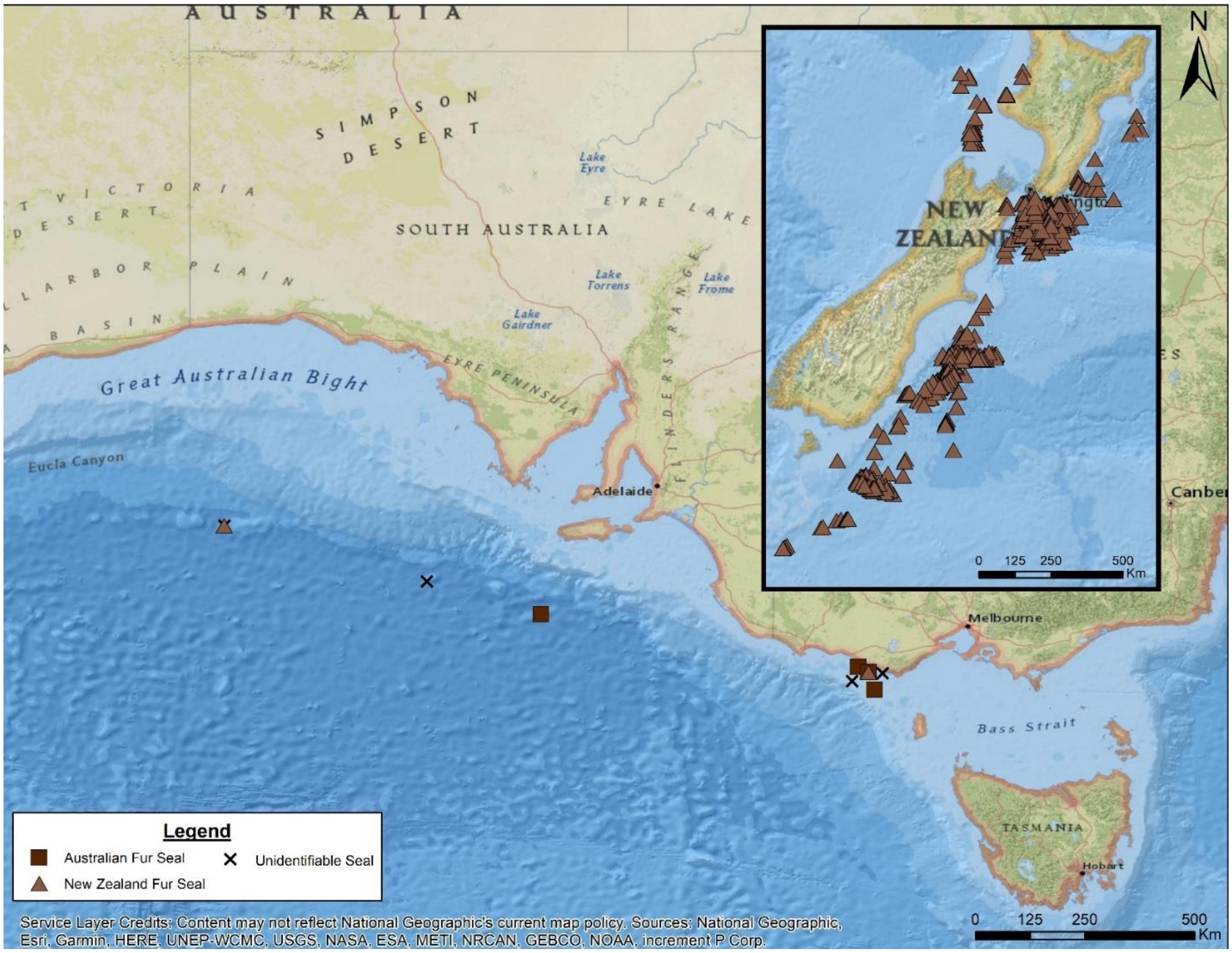
Australia sperm whale detections



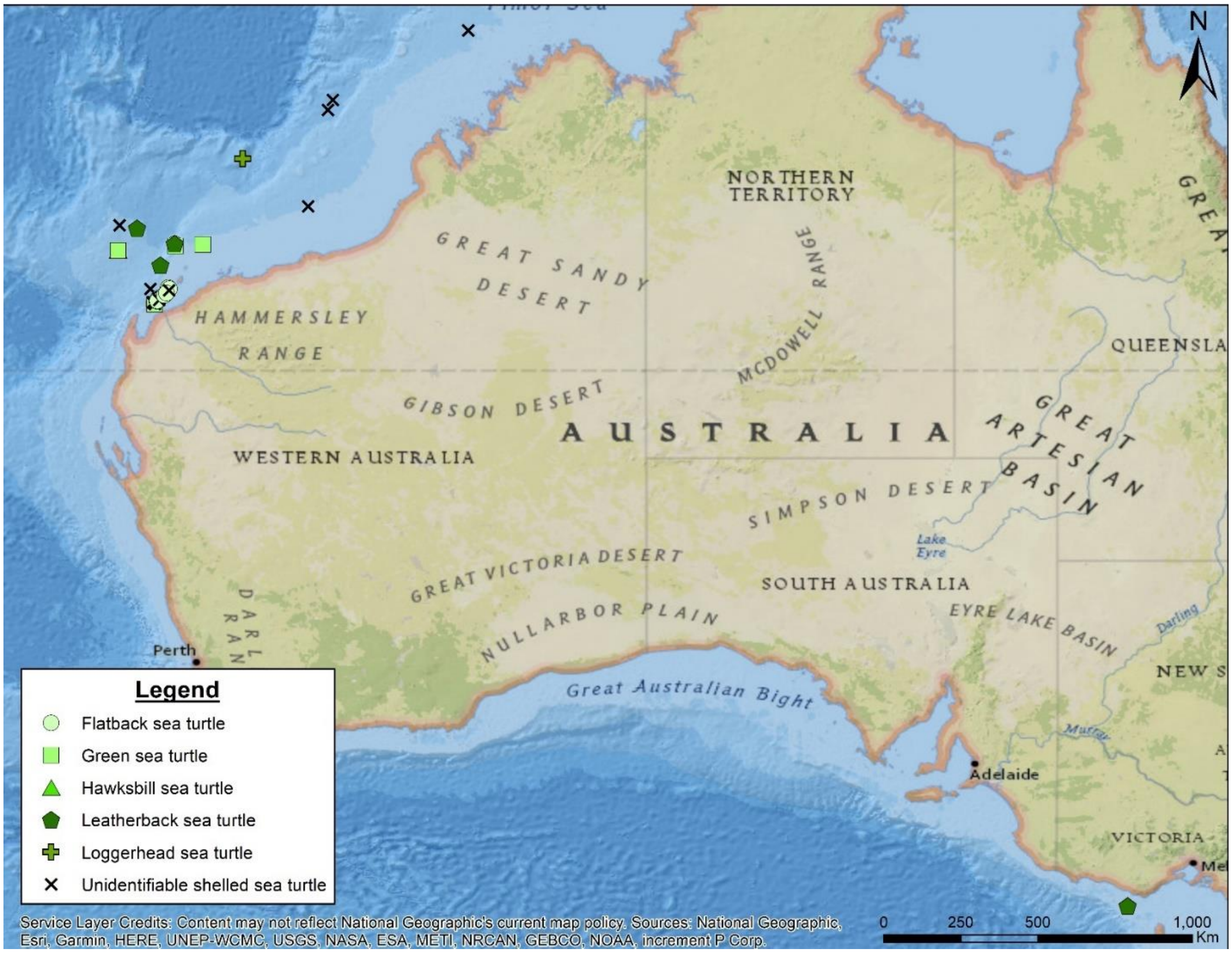
Australia beaked whale detections



Australia dolphin detections



Australia pinniped detections



Australia sea turtle detectionsWeir, C.R., Ron, T., Morais, M. and Duarte, A.D.C. (2007). Nesting and pelagic distribution of marine turtles in Angola, West Africa, 2000–2006: occurrence, threats and conservation implications. Oryx, 41: 224–231.

Appendix D

Global Region Analysis

Combined and Other Regions

Along with three focused areas of study, data from other areas were received for other regions and the JIP requested that these datasets be included in a combined analysis to increase sample sizes. A total of 86 reports from 26 surveys were obtained for Other Regions. The Other Region's data set included data from the Southern Atlantic, Bangladesh, Costa Rica, the Falkland Islands, Mexico, Peru, South Africa, South Georgia and the South Sandwich Islands, Spain, the United States (Alaska, Hawaii, Pacific Northwest), and Uruguay and spanned the years from 2010 to 2016. It should be noted that other regions with regulatory regimes have robust PSO datasets but they were not actively solicited in the study due to budgeting and time constraints. The 86 reports had 14484 hours and 3 minutes of visual monitoring. The shortest report covered a period of one day, while the longest report covered a duration of 1594 days.

Other Regions

A number of limited sightings records were obtained for areas outside of the three regions detailed above, spread across a global area. These were analyzed as part of the miscellaneous 'Other Regions'.

A total of 2,224 sighting records were obtained for the 'Other Regions' sightings analyses. Approximately 28,500 individual animals were identified. Cetaceans comprised 1,739 (78.2%) of records with 26 species identified. Sea turtles consisted of 296 (13.3%) of the records with 5 species identified. Pinnipeds consisted of 189 (8.5%) of the remaining records with 11 species identified (Figure A-0).

The most common cetacean encountered was the humpback whale (N=445 records); the most common small cetacean identified was the common dolphin, Delphinus sp (N=74 records) (Table A-0).

Sea turtles had the smallest average group size with a reported average group size of 1.4 individuals. Dolphins had the largest average group size of 48.2 individuals. Sperm whales had an average group size recorded at 4.5 individuals, pinnipeds at 2.9 individuals, and baleen whales at 2.1 individuals (Table A-0).

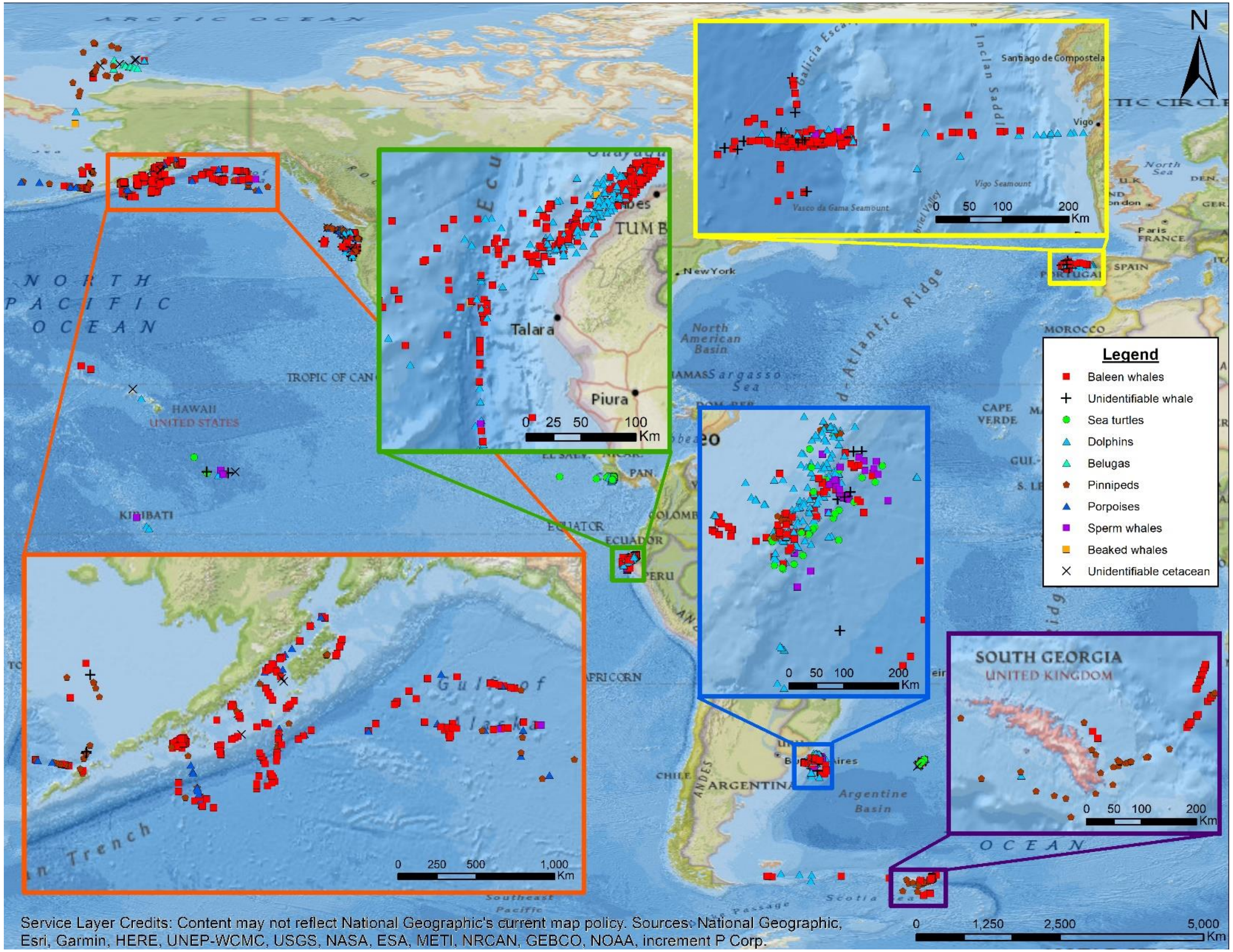


Figure A-0. Map of Other Region detections by species group. See Appendix A for more detailed maps.

Table A-0 Species Sighting Summaries by Lowest Identified Taxonomic Group in Other Regions

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance from Airguns (m)
WHALE								
	Balaenopteridae							
		Balaenoptera	*brydei*	Bryde's whale	5	19	3.8	842.5
			acutorostrata	Common minke whale	7	7	1.0	506.3
			borealis	Sei whale	42	104	2.5	918.8
			physalus	Fin whale	146	371	2.5	1217.6
			musculus	Blue whale	13	17	1.3	1271.7
		Megaptera	*novaeangliae*	Humpback whale	445	523	1.2	391.7
				Unidentified baleen whale	227	390	1.7	1456.4
				Unidentified whale	65	80	1.2	2267.0
				Unidentified beaked whale	4	4	1.0	1288.3
				Unidentified cetacean	29	36	1.2	1234.8
	Kogiidae							
		Kogia	*breviceps*	Pygmy killer whale	3	58	19.3	153.1
	Physeteridae							
		Physeter	*macrocephalus*	Sperm whale	69	313	4.5	964.7

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance from Airguns (m)
DOLPHIN								
	Delphinidae							
		Delphinus sp.		Common dolphin	74	14020	189.5	126.5
				Long-beaked common dolphin	9	807	89.7	119.6
		Globicephala	*macrorhynchus*	Short-finned pilot whale	34	1978	58.2	77.9
		Grampus	*griseus*	Risso's dolphin	13	381	29.3	174.8
		Lagenodelphis	*hosei*	Fraser's dolphin	3	102	34.0	872.5
		Orcinus	*orca*	Killer Whale	5	26	5.2	94.2
		Peponocephala	*electra*	Melon-headed whale	1	50	50.0	45.7
		Pseudorca	*crassidens*	False killer whale	4	32	8.0	310.3
			attenuata	Pantropical spotted dolphin	46	739	16.1	349.9
			longirostris	Spinner dolphin	10	1175	117.5	478.0
			coeruleoalba	Striped dolphin	6	160	26.7	88.2
		Steno	*bredanensis*	Rough-toothed dolphin	9	73	8.1	695.5
		Tursiops	*truncatus*	Common bottlenose dolphin	43	1413	32.9	164.3

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance from Airguns (m)
				Unidentified dolphin	427	4015	9.4	199.5
TURTLE								
	Cheloniidae							
		Caretta	*caretta*	Loggerhead sea turtle	27	28	1.0	544.4
		Chelonia	*mydas*	Green sea turtle	5	5	1.0	422.5
		Lepidochelys	*olivacea*	Olive Ridley sea turtle	230	727	3.2	351.9
	Dermochelyidae							
		Dermochelys	*coriacea*	Leatherback sea turtle	1	1	1.0	100.0
				Unidentified shelled sea turtle	33	31	0.9	468.1
PINNIPED								
	Odobenidae							
		Odobenus	*rosmarus*	Walrus	13	24	1.8	2279.5
	Otariidae							
		Arctocephalus	*gazella*	Antarctic Fur Seal	44	570	13.0	50.1
			australis	South American Fur Seal	15	34	2.3	518.7
		Callorhinus	*ursinus*	Northern fur seal	57	165	2.9	67.7
		Eumetopias	*jubatus*	Steller Sea Lion	8	28	3.5	122.2

NTL Category	Family	Genus	Species	Common Name	Number of Sighting Records Represented	Number of Individuals Recorded	Mean Group Size	Mean Closest Distance from Airguns (m)
	Phocidae							
		Phoca	*largha*	Spotted Seal	3	3	1.0	451.7
			vitulina	Harbor Seal	5	14	2.8	155.3
		Erignathus	*barbatus*	Bearded Seal	6	7	1.2	401.3
		Pusa	*hispida*	Ringed Seal	5	5	1.0	513.0
				Unidentified Sea Lion	1	1	1.0	700.0
				Unidentified Seal	32	36	1.1	203.5

Sightings by source activity – Minimum distance of approach

Data was merged across the three regions (Gulf of Mexico, West Africa and Australia) where these existed, with the inclusion of 'other regions', to provide a global assessment of the relationship between CA source status and the minimum distance of approach. In Table B-1 the species groups are summarized to show the median minimum distance of approach to the seismic source during different modes of seismic operation compared to silence. All results, apart from Beaked Whales demonstrated significant relationships when in full power operating mode. The significant difference between operating mode and silence was greatest for the 'Sperm Whale' species category during mitigation firing when compared against silence (Figure B-1). All species categories were significantly different and observed further from the source activity during ramp-up compared to silence (Figure A-1).

Figure A-2 shows the distribution of the data for distance of sightings in Global Regions. The proportion of sightings of all cetaceans within a given range of CA source arrays was reduced during periods when CA source activity was firing up to 1km, with Mitigation Firing with an increased percentage of sightings over silence from 1km+.

Table A-1: Median distance of approach for each species group for each source activity mode comparison to silence for global region.

	Species Group	Count	Firing Median	Silent Median	H	p- value
Full Power vs. Silent	**All Cetaceans**	7582	715	500	180.18	0.00
	Baleen Whales	1043	1000	775	24.92	0.00
	Delphinids	4433	633	500	68.92	0.00
	Sperm Whales	924	1750	900	94.15	0.00
	Turtles	958	208	200	8.52	0.00
	Beaked Whales	34	1688	1000	2.27	0.13
Mitigation Firing vs. Silent	**All Cetaceans**	4215	597	500	2.57	0.11
	Baleen Whales	559	723	775	0.26	0.61
	Delphinids	2481	500	500	0.33	0.57
	Sperm Whales	492	2000	900	18.84	0.00
	Turtles	531	249	200	2.25	0.13
Ramp-up vs. Silent	**All Cetaceans**	4417	700	500	25.34	0.00
	Baleen Whales	624	1000	775	5.37	0.02
	Delphinids	2630	500	500	5.32	0.02
	Sperm Whales	488	1650	900	8.47	0.00
	Turtles	757	250	200	11.77	0.00

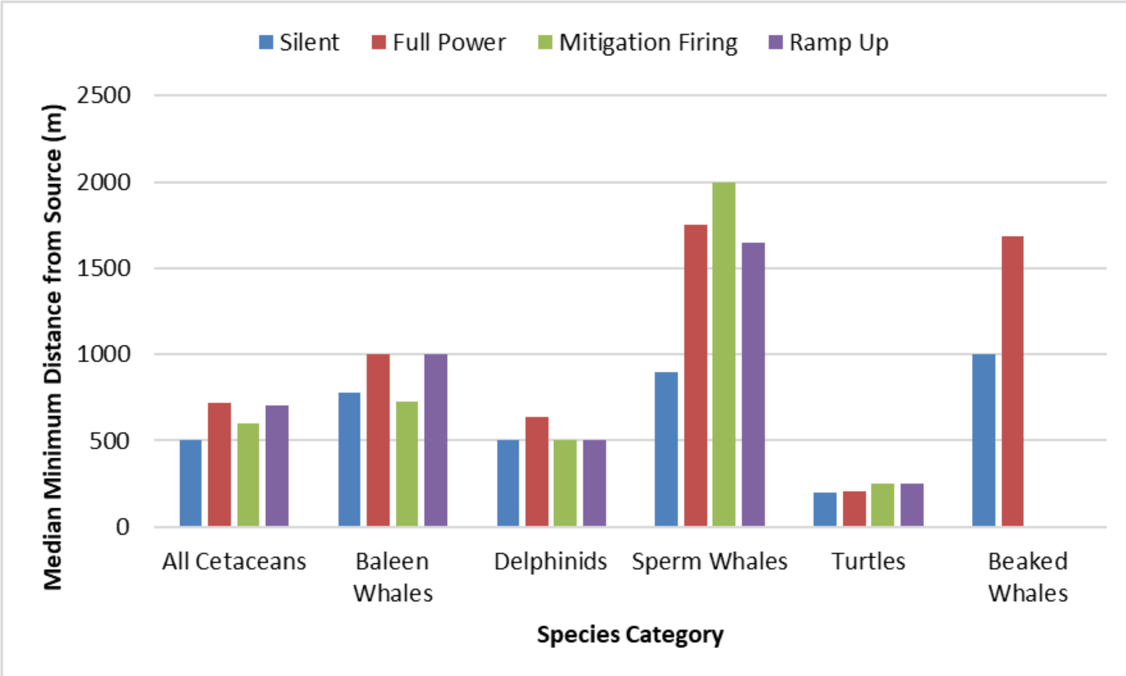


Figure A-1: Comparison of the Distance to the Seismic Source during Full Power, Mitigation, Ramp-up and Silence in Global dataset

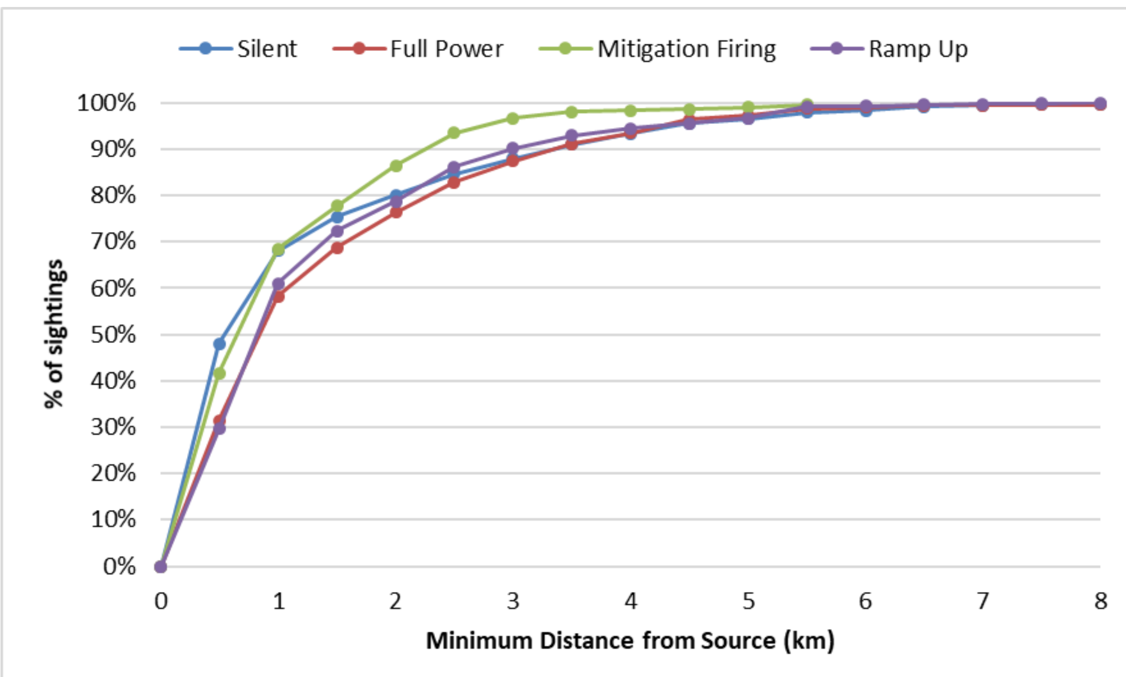


Figure A-2: Proportion of sightings occurring within specified distances of CA source arrays, in relation to CA source activity, for the Global dataset

Sightings by source activity – Duration of sighting

The data was merged across the three regions where data existed, with the inclusion of 'other regions', to provide a global assessment of the relationship between CA source status and the sightings duration. Table A-2 shows that all results, excluding pinnipeds, with sufficient sample size demonstrated significant relationships between the full power activity and the duration of the sightings. Pinnipeds had a very low sample for all source activities therefore weren't recorded. The difference between operating mode and silence is greatest (statically significant) for the 'Baleen Whales' and 'Turtles' species categories during Mitigation when compared against the silence (Figure A-3). Baleen Whales and Delphinids significantly different durations during ramp-up when compared to silence. Baleen Whales overall had the highest median sighting duration across all operating modes (Figure A-3).

Figure A-4 shows the distribution of the data for duration of sightings in Global Regions. The proportion of sightings of all cetaceans within a given range of CA source arrays was increased during periods when CA source activity was full power at all durations.

Table A-2: Median duration of sighting for each species group for each source activity mode comparison to silence in global regions.

	Species Group	Count	Median	Silent Median	H	p- value
Full Power vs. Silent	**All Cetaceans**	24497	7	8	64.84	0.00
	Baleen Whales	1593	21	18	8.40	0.00
	Delphinids	17529	8	10	109.05	0.00
	Sperm Whales	2305	9	11	20.44	0.00
	Turtles	2622	1	1	27.36	0.00
	Beaked Whales	48	11	5	1.73	0.19
Mitigation vs. Silent	**All Cetaceans**	10458	7	8	1.90	0.17
	Baleen Whales	835	25	18	4.55	0.03
	Delphinids	6841	10	10	0.45	0.50
	Sperm Whales	1179	15.5	11	1.42	0.23
	Turtles	1348	2	1	16.16	0.00
Ramp-up vs. Silent	**All Cetaceans**	10305	7	8	0.42	0.52
	Baleen Whales	854	28.5	18	6.38	0.01
	Delphinids	6831	7	10	14.80	0.00
	Sperm Whales	1165	9.5	11	0.17	0.68
	Turtles	1251	1	1	0.03	0.86

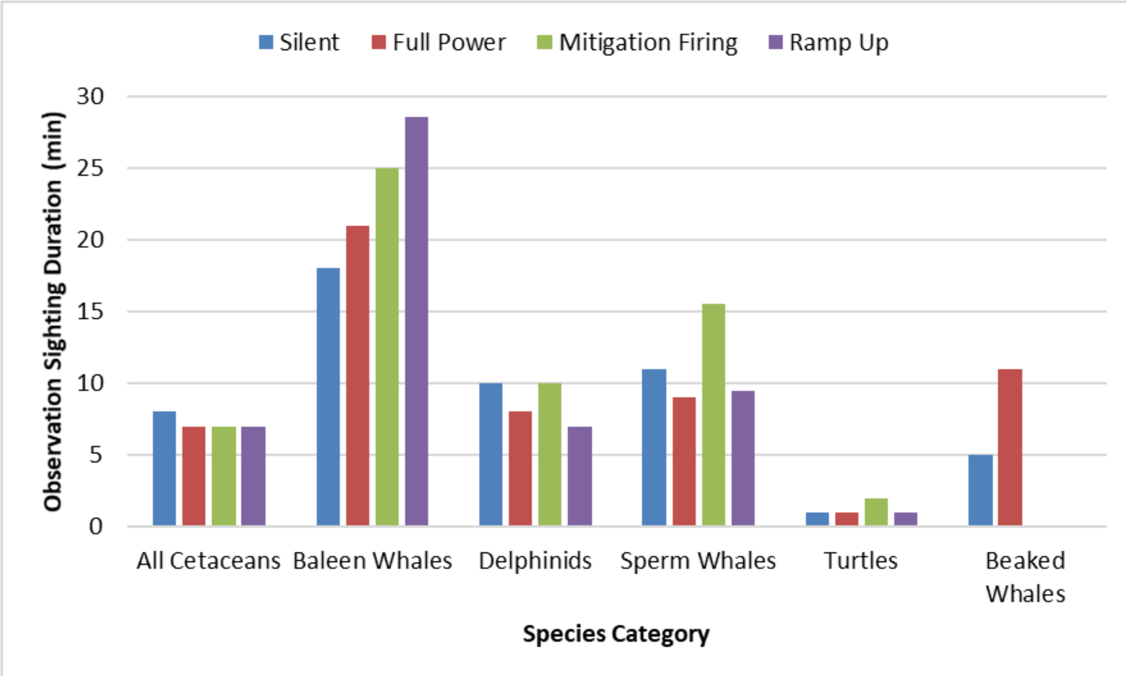


Figure A-3: Comparison of Median Sighting Duration during Full Power, Mitigation, Ramp-up and Silence in Global Regions dataset

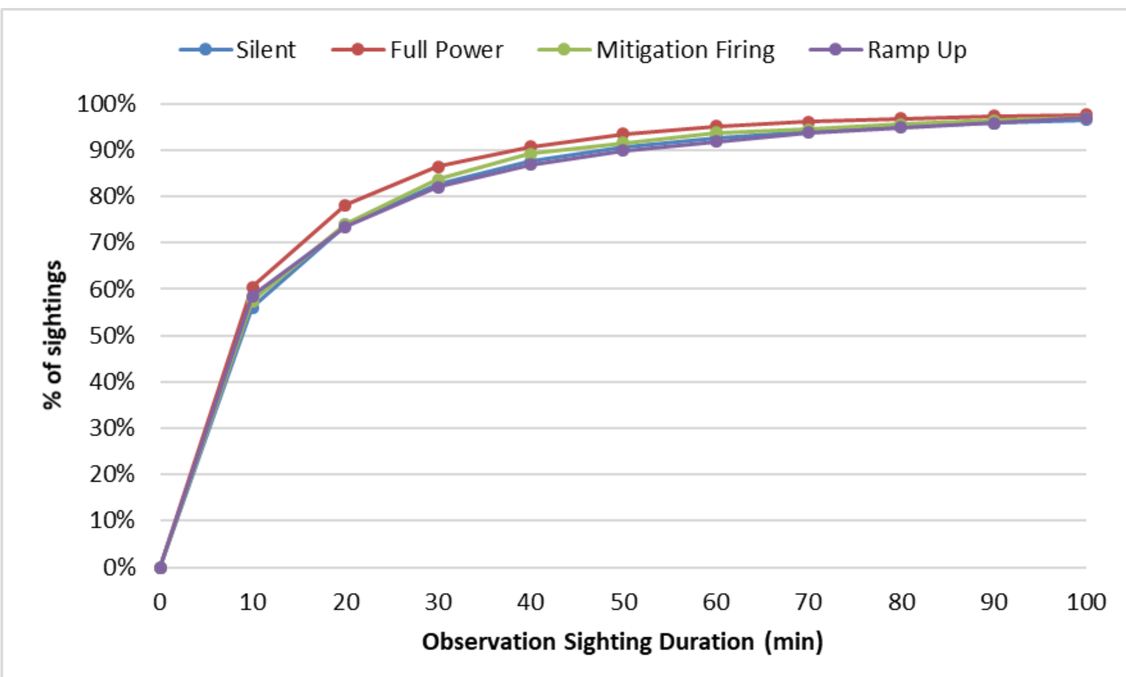


Figure A-4: Proportion of sightings occurring within specified durations of CA source ***arrays, in relation to*** CA source ***activity, for the Global dataset***

Sightings by source activity – Sighting Rate

The data was merged across the three regions where data existed, with the inclusion of 'other regions', to provide a global assessment of the relationship between CA source status and the sightings rate. Table A-3 shows that all results demonstrated statistically significant relationships between the source activity and silent. The difference between operating mode and silence is greatest for all species categories when silent (Figure A-5).

Figure A-6 shows the distribution of the data for rate of sightings in Global Regions. The proportion of sightings of all cetaceans within a given range of CA source arrays was increased during periods when CA source activity was firing at all durations.

Table A-3: Median sighting rate for each species group for firing activity mode comparison to silence in global regions

	Species Group	Count	Firing Median	Silent Median	H	p- value
Firing vs. Silent	**All Cetaceans**	4218	13.6	27.7	329.78	0.00
	Baleen Whales	211	17.1	41.9	5.99	0.01
	Delphinids	2071	22.4	43.0	167.32	0.00
	Sperm Whales	869	9.4	18.2	114.58	0.00
	Turtles	806	7.9	19.2	161.31	0.00
	Beaked Whales	35	5.0	10.7	10.78	0.00

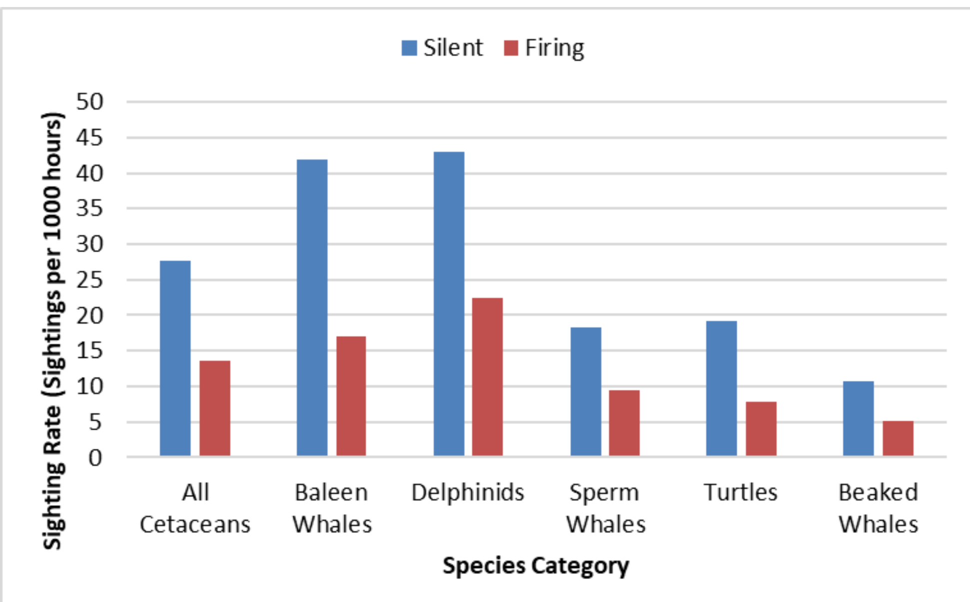


Figure A-5: Comparison of Median Sighting Rate per 1000 hours during Firing and Silence in Global Regions dataset.

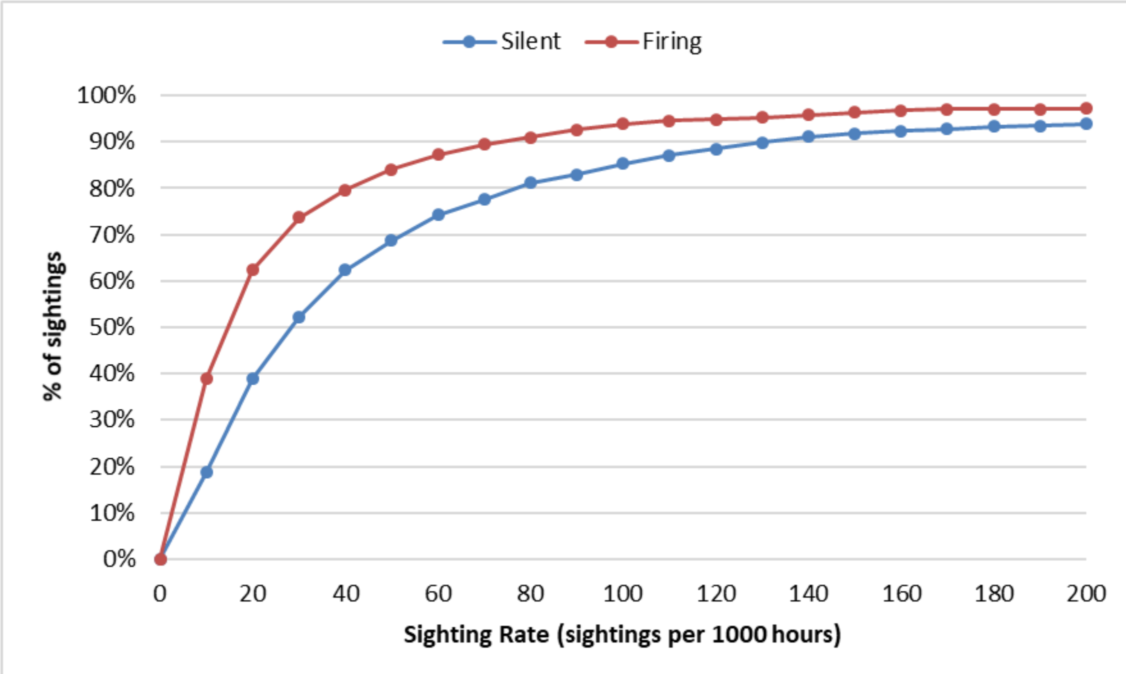


Figure A-6: Proportion of sightings occurring within specified sighting rate of CA source arrays, in relation to CA source activity, for the Global dataset.

Grouped Behavioural Observation

Table A-4, Table A-5, and Table A-6 below show a summary of the chi-squared behavioural analysis. For full power versus silence operating modes, ‘All Cetaceans’, ‘baleen whales’ ‘sperm whales’, ‘Delphinids’ and ‘turtles’ groups show significant behavioural relationships to the firing mode. ‘Beaked whales’ and ‘Pinnipeds’ had a limited sample size and no relationship (Table A-4). Figure A-7 presents that during full power operation, where ‘blowing, ‘diving’ and ‘swimming’ behaviours were most prevalent overall for ‘All Cetaceans’. The same species behaviour trend is present for mitigation and ramp-up (Figure A-8 and Figure A-9).

During mitigation versus silent operation mode ‘All Cetaceans’, ‘Delphinids’ and ‘Turtles’ species groups displayed significant relationships in their behaviour (Table A-5), whereas for ramp-up operation mode, no species group presented significance differences in behaviours (Table A-6).

‘Beaked Whales’ and ‘Pinnipeds’ had no significant relationship in the data for full power operation mode and limited sample size for mitigation and ramp-up modes (Table A-4).

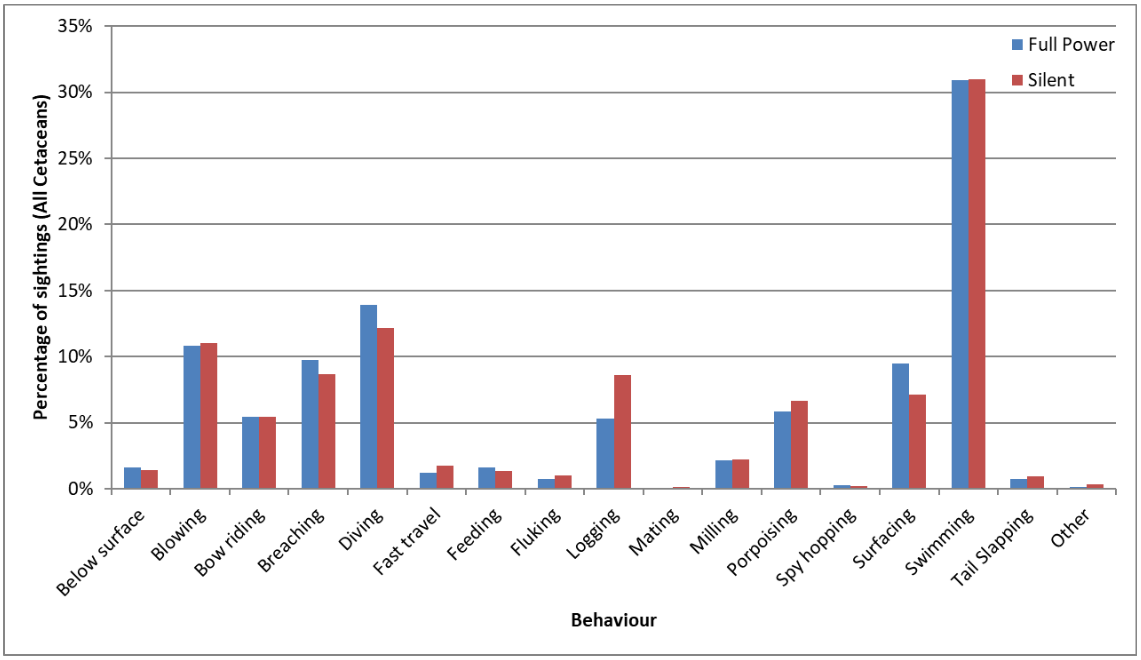


Figure A-7 Comparative behavioural responses of the 'All Cetaceans' group during full power and silence

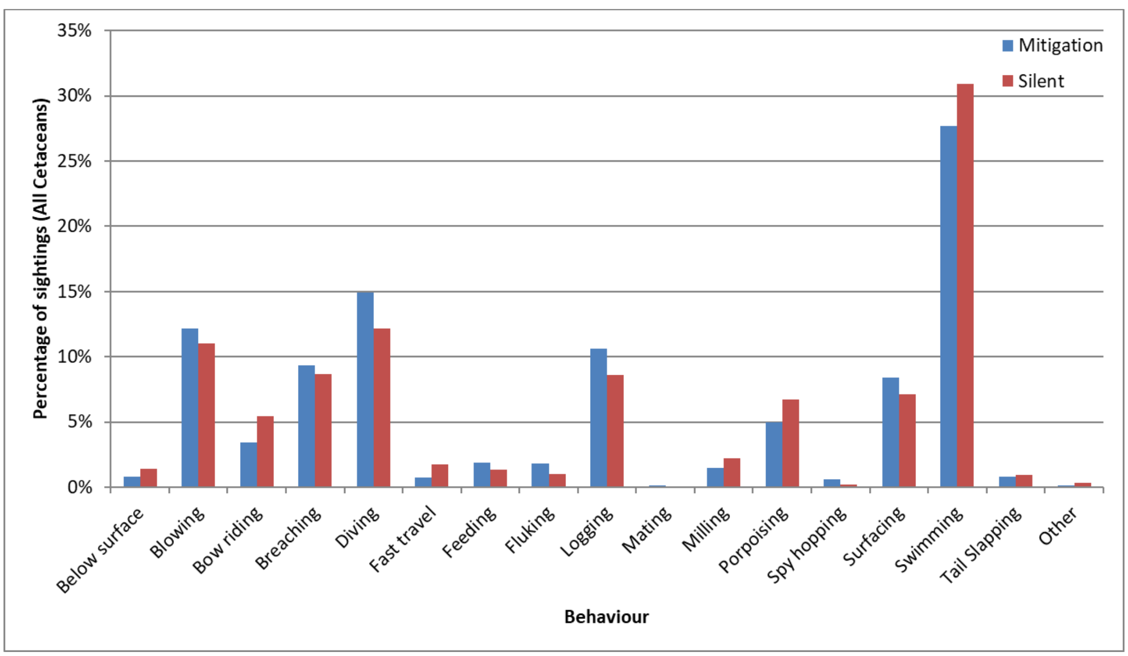


Figure A-8 Comparative behavioural responses of the 'All Cetaceans' group during mitigation and silence

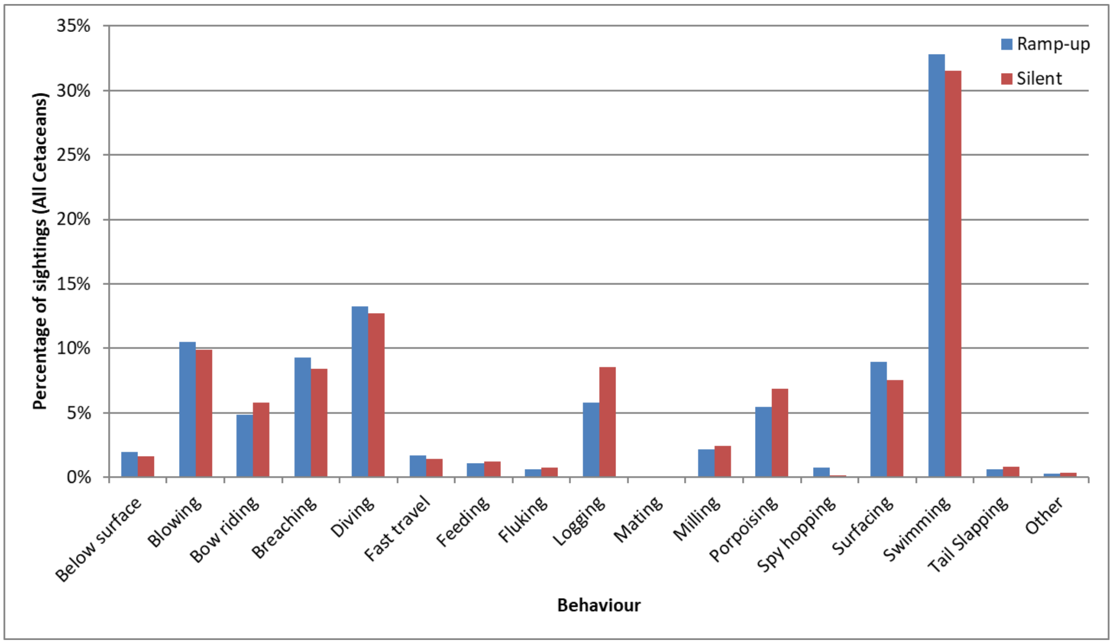


Figure A-9 Comparative behavioural responses of the 'All Cetaceans' group during ramp-up and silence.

Table A-4 Chi-squared results for Grouped Behaviours by Full Power CA source Status for the Global Regions (Greyed areas not included within analysis due to low sample size; n.s. = not significant)

	Full Power vs. Silent													
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**		**Beaked Whales**		**Pinnipeds**	
CA source Activity	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**	**Full Power**	**Silent**
Below surface	2%	1%	0%	0%	1%	1%	0%	0%	6%	5%	0%	0%	0%	0%
Blowing	11%	11%	42%	41%	4%	3%	34%	32%	0%	1%	33%	25%	0%	0%
Bow riding	5%	5%	0%	0%	9%	10%	0%	0%	0%	0%	0%	0%	0%	0%
Breaching	10%	9%	6%	8%	15%	14%	1%	1%	0%	0%	7%	8%	0%	1%
Diving	14%	12%	10%	6%	10%	9%	20%	19%	25%	24%	19%	13%	16%	6%
Fast travel	1%	2%	2%	1%	2%	2%	0%	0%	0%	1%	0%	2%	2%	1%
Feeding	2%	1%	2%	2%	2%	2%	0%	0%	1%	0%	0%	0%	0%	0%
Fluking	1%	1%	0%	0%	0%	0%	3%	4%	0%	0%	0%	1%	0%	0%
Logging	5%	9%	2%	2%	2%	5%	11%	12%	13%	16%	5%	4%	24%	40%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Milling	2%	2%	1%	1%	3%	3%	1%	1%	1%	1%	0%	1%	0%	4%
Porpoising	6%	7%	0%	0%	9%	10%	0%	0%	0%	0%	0%	1%	16%	20%
Spy hopping	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%
Surfacing	9%	7%	8%	7%	9%	7%	9%	9%	11%	8%	19%	18%	4%	2%
Swimming	31%	31%	25%	26%	32%	33%	20%	21%	41%	41%	17%	25%	35%	25%
Tail Slapping	1%	1%	3%	5%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Full Power vs. Silent													
Species Group	All Cetaceans		Baleen Whales		Delphinids		Sperm Whales		Turtles		Beaked Whales		Pinnipeds	
CA source Activity	Full Power	Silent	Full Power	Silent	Full Power	Silent	Full Power	Silent	Full Power	Silent	Full Power	Silent	Full Power	Silent
ϰ2	547.671		58.233		381.553		24.9748		62.1749		2.97576		5.04001	
n	17713		947		11054		2841		2482		37		37	
d.f.	17		10		16		8		10		3		2	
p	0.000		0.000		0.000		0.002		0.000		0.395		0.08	

Table A-5 Chi-squared results for Grouped Behaviours by Mitigation CA source Status for the Global Regions (Greyed areas not included within analysis due to low sample size; n.s. = not significant)

	Mitigation vs. Silent											
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**		**Pinnipeds**	
CA source Activity	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**
Below surface	1%	1%	0%	0%	1%	1%	0%	0%	2%	5%	0%	0%
Blowing	12%	11%	40%	39%	4%	3%	36%	31%	0%	1%	0%	0%
Bow riding	3%	5%	0%	0%	7%	10%	0%	0%	0%	0%	0%	0%
Breaching	9%	9%	3%	7%	18%	14%	2%	1%	0%	0%	0%	0%
Diving	15%	12%	7%	5%	6%	9%	19%	19%	39%	24%	20%	6%
Fast travel	1%	2%	1%	1%	0%	2%	1%	0%	0%	1%	0%	0%
Feeding	2%	1%	2%	2%	3%	2%	0%	0%	0%	0%	0%	0%
Fluking	2%	1%	13%	4%	0%	0%	2%	4%	0%	0%	0%	0%
Logging	11%	9%	1%	2%	4%	5%	11%	12%	30%	16%	20%	39%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
Milling	2%	2%	1%	1%	3%	3%	1%	1%	0%	1%	0%	4%
Porpoising	5%	7%	1%	0%	9%	11%	0%	0%	0%	0%	14%	20%
Spy hopping	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Surfacing	8%	7%	6%	6%	11%	7%	11%	9%	2%	8%	11%	2%
Swimming	28%	31%	22%	25%	32%	33%	15%	21%	27%	41%	34%	26%
Tail Slapping	1%	1%	2%	5%	1%	1%	2%	0%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ϰ2	64.2958		34.3822		51.5284		5.99626		81.6434		4.31949	

	Mitigation vs. Silent											
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**		**Pinnipeds**	
CA source **Activity**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**	**Mitigation**	**Silent**
n	1252		138		600		167		261		24	
d.f.	13		6		12		5		4		2	
p	0.000		0.000		0.000		0.307		0.000		0.115	

Table A-6 Chi-squared results for Grouped Behaviours by Ramp-up CA source Status for the Global Regions (Greyed areas not included within analysis due to low sample size; n.s. = not significant)

	Ramp-up vs. Silent									
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**	
CA source Activity	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**
Below surface	2%	2%	0%	0%	1%	1%	0%	0%	7%	5%
Blowing	10%	10%	40%	39%	2%	3%	33%	31%	1%	1%
Bow riding	5%	6%	0%	0%	7%	10%	0%	0%	0%	0%
Breaching	9%	8%	8%	8%	15%	14%	1%	1%	2%	0%
Diving	13%	13%	6%	5%	8%	9%	21%	19%	25%	24%
Fast travel	2%	1%	3%	1%	3%	2%	0%	0%	0%	1%
Feeding	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%
Fluking	1%	1%	6%	4%	0%	0%	3%	4%	0%	0%
Logging	6%	9%	0%	2%	4%	5%	9%	12%	18%	16%
Mating	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Milling	2%	2%	1%	1%	3%	3%	2%	1%	1%	1%
Porpoising	5%	7%	0%	0%	10%	10%	0%	0%	0%	0%
Spy hopping	1%	0%	3%	0%	1%	0%	0%	0%	0%	0%
Surfacing	9%	8%	8%	7%	7%	7%	10%	9%	10%	8%
Swimming	33%	31%	21%	25%	34%	33%	21%	21%	35%	41%
Tail Slapping	1%	1%	3%	5%	1%	1%	0%	0%	0%	0%
Other	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
χ2	13.2705		0.802309		9.08802		1.05723		2.25414	

	Ramp-up vs. Silent									
Species Group	**All Cetaceans**		**Baleen Whales**		**Delphinids**		**Sperm Whales**		**Turtles**	
CA source Activity	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**	**Ramp-up**	**Silent**
n	647		59		465		122		95	
d.f.	12		3		11		4		4	
p	0.350		0.849		0.614		0.901		0.689	

Individual Behavioural Analysis

There were significant differences in 'Delphinids' behaviours for some behaviours listed in Table A-7 when the seismic source was active compared with silent, including greater incidences of blowing, breaching, diving and surfacing. There was a lower incidence of bow-riding, logging and porpoising during full power operation. 'Baleen whales' were observed to dive and fast travel significantly more frequently in full power and less frequently breaching and tail slapping. The 'Sperm Whales' species category was observed to undertake blowing activity significantly more frequently during full power compared to silence and fluking less frequently.

Turtles were observed to be swimming below the surface and also surfacing significantly more frequently during full power compared to silence, whereas they were observed to be logging significantly less frequently compared to silence. Pinnipeds were observed swimming significantly more frequently when in full power compared to silent.

Table A-7 Chi-squared results for individual behaviours during full power operation compared with silence

Species Group	Behaviour Category	*CA source* Activity	Behaviour Frequency	ϰ2	n	d.f.	p
Baleen Whales	Blowing	Full Power	42%	0.710077	947	1	0.399
		Silent	41%				
	Breaching	Full Power	6%	5.85744	947	1	0.016
		Silent	8%				
	Diving	Full Power	10%	28.9437	947	1	0.000
		Silent	6%				
	Fast Travel	Full Power	2%	8.97279	947	1	0.003
		Silent	1%				
	Feeding	Full Power	2%	0.0348055	947	1	0.852
		Silent	2%				
	Fluking	Full Power	0%	3.95163	947	1	0.047
		Silent	0%				
	Logging	Full Power	2%	0.743145	947	1	0.389
		Silent	2%				
	Milling	Full Power	1%	2.36046	947	1	0.124
		Silent	1%				
	Surfacing	Full Power	8%	1.17581	947	1	0.278
		Silent	7%				
	Swimming	Full Power	25%	0.501717	947	1	0.479
		Silent	26%				
	Tail Slapping	Full Power	3%	8.19601	947	1	0.004

Species Group	Behaviour Category	*CA source* Activity	Behaviour Frequency	ϰ2	n	d.f.	p
		Silent	5%				
Delphinids	Below surface	Full Power	1%	4.45662	11054	1	0.035
		Silent	1%				
	Blowing	Full Power	4%	13.3255	11054	1	0.000
		Silent	3%				
	Bow riding	Full Power	9%	14.1716	11054	1	0.000
		Silent	10%				
	Breaching	Full Power	15%	10.5418	11054	1	0.001
		Silent	14%				
	Diving	Full Power	10%	29.9092	11054	1	0.000
		Silent	9%				
	Fast travel	Full Power	2%	24.9145	11054	1	0.000
		Silent	2%				
	Feeding	Full Power	2%	2.40013	11054	1	0.121
		Silent	2%				
	Fluking	Full Power	0%	1.42753	11054	1	0.232
		Silent	0%				
	Logging	Full Power	2%	116.378	11054	1	0.000
		Silent	5%				
	Mating	Full Power	0%	4.40742	11054	1	0.036
		Silent	0%				
	Milling	Full Power	3%	0.007870 1	11054	1	0.929
		Silent	3%				
	Porpoising	Full Power	9%	17.5425	11054	1	0.000
		Silent	10%				
	Spy hopping	Full Power	0%	13.171	11054	1	0.000
		Silent	0%				
	Surfacing	Full Power	9%	129.557	11054	1	0.000
		Silent	7%				
	Swimming	Full Power	32%	1.88898	11054	1	0.169
		Silent	33%				

Species Group	Behaviour Category	*CA source* Activity	Behaviour Frequency	ϰ2	n	d.f.	p
	Tail slapping	Full Power	1%	0.139129	11054	1	0.709
		Silent	1%				
	Other	Full Power	0%	20.5407	11054	1	0.000
		Silent	0%				
Sperm Whales	Below surface	Full Power	0%	3.41184	2842	1	0.065
		Silent	0%				
	Blowing	Full Power	34%	6.21078	2842	1	0.013
		Silent	32%				
	Breaching	Full Power	1%	3.70815	2842	1	0.054
		Silent	1%				
	Diving	Full Power	20%	2.28137	2842	1	0.131
		Silent	19%				
	Fluking	Full Power	3%	5.17643	2842	1	0.023
		Silent	4%				
	Logging	Full Power	11%	3.22827	2842	1	0.072
		Silent	12%				
	Milling	Full Power	1%	3.57868	2842	1	0.059
		Silent	1%				
	Surfacing	Full Power	9%	0.227424	2842	1	0.633
		Silent	9%				
	Swimming	Full Power	20%	0.480266	2842	1	0.488
		Silent	21%				
Turtles	Below surface	Full Power	6%	10.8197	2482	1	0.001
		Silent	5%				
	Blowing	Full Power	0%	3.0005	2482	1	0.083
		Silent	1%				
	Breaching	Full Power	0%	0.379321	2482	1	0.538
		Silent	0%				
	Diving	Full Power	25%	0.0824883	2482	1	0.774
		Silent	24%				
	Fast travel	Full Power	0%	3.01928	2482	1	0.082

Species Group	Behaviour Category	*CA source* Activity	Behaviour Frequency	ϰ2	n	d.f.	p
		Silent	1%				
	Feeding	Full Power	1%	0.795938	2482	1	0.372
		Silent	0%				
	Logging	Full Power	13%	20.455	2482	1	0.000
		Silent	16%				
	Milling	Full Power	1%	0.163422	2482	1	0.686
		Silent	1%				
	Surfacing	Full Power	11%	29.3303	2482	1	0.000
		Silent	8%				
	Swimming	Full Power	41%	0.566865	2482	1	0.452
		Silent	41%				
Beaked Whales	Blowing	Full Power	33%	0.838605	37	1	0.360
		Silent	25%				
	Diving	Full Power	19%	0.809043	37	1	0.368
		Silent	13%				
	Surfacing	Full Power	19%	0.0041135	37	1	0.949
		Silent	18%				
	Swimming	Full Power	17%	2.48093	37	1	0.115
		Silent	25%				

Direction of travel

Table A-9 below shows a summary of the chi-squared species directional analysis. For all operational modes versus silence 'All Cetaceans', 'Baleen Whales', 'Sperm Whales' and 'Delphinids' groups showed significant directional relationships to the CA source activity modes. 'Beaked Whales' were only observed during full power and silent status and presented significance in regard to direction of travel. However, they had a limited sample size (N=29). No sightings were recorded for 'Beaked Whales' during mitigation and Ramp-up status. 'Pinnipeds' were only observed during full power and mitigation, presenting significant differences for the former but both seismic status' had limited sample sizes. During ramp-up operational mode, 'Turtles' were found to have no significant relationship.

Figure A-10 shows that during full power, operation 'parallel to ship same direction' and 'towards ship' were most prevalent overall for 'All Cetaceans' at >20% sighting frequency. Statistical differences can be seen in directional types such as 'away from ship' and 'crossing path of ship', which were more prevalent for 'All Cetaceans' when the seismic source was at full power (Figure A-10). Conversely, 'milling', 'parallel to ship in opposite direction', 'parallel to ship in same direction' and 'towards ship' were more prevalent when the seismic source was silent.

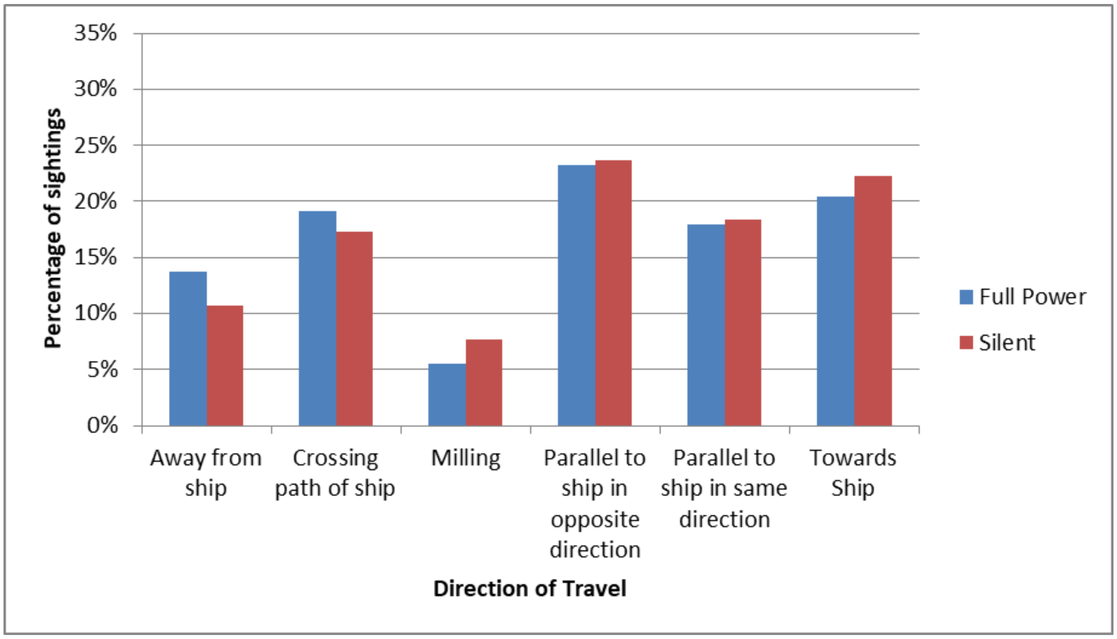


Figure A-10: Comparative directional travel responses of the "All Cetaceans" group during full power and silence

During mitigation versus silent operation mode (Figure A-11), when comparing direction of travel, 'away from ship', 'crossing path of ship', 'millings' and 'parallel to ship in opposite direction' are more common directional types for 'All Cetaceans' during mitigation whereas 'parallel to ship in same direction' and 'towards ship' were more frequently displayed during silent periods.

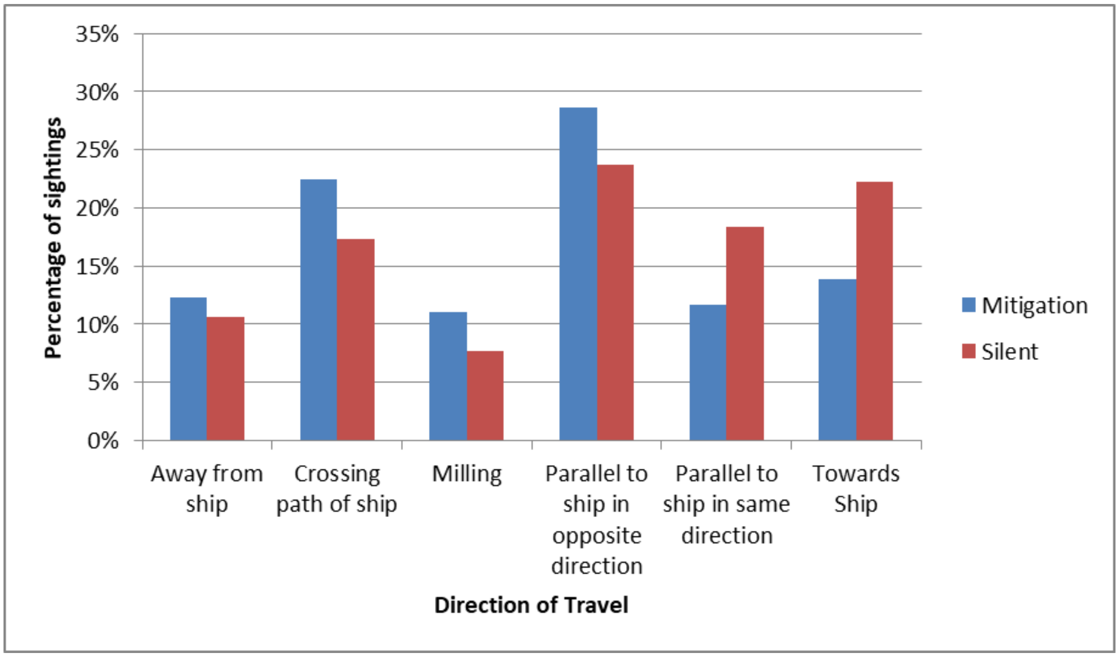


Figure A-11: Comparative directional travel responses of the "All Cetaceans" group during mitigation and silence.

When comparing the direction of travel between silent and ramp-up for 'All Cetaceans' (Figure A-12), 'crossing path of ship', 'milling' and 'parallel to ship in same direction' were more commonly observed directional types during ramp-up whereas 'away from ship', 'parallel to ship in same direction' and 'towards ship' were more frequently observed during silent periods, with the latter the most frequently sighted (approx. 25%).

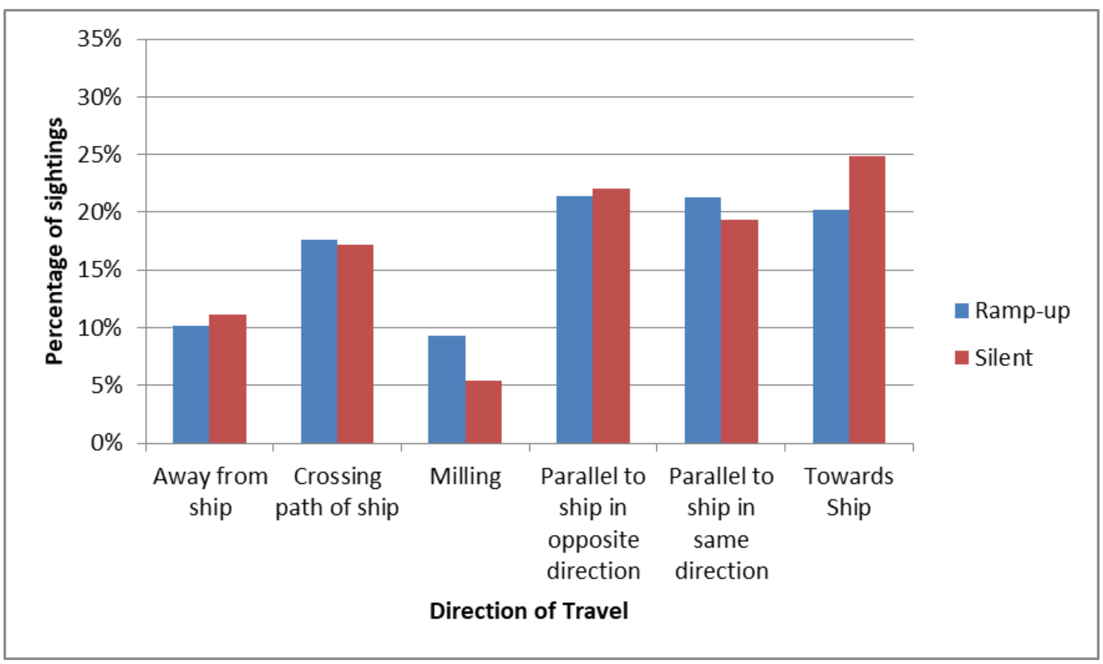


Figure A-12: Comparative directional travel responses of the "All Cetaceans" group during ramp-up and silence.

Table A-9 Chi-squared results for Grouped Direction of travel by seismic source status for the Combined Regions (Greyed areas not included within analysis due to low sample size)

			Percentage									
	Species Group	Airgun Activity	Away from ship	Crossing path of ship	Milling	Parallel to ship in opposite direction	Parallel to ship in same direction	Towards Ship	2	n	d.f.	p
Full Power vs. Silent	All Cetaceans	Full Power	14%	19%	6%	23%	18%	20%	297.469	16344	5	0.000
		Silent	11%	17%	8%	24%	18%	22%				
	Baleen Whales	Full Power	14%	24%	13%	34%	12%	4%	79.4958	868	5	0.000
		Silent	9%	17%	17%	40%	12%	7%				
	Delphinids	Full Power	8%	21%	5%	18%	20%	28%	279.592	10209	5	0.000
		Silent	7%	17%	7%	16%	20%	33%				
	Sperm Whales	Full Power	29%	22%	5%	18%	22%	4%	301.672	2669	5	0.000
		Silent	16%	27%	6%	22%	24%	6%				
	Turtles	Full Power	21%	4%	5%	46%	10%	14%	70.9691	2370	5	0.000
		Silent	20%	6%	6%	48%	10%	9%				
	Beaked Whales	Full Power	45%	17%	0%	38%	0%	0%	170.576	29	5	0.000
		Silent	3%	43%	2%	18%	10%	23%				
	Pinnipeds	Full Power	12%	27%	37%	12%	8%	4%	16.5141	43	3	0.001
		Silent	18%	8%	32%	14%	15%	14%				
Mitigation vs. Silent	All Cetaceans	Mitigation	12%	22%	11%	29%	12%	14%	114.453	1148	5	0.000
		Silent	11%	17%	8%	24%	18%	22%				
	Baleen Whales	Full Power	15%	24%	10%	38%	5%	8%	17.1885	131	5	0.004
		Silent	9%	17%	17%	39%	11%	7%				
	Delphinids	Mitigation	7%	30%	8%	20%	12%	22%	98.0805	559	5	0.000
		Silent	7%	17%	7%	16%	20%	33%				
	Sperm Whales	Mitigation	25%	29%	8%	14%	21%	3%	16.2544	155	5	0.006
		Silent	16%	27%	6%	22%	24%	6%				
	Turtles	Mitigation	14%	3%	16%	54%	9%	3%	68.9251	237	5	0.000
		Silent	20%	6%	6%	48%	10%	9%				
	Pinnipeds	Ramp-up	23%	9%	37%	26%	0%	6%	1.03294	30	2	0.597
		Silent	63%	34%	146%	69%	69%	49%				
Ramp-up vs. Silent	All Cetaceans	Ramp-up	10%	18%	9%	21%	21%	20%	22.7587	579	5	0.000
		Silent	11%	17%	5%	22%	19%	25%				
	Baleen Whales	Full Power	5%	20%	13%	38%	23%	0%	13.3841	60	5	0.020
		Silent	9%	17%	17%	39%	11%	7%				
	Delphinids	Ramp-up	8%	20%	12%	17%	17%	25%	29.6018	428	5	0.000
		Silent	7%	17%	7%	16%	20%	33%				
	Sperm Whales	Ramp-up	18%	21%	12%	23%	27%	0%	17.2935	119	5	0.004
		Silent	16%	27%	6%	22%	24%	6%				
	Turtles	Ramp-up	10%	6%	5%	50%	16%	13%	8.98555	94	5	n.s.
		Silent	20%	6%	6%	48%	10%	9%				