Preliminary Analysis of Marine Observer data from New Zealand seismic surveys

Report prepared by Blue Planet Marine for the New Zealand
Department of Conservation Marine Species and Threats Team

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Department of Conservation
Te Papa Atawhai

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1. Analysis of Seismic Survey Observer Data: An Introduction

The following report provides a summary analysis of the data collected by visual and acoustic observers during seismic surveys in New Zealand waters and other related information. This data was collected during seismic surveys undertaken with the *2012* and *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code). New Zealand's Department of Conservation (DOC) determined that such a summary analysis was required to inform the review of the Code that began in earnest in early 2015. No formal review of the data contained in this record had been made to date.

This data analyses sought to provide a rigorous exploration of the data contained within this record to generate additional information about the marine mammals in New Zealand waters and to inform the current review of the Code. This included: a review of the species recorded and their locations; an assessment of any differences in the rates of detection made by visual and acoustic means; and a review of the mitigation measures taken in association with the detections. A discussion of the various limitations within the data collected, as well as possible areas of improvement, was also sought.

Due to the pressing need for this information during the Code review process, the extent to which the data could be subjected to a quality control process was limited. Furthermore, it is not possible to identify or correct many errors after-the-fact, especially for surveys that occurred two or three years previously. Moreover, data collected under the first year of the Code was less comprehensive and complete than later data, as the Code was introduced only as a voluntary set of articles in 2012. However, after the Code was brought into regulatory effect in the EEZ in 2013 data collection by observers became more important and more consistent.

Accordingly, we acknowledge that errors persist within the data and thus also the resulting analyses. However, for the most part, the following results provide an indication of the real trends and patterns that are contained within. For example, even if species are misidentified on occasion, it is unlikely that an area with very high detection rates could be indicated without a true real-world basis. Similarly, while any individual record of the distance from a seismic source to a marine mammal may be incorrect, the influence of such an error is diminished when considered as part of a fairly extensive data set.

The greatest exception to this confidence in the following review is related to the analyses of the behavioural data. In addition to the known and unknown errors in these data, they are subjective at best. Furthermore, a number of the behavioural categories recorded were uninformative – admittedly a fault of the original sheets.

Even so, this and other such discoveries have provided insight that will help improve the quality and usefulness of the data collected going forward. The review also helped identify data that either should be collected to answer pressing management questions, or that were not of great use to such needs.

In short, given the paucity of data in this area, we feel that the following review contains useful information for those seeking to appropriately manage and mitigate acoustic impacts on marine mammals and other marine life.

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Report:

Analysis of Marine Observer data from New Zealand seismic surveys

BPM-15-DOC-Analysis of Marine Observer data from NZ seismic surveys-v1.4

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1. Executive Summary

The *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code) requires operators undertaking seismic surveys to report all marine mammal sightings and marine mammal interactions with seismic operations. These must be provided to the Department of Conservation (DOC) following completion of each survey. These records comprise a data set potentially useful in increasing our understanding of marine mammals in New Zealand waters, and in understanding both the interactions of marine mammals with seismic operations and the operation of the Code.

Blue Planet Marine (BPM) was commissioned by DOC to undertake a preliminary analysis and summary of data collected by Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring Operators (PAMOs) on seismic surveys in New Zealand waters since 2013. This includes operations under the original 2012 Code and the revised 2013 Code.

DOC provided records from 26 different surveys. Data from all surveys were used for all analyses, except where data were recorded on non-standard Electronic Reporting Forms (ERFs) and/or were incomplete. Surveys were given a Survey Identification Number (ID) in order to maintain confidentiality. Overall, most were 3D Marine Seismic Surveys (MSS) (46%), followed by 2D MSS (31%), Vertical Seismic Profiling (which also includes Check Shot Surveys) (19%) and Multi-beam (4%). They comprised Level 1 Surveys (77%), followed by Level 2 Surveys (19%), and Level 3 Surveys (4%). All surveys were used to investigate marine mammal sightings data, but only Level 1 and 2 surveys were used to analyse mitigation actions, as these are not mandatory for Level 3 surveys.

Overall, there were 1,159 suitable records of detections (i.e. detected by either visual or acoustic methods) of cetaceans from the 26 surveys. There were 36 different taxa identification descriptions recorded in the data. The ten most common taxa identifications comprised 91% of all detections and 92% of all individuals detected. Of the ten most common identifications, only five represent identification to species level (i.e. common dolphin, blue whale, long-finned pilot whale, sperm whale, dusky dolphin) and the remainder are generic identification to group or general description (i.e. Dolphins and toothed whales, Whale (unspecified), Baleen whale, Unidentified large cetacean, unidentified small cetacean).

In addition, there were 1,550 detections of NZ fur seals from the 26 surveys. These are reported separately to cetaceans and also have generally different mitigation requirements. For that reason, we have reported NZ fur seal data separately to cetaceans.

Of the 1,159 cetacean detections, data were sufficient to determine the method of detection for 1,108 records with the remaining records being incomplete. Of these, detections made visually by MMOs accounted for 816 (74%), detections made acoustically by PAMOs accounted for 202 (18%) and detections that were made by both visual and acoustics were 90 (8%). Visual and acoustic monitoring can be undertaken at different times (e.g. PAM only at night), and under different conditions so it is not appropriate to compare them directly as effort can vary considerably. However, during times when both monitoring methods were in operation simultaneously, there were 626 detections. Of these, 493 (79%) were detected only by MMOs, 43 (7%) only by PAMOs and 90 (14%) were detected by both. All NZ fur seals were detected visually. There were no records of any acoustic detections of NZ fur seals, which is expected.

There were 172 mitigation actions undertaken as a result of a cetacean interaction and an additional 3 mitigation actions for fur seals. Of these, 140 were shutdowns, 31 were delays to soft starts (including all three fur seal mitigation actions), and four other actions. All but one action were undertaken during Level 1 surveys. The most common species for mitigation actions were long-finned pilot whales, dolphins and toothed whales, blue whales and sperm whales. Overall, there was a total

of 444 hours of survey time lost due to marine mammal mitigation actions (i.e. shut downs, delays to soft starts) with an average length of mitigation action of 2.5 (SE = 0.2) hours.

Total survey effort (e.g. port to port) from the 26 surveys was 18,499 hours. Of this, 44% of survey effort was in the Taranaki Petroleum Basin, 19% in the Canterbury Basin, with the remainder split between the Great South, Pegasus, East Coast and Reinga Basins. Overall, 7,964 hours of seismic acquisition (i.e. total amount of time in Full Power status) was undertaken again with the majority in Taranaki and Canterbury Basins.

Overall, the mean detection rate of cetaceans across all observation time was 0.07 detections per hour. This varied from a high of 0.11 in the East Coast to a low of 0.04 in both the Great South and Pegasus Petroleum Basins. The average fur seal detection rate was 0.09 per hour varying from 0.26 to 0.02 in the Canterbury and Taranaki Petroleum Basins respectively. For periods with only MMOs or only PAMOs on watch, the average hourly detection rates for cetaceans were 0.09 and 0.03 respectively. When both MMOs and PAMOs were on watch together the average hourly detection rates for cetaceans was 0.08.

It was not possible to compare detection rates from these seismic surveys with a control situation with no seismic activity as all data is collected from seismic survey vessels. However, we were able to compare the hourly cetacean detection rate for when the seismic source was active and at full power (0.11) with when the seismic source was inactive (0.15). While these values are useful, they are not necessary directly comparable as survey effort varied both temporally and spatially, potentially influencing the results.

Overall, this project provides a useful insight into the operation of the Code in New Zealand waters and represents a useful preliminary investigation of the monitoring of cetaceans and fur seals from seismic surveys, including the mitigation of the impacts of seismic on them.

2. Introduction

In June 2013, the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 was brought into force by the making of regulations that permit lower impact activities, subject to conditions. Under the regulations, seismic surveying is classified as a permitted activity if the person undertaking the seismic survey complies with the *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code).

Amongst other things, the Code stipulates assessments and actions required for various 'Levels' of seismic surveys in order to mitigate their potential effects on marine mammals. This includes the development and approval of a Marine Mammal Impact Assessment (MMIA), sound transmission loss modelling (when required), and a Marine Mammal Mitigation Plan (MMMP). Additional mitigation measures may be required by the Director General of Conservation (DG) of the Department of Conservation (DOC) if the survey is in, or close to, an area of ecological importance (AEI) or marine mammal sanctuary (MMS).

The Code requires operators undertaking seismic surveys to report all marine mammal sightings and marine mammal interactions with seismic operations. These must be provided to DOC following completion of each survey. These records comprise a data set potentially useful in increasing our understanding of marine mammals in New Zealand waters, and in understanding both the interactions of marine mammals with seismic operations and the operation of the Code.

Blue Planet Marine (BPM) was commissioned by DOC to undertake a preliminary analysis and summary of data collected by Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring Operators (PAMOs) on seismic surveys in New Zealand waters since 2013. This includes operations under the original 2012 Code and the revised 2013 Code.

2.1 Aims and objectives

The overall objective of the analysis was to provide a summary of marine mammal interactions with seismic surveys with a view to informing the present review of the Code.

The specific aims of the analysis were:

1. Undertake a general review of marine mammal survey data including:
    a. Species;
    b. Location; and
    c. Numbers.
2. Summarise marine mammal detections by both visual and acoustic methods including:
    a. Breakdown of detections into by visual, acoustic or both methods;
    b. Simple analysis of how many times marine mammals have been detected by one method but not the other when they were both operating including any explanations when a detection was not made by both methods; and
    c. Summary of Effort (i.e. hours) for each detection method.
3. Review and summarise possible areas for improvement with the DOC standard Seismic on- and off-effort reporting forms;
4. Summarise details of shutdowns and delayed starts including:
    a. Number;
    b. Reason for shut down/delay start (e.g. species inside mitigation zone; PAM non-operational);
    c. Geographic location;
    d. Length of seismic downtime before restarting;
    e. General review of which species were responsible for mitigation actions; and
    f. Distances of marine mammal detections at which shutdown occurred.

5. Summarise MMO and PAM survey effort and also seismic acquisition including:
    a. Number of hours (and km, where possible) for on- and off-effort monitoring; and
    b. Breakdown by geographic area.
    c. General review of marine mammal data including predominant behaviour.
6. Compile a Master database of all the collated data to be made available to DOC.

3. Methodology

3.1 Data provided

DOC provided data from all marine surveys that were undertaken in accordance with the Code or under the auspices of the Code (including some cases where operators voluntarily agreed to follow the Code) since 2013. This includes operations under the original 2012 Code and the revised 2013 Code. These surveys included standard marine seismic surveys using vessels towing a seismic source and streaming arrays but also included other survey types such as Vertical Seismic Profiling (VSP), Check Shot Surveys (CSS) and also some multi-beam echo sounder (MBES) surveys.

There are two files provided by DOC to operators for use in the collection of marine mammal sighting and interaction data. Copies of the blank forms are available from DOC[1]. These Effort Reporting Forms (ERFs) comprise:

- ON survey Excel reporting form; and
- OFF survey Excel reporting form.

These ERFs are completed by MMOs and PAMOs on the vessels or platforms and are returned to DOC at the completion of the survey (or each swing).

The terms on- and off-effort are applied differently in this data set to the standard use of the terms. In most other cases, off-effort generally corresponds to times when there was no observation effort and on-effort to when observations were undertaken. This is not the case with this data set as observations can be made during both on- and off-effort. The only difference between these effort categories was that on-effort observations were undertaken inside the designated operational area for that survey and off-effort observations were undertaken outside of the designated operational area. Data is collected and effort is apportioned in exactly the same way under both circumstances.

It is important to note that all detections of marine mammals other than fur seals are reported in a single form but fur seals are reported in a separate worksheet within the same excel file. Not only are fur seals reported separately but they also have different reporting fields. As a result and consistent with the separate reporting mechanisms, we will also report fur seals separate to all other marine mammals.

3.2 Quality assurance (QA)

For the purposes of this preliminary analysis and summary, BPM undertook some general QA testing and review of the data provided. Given the short period available for this project, only basic QA was undertaken. Most QA was undertaken while analysing data, whereby confusing or apparently incorrect results would cause further examination of specific issues. Other data were generally reviewed, including but not limited to species identification codes and positions provided for fields related to location at first detection.

[1] http://www.doc.govt.nz/our-work/seismic-surveys-code-of-conduct/notification-and-reporting/

Given some complexities and intricacies of the ERFs, not all data could be directly lifted from these forms into the Master database and a considerable amount of manual data copying was required.

Whenever a data irregularity or error was detected it was recorded, and if appropriate corrected in the Master database. Detailed notes were kept of all records that were amended and how they were amended. The original raw, data files were not amended or altered in any way.

3.3 Data summaries

Unless otherwise stated all data are derived from the On-Effort and Off-Effort ERFs and associated worksheets within those files. BPM notes that the analysis provided in this report provides a preliminary review and the focus of the project was in developing a complete Master database of records and in undertaking preliminary assessments. Given the limited time available for this research, additional more detailed investigations could be useful for addressing these questions in more detail or addressing new questions.

3.3.1 General marine mammal observations

AIM 1: Undertake a general review of marine mammal survey data including species, location, and numbers.

Species	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. The "*Sub Order and Family*" and "*Species*" fields were used to develop a new field called "*Final identification*". The value in the "Species" field was used but if there was no record in this field, then the value from "*Sub Order and Family*" was used. This provided the most accurate level of identification for each record.
Location	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. The fields "*1st detect lat degree*" and "*1st detect lng degree*" plus associated minute information was used as the location of each record. This represents the position of the vessel or platform at the time the first sighting was made. We chose to use this value in the preliminary analysis because it was the most complete location field and most easily transferred from the ERFs. We note that this location does not reflect the exact position of the actual marine mammal being detected but is a useful proxy during preliminary analysis. Based on preliminary analysis, the average distance of first sighting for each detection was 1.8 km (SE = 0.05 km) from the observer position on the source vessel and 90% of first sightings were made within 3.8km of the source vessel.
Breakdown by geographic area	For the purposes of preliminary analysis, we have allocated all effort to a specific sedimentary basin following GNS Science (2011) map[2]. Where a single survey crossed between one or more boundaries, we have attempted to allocate effort proportionally based on the time spent in each area. This was estimated using the dates provided in the "*On Survey Effort*" and the "*Off Survey Effort*" worksheets from the ERFs. Then, the total effort was allocated pro rata between each sedimentary basin based on the proportion of time spent in each basin.
Number	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. There are a range of fields that report the number of marine mammals. We chose to use three fields "*No. adults. Best estimate*", "*No. calves. Best estimate*", and "*Total Best Estimate*".

[2] http://www.gns.cri.nz/Home/Learning/Science-Topics/Fossil-Energy/New-Zealand-s-Sedimentary-Basins

Season	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. The "*Date*" field was used to assign a season to all sightings according to the following criteria: Spring (September, October, November); Summer (December, January, February); Autumn (March, April, May); and Winter (June, July, August).

3.3.2 Summarise marine mammal detections by both visual and acoustic methods

AIM 2: Summarise marine mammal detections by both visual and acoustic methods including:

- ***a. Breakdown of detections into by visual, acoustic or both methods;***
- ***b. Simple analysis of how many times marine mammals have been detected by one method but not the other when they were both operating including any explanations when a detection was not made by both methods; and***
- ***c. Summary of Effort (i.e. hours) for each detection method.***

Breakdown of detections into visual and acoustic	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. There are two fields for this: "*Record type*" and "*First detection cue*". The first indicates whether the detection was made by visual, PAM or both visual and PAM. The second indicates which method first made the detection.
Detection rate	The above field was used to investigate the relative frequency of detections made by visual/PAM/both. Associated notes and the original detection record were used to provide additional information.
Summary of effort	The "*On Survey Effort*" and the "*Off Survey Effort*" worksheets from the ERFs were used to estimate effort. Total amount of effort was estimated from summing the total time for visual only effort (i.e. 1 MMO, 2 MMOs, 3 MMOs), acoustic only effort (i.e. PAM only) with effort for when both monitoring methods were being utilised (i.e. 1 MMO & PAM, 2 MMOs & PAM and 3 MMOs & PAM). Analysis didn't attempt to weight visual survey times when more than one MMO was on duty as part of this preliminary review.

3.3.3 Review and summarise possible areas for improvement

AIM 3: Review and summarise possible areas for improvement with the DOC standard Seismic on- and off-effort reporting forms

During the review of data (including inputting, irregularities and analysis), and BPM's ongoing experience with the use of these forms at sea, we include some suggested areas for improvement.

3.3.4 Summarise details of shutdowns and delayed starts

AIM 4: Summarise details of shutdowns and delayed starts including:

- ***a. Number;***
- ***b. Reason for shut down/delay start (e.g. species inside mitigation zone; PAM non-operational);***
- ***c. Geographic location;***
- ***d. Length of seismic downtime before restarting;***
- ***e. General review of which species were responsible for mitigation actions; and***
- ***f. Distances of marine mammal detections at which shutdown occurred.***

Number of events	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. The fields "*Vessel array status at first sighting*" and "*Action taken*" fields were used to determine the number of mitigation events.
Reason for shut down or delayed start	This information was determined from the individual marine mammal detection record related to the mitigation event in question.
Geographic location	Data provided in the "*Detection Summary*" worksheet from the ERFs were used. The fields "*1st detect lat degree*" and "*1st detect lng degree*" plus associated minute information was used as the location of each record. This represents the position of the vessel or platform at the time that the first sighting was made. We chose to use this value in the preliminary analysis because it was the most complete location field and most easily transferred from the ERFs. We note that this location does not necessarily reflect the exact position of the actual mitigation event but is a useful proxy.
Length of seismic down time	The "*On Survey Effort*" and the "*Off Survey Effort*" worksheets from the ERFs were used to estimate length of seismic downtime. The fields "*Vessel array status at first sighting*" and "*Time Start (NZDT)*" were used to identify each mitigation event and estimate total time lost to mitigation. The events we specifically estimated were: • Shut Down (SD) during Full Power (FP) operations: estimated from start time of SD until start time of next FP; • Shut Down (SD) during Soft Start (SS) procedures: estimated from start time of SD until start time of next SS; • Shut down (SD) during source Testing (TT): estimated from start time of SD to start time of FP; and • Delayed Start (DS) during soft start (SS) procedures: estimated from start time of DS until start of next SS. There are some assumptions inherent in these approaches. One example: if multiple mitigation events occur before the source achieves full power then we have considered it to be one single event from the start of the first until reaching full power. Another example relates to source testing, and given that sometimes the operation doesn't return to TT status it is difficult to estimate how much time has been lost. Our approach estimates time lost to seismic operations rather than the length of a mitigation event itself. It is possible that this approach may: • overestimate the time lost to mitigation events (e.g. additional operational delays occurring during the mitigation event would be attributed to mitigation rather than an operational event); and/or • underestimate the additional time required to complete seismic acquisition (e.g. shut downs when the survey doesn't immediately go back and cover the missed survey lines may lead to the requirement for infill of missing lines which could require significant additional survey effort which wouldn't be captured in this approach).

Species responsible for mitigation actions	As noted in Section 3.3.1, we developed the field "*Final identification*" to best represent the most accurate identification. This field was matched against the "*Action taken*" field from the "*Detection Summary*" worksheet from the ERFs.
Distances of marine mammal at which shut down occurred	This information was determined from the individual marine mammal detection record related to the mitigation event in question. In addition to this specific question, we also summarised the closest recorded approach of the marine mammal to the acoustic source.

3.3.5 Summarise MMO and PAM survey effort and seismic acquisition

AIM 5: Summarise MMO and PAM survey effort and seismic acquisition

- ***a. Number of hours (and km where ever possible) for on- and off-effort monitoring; and***
- ***b. Breakdown by geographic area.***
- ***c. General review of marine mammal data including predominant behaviour***

MMO and PAM survey effort	This has already been described in Section 3.3.2 with respect to hours of monitoring effort. It is not possible to determine the length of achieved survey effort in km as that is not reported to DOC in any of the ERFs. As a result we have not reported results here.
Seismic acquisition effort	The "*On Survey Effort*" and the "*Off Survey Effort*" worksheets from the ERFs were used to estimate seismic acquisition effort. By using the "*Array Status*" field it is possible to estimate total effort in "*FP*" (Full Power). We make the assumption that the source operating at full power is equivalent to seismic acquisition but note that this will include periods when the source may be at full power but not necessarily at the exact position where data acquisition commenced.
Breakdown by geographic area	As described in Section 3.3.1, for the purposes of preliminary analysis, we have allocated all effort to a specific sedimentary basin following GNS Science (2011) map[3]. Where a single survey crossed between one or more boundaries, we have attempted to allocate effort proportionally based on the time spent in each area.
General review of marine mammal data	As described in Section 3.3.1, data provided in the "*Detection Summary*" worksheet from the ERFs were used. The fields "*1st Behaviour*", "*Predominate Behaviour*", "*Last Behaviour*" and "*General behaviour of animals*" were summarised. This was supplemented by any notes recorded on the individual sighting records. With respect to "*1st Behaviour*", "*Predominate Behaviour*", and "*Last Behaviour*", only those records that had observations in all three fields were used in analysis.

3.3.6 Compile a database of reference material

AIM 6: Compile a Master database of all the collated data to be made available to DOC.

[3] http://www.gns.cri.nz/Home/Learning/Science-Topics/Fossil-Energy/New-Zealand-s-Sedimentary-Basins

All of the individual survey records were compiled into a single Master database using Microsoft Excel software (2013). This allows summaries to be made across all the available records. The Master database can be saved as older versions of Excel (e.g. Excel 97-2003) although some functionality – mainly associated with pivot tables – may be lost.

3.4 Data analysis

A preliminary analysis of all the data identified in Section 3.3 was undertaken to provide an overview of summary statistics. In addition, simple spatial analyses were also undertaken in QGIS in order to investigate a range of data spatial characteristics.

3.5 Assumptions

This work represents a preliminary analysis and was completed under very tight and short deadlines but is a useful first look at these data. Therefore, it has been necessary to make a range of assumptions in undertaking this analysis including:

- All data provided is accurate and correct. A simple QA process was undertaken on some of the main features of the data and any errors identified were corrected. However, the data set would benefit from a full QA process to identify other potential irregularities or errors;
- This analysis does not include any investigations of issues related to non-compliances and these issues were specifically excluded from this analysis;
- The analyses undertaken are generally directly representative of the questions of interest but in some cases, the data available are not optimal for investigating the question. However, analyses and results do represent useful proxies that can inform these questions. Some other data useful to these questions may be available but was not accessible at the time of this research;
- Data was collected on all marine mammal species but the only non-cetacean species recorded were New Zealand fur seals. Sightings of fur seals are recorded separately from other marine mammals in the DOC Reporting Forms. For the purpose of this report, sightings of fur seals are reported separately to other marine mammals. Furthermore, given that all marine mammal detections other than fur seals were cetaceans, it is more appropriate to use the term cetacean rather than marine mammal when reporting detections other than fur seals; and
- The location used in reporting represents the position of the vessel or platform at the time the first sighting was made. We chose to use this value in the preliminary analysis because it was the most complete location field and most easily transferred from the ERFs. We note that this location does not necessarily reflect the exact position of the actual marine mammal being detected but is a useful proxy during preliminary analysis. Based on preliminary analysis, the average distance of first sighting for each detection was 1.8 km (SE = 0.05 km) from the observer position on the source vessel and 90% of first sightings were made within 3.8km of the source vessel. Based on this assessment and the geographic scope of the review, we believe that this a useful proxy for location. Ideally, future updates would use the exact position of the detection.

4. Results and Discussion

4.1 General summary of available data

DOC provided records from 26 different surveys. Data from all surveys were used for all analyses, except where data were recorded on non-standard ERFs and/or were incomplete. Surveys were given a Survey Identification Number (ID) in order to maintain confidentiality and are based on the year in which the survey commenced followed by a letter. Summary information is provided in Table 1.

Overall, most were 3D Marine Seismic Surveys (MSS) (46%), followed by 2D MSS (31%), Vertical Seismic Profiling (which also includes Check Shot Surveys) (19%) and Multi-beam (4%). They comprised Level 1 Surveys (77%), followed by Level 2 Surveys (19%), and Level 3 Surveys (4%). All surveys were used to investigate marine mammal sightings data, but only Level 1 and 2 surveys were used to analyse mitigation actions, as these are not mandatory for Level 3 surveys.

Table 1: Summary of marine surveys analysed including approximate proportion of time spent in each Petroleum Basin.

No	ID	Type	Level	Approximate % of time in each Petroleum Basin					
				Taranaki	Great South	Canterbury	Pegasus	East Coast	Reinga
1	2013A	3D MSS	1	100					
2	2013B	3D MSS	1	100					
3	2013C	3D MSS	1	100					
4	2013D	3D MSS	1	100					
5	2013E	3D MSS	1	100					
6	2013F	2D MSS	2	100					
7	2013G	VSP	2	100					
8	2013H	3D MSS	1			100			
9	2014A	3D MSS	1	100					
10	2014B	2D MSS	1		5	95			
11	2014C	VSP	2	100					
12	2014D	2D MSS	1				100		
13	2014E	VSP	1	100					
14	2014F	VSP	1			100			
15	2014G	2D MSS	1	100					
16	2014H	2D MSS	1	100					
17	2014I	2D MSS	1				20	80	
18	2014J	2D MSS	2	100					
19	2014K	VSP	2	100					
20	2014L	2D MSS	1	40					60
21	2014M	3D MSS	1			100			
22	2015A	3D MSS	1	100					

No	ID	Type	Level	Approximate % of time in each Petroleum Basin					
				Taranaki	Great South	Canterbury	Pegasus	East Coast	Reinga
23	2015B	3D MSS	1			100			
24	2015C	3D MSS	1	100					
25	2015D	3D MSS	1		100				
26	2015E	Multi-beam	MBES[4]	100					

4.2 General marine mammal observations

AIM 1: Undertake a general review of marine mammal survey data including species, location, and numbers.

Unless otherwise stated, results below exclude NZ fur seals.

Overall, there were 1,168 records of detections (i.e. detected by either visual or acoustic methods) of marine mammals from the 26 surveys. Nine records were excluded due to insufficient identification information leaving 1,159 useful records. There were 36 different taxa Identification descriptions recorded in the data. The ten most common taxa identifications comprised 91% of all detections and 92% of all individuals detected. Of the ten most common identifications, only five represent identification to species level (i.e. common dolphin, blue whale, long-finned pilot whale, sperm whale, dusky dolphin) and the remainder are generic identification to group or general description (i.e. Dolphins and toothed whales, Whale (unspecified), Baleen whale, Unidentified large cetacean, unidentified small cetacean). Given that no pinnipeds other than fur seals were detected, it is more correct to refer to all detections as cetaceans when discussing general detections.

Of the 36 different taxa identification descriptions, 22 were to species or sub-species level and the remainder were to varying levels of identification. Confidence of identification was rated as certain/probable/possible in 75%/19%/6% of all records accordingly. The seasonal breakdown of records by Spring/Summer/Autumn/Winter was 1%/52%/42%/5% respectively.

Overall, all 'dolphins' (consisting of common dolphin, dusky dolphin, unidentified small cetacean, Orca, southern right whale dolphin, dolphins, bottlenose dolphin, unidentified dolphin, Hector's dolphin, killer whale, long-beaked common dolphin, porpoise, Risso's dolphin) and all 'whales' (consisting of blue whale, long-finned pilot whale, whale (unspecified), sperm whale, baleen whale, unidentified large cetacean, Sei whale, Bryde's whale, pilot whale, false killer whale, fin whale, southern right whale, Balaenopteridae rorquals, beaked whales, minke whale, short finned pilot whale, pygmy blue whale, humpback whale, southern bottlenose whale, Ziphidae beaked whale) comprised 31% and 52% of all detections respectively. Seventeen percent were unable to be assigned to either whale or dolphin given the lack of specificity of the record.

The average distance offshore for all cetaceans and fur seals was 77 (SE = 1.8) km and 72 (SE = 1.1) respectively (Figure 1).

[4] MBES: Multibeam Echo Sounder

Table 2: Summary of cetacean detections

Taxa	No records	Total number of individuals	Average number of individuals per detection	No records with calves	Total number of calves	Average number of calves per detection
Common dolphin	262	7,594	29	33	154	5
Dolphins and toothed whales	184	1,430	8	5	23	5
Blue whale	136	253	2	11	11	1
Long-finned pilot whale	123	2,546	21	57	187	3
Whale (Unspecified)	91	138	2	4	5	1
Sperm whale	87	262	3	6	7	1
Baleen whales	76	118	2	2	2	1
Unidentified large cetacean	42	60	1	0		
Dusky dolphin	39	3,763	96	6	17	3
Unidentified small cetacean	18	26	1	0		
Delphinidae	12	56	5	0		
Orca	8	21	3	1	1	1
Southern right-whale dolphin	8	243	30	0		
Dolphins	7	48	7	0		
Sei whale	7	10	1	0		
Bottlenose dolphin	6	32	5	0		
Bryde's whale	6	9	2	1	1	1
Pilot whale	6	51	9	3	10	3
False killer whale	5	51	10	0		
Fin whale	5	11	2	0		
Southern right whale	4	7	2	0		
Balaenopteridae rorquals	3	3	1	0		
Beaked whales	3	3	1	0		
Minke whale	3	3	1	0		
Short-finned pilot whale	3	22	7	0		
Unidentified dolphin	3	13	4	1	1	1
Odontoceti	2	5	3	0		
Pygmy blue whale	2	5	3	1	1	1
Hector's dolphin	1	13	13	0		
Humpback whale	1	4	4	1	2	2
Killer whale	1	1	1	0		
Long-beaked common dolphin	1	800	800	0		
Porpoise	1	3	3	0		

Taxa	No records	Total number of individuals	Average number of individuals per detection	No records with calves	Total number of calves	Average number of calves per detection
Risso's dolphin	1	6	6	0		
Southern bottlenose whale	1	1	1	0		
Ziphidae Beaked whale	1	2	2	0		
TOTAL	**1,159**	**17,613**	**15.1**	**132**	**422**	**0.36**

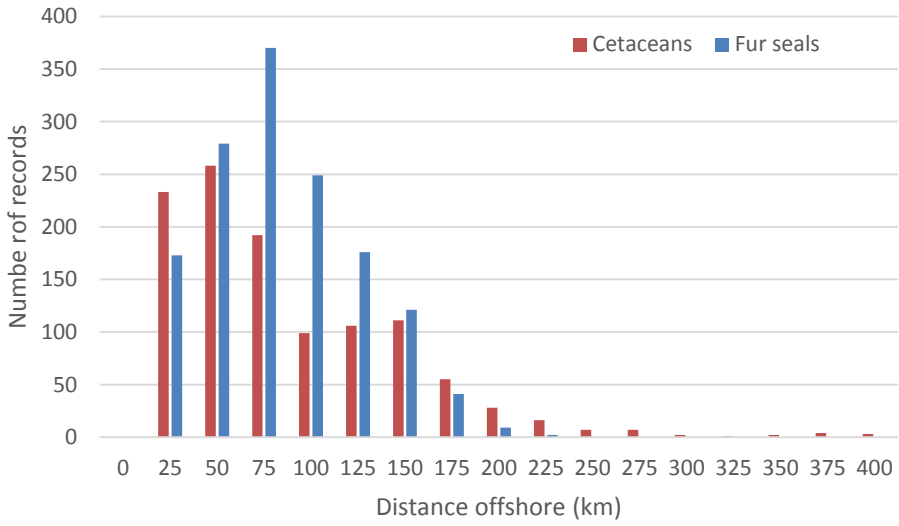

Figure 1: Summary of distance offshore of all cetacean (n=1124) and fur seal (n=1420) detections for which locations were available (NB. Not weighted by offshore distance of survey effort).

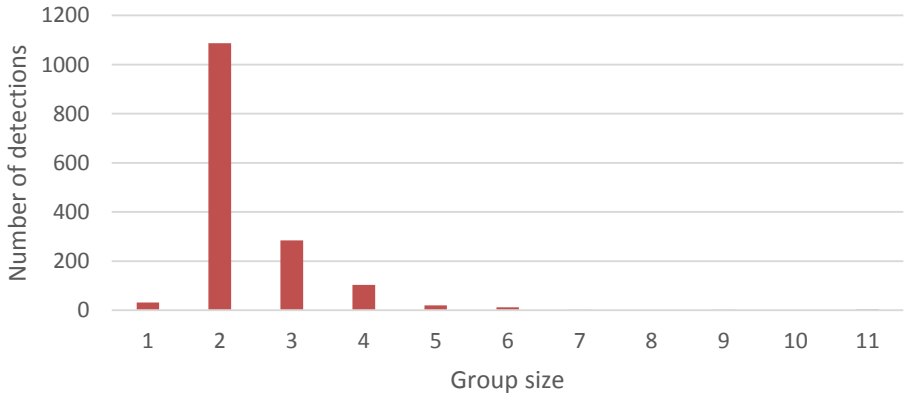

Figure 2: Summary of group size of NZ fur seal detections.

Overall, there were 1,550 detections of NZ fur seals from the 26 surveys. These are reported separately to cetaceans and have their own effort worksheet (*'On Survey Seal'* and *'Off Survey Seal'*) within the

ERFs. They also have generally different mitigation requirements. For that reason, we have reported NZ fur seal data separately to cetaceans.

4.3 Summarise marine mammal detections by both visual and acoustic methods

AIM 2: Summarise marine mammal detections by both visual and acoustic methods including:

a. Breakdown of detections into by visual, acoustic or both methods; and
b. Summary of Effort (i.e. hours) for each detection method.

Of the 1,159 cetacean detections, data were sufficient to determine the method of detection for 1,108 records with the other records being incomplete. Of these, detections made visually by MMOs accounted for 816 (74%), detections made acoustically by PAMOs accounted for 202 (18%) and detections that were made by both visual and acoustics were 90 (8%). Visual and acoustic monitoring can be undertaken at different times (e.g. PAM only at night), and under different conditions so it is not appropriate to compare them directly as effort varies (see Section 4.6 for further discussion of this issue). However, during times when both monitoring methods were in operation simultaneously, there were 626 detections. Of these, 493 (79%) were detected only by MMOs, 43 (7%) only by PAMOs and 90 (14%) were detected by both.

All NZ fur seals were detected visually. There were no records of any acoustic detections of NZ fur seals, which is expected.

Table 3: Summary of cetacean detections by detection method.

Detected by:	MMO only operating	PAM only operating	MMO and PAM operating	Combined
MMO only	323	0	493 (79%)	816 (74%)
PAM only	0	159	43 (7%)	202 (18%)
Both	0	0	90 (14%)	90 (8%)
TOTAL	**323**	**159**	**626 (100%)**	**1,108 (100%)**

4.4 Review and summarise possible areas for improvement

AIM 3: Review and summarise possible areas for improvement with the DOC standard Seismic on- and off-effort reporting forms

Investigation of the DOC ERFs will be part of the wider review of the Code. In light of this we have focussed on what we think are some more fundamental areas where the ERFs may be improved. We also pose some questions that may assist in determining priorities, which in turn may inform any future redesign of ERFs. These include:

- The ERFs are complex and can take observers considerable time to complete. This often decreases the time observers are able to maintain watch as they are busy filling in forms.
- What is the priority: are observers on seismic vessels to implement mitigation as per the Code, or to collect data to be used for research and management decisions?
- An overall review of the utility of data fields would be useful. What are the core reasons for recording the current data and what data are essential to inform these core reasons? Core reasons for data collection may include:
    - An understanding of the effects of seismic surveys on marine mammals;

- Government enforcement of the Code; and
- A general understanding of marine mammal species distribution in order to inform adaptive management.

- ERF software compatibility and ERF usability:
  - While Excel is widely-used software, it can be limiting. Consideration of alternative platforms (such as specifically designed relational databases) may provide a better platform for data entry and more powerful tool for data analysis. For example, see the Australian Government Cetacean Sighting Application (CSA) https://data.marinemammals.gov.au/csa;
  - Currently the ERF is in Excel 2003 format. Using newer versions of Excel has caused compatibility issues, corrupted files and affected data;
  - There are errors in the ERF, which affect data accuracy. It would be useful to fix these and release updated ERFs. Errors have two main forms: formula errors within the ERF and errors that allow inconsistency of data entry by observers. Examples of formula errors are listed in Table 4 below. Data entry errors/inconsistencies include:
    - Observers choosing 'Family' and 'Species' entries from drop-down lists in a marine mammal detection worksheet, that are inconsistent. For example, The Family 'Dolphins' may be chosen, and then the species is 'Dolphins and toothed whales'. These lists could be refined and options in the species cell should be relevant to the family which has been chosen;
    - Sometimes cells are able to be left empty (e.g. observation point – Cell C6 in a marine mammal detection worksheet – is often left empty if the detection is made by PAM) when they require an entry for subsequent data calculations (e.g. MM Distance to source – Cell K52 of a marine mammal detection worksheet). This often causes the #VALUE error;
    - Observers inconsistently enter 'NA' rather than 'Poor' in the 'sighting conditions for visual observations' column in the 'On survey Effort' and 'Off Survey Effort' worksheets when PAM only is on watch. 'NA' should only be used then the entry in the 'Monitoring' column is 'No observations'.

Table 4: Examples of formula errors in the DOC ON survey excel reporting form

Worksheet	Cell #	Formula Error	Correct Formula
On Survey Summary	P2002	=SUMIF(M2:M881,"NA",H2:H881)	=SUMIF(M2:M1989,"NA",H2:H1989)
As above	P2006	=SUMIF(I2:I881,"dr",H2:H881)	=SUMIF(I2:I1989,"dr",H2:H1989)
As above	P2012	=SUMIF(J2:J881,"fo",H2:H881)	=SUMIF(J2:J1989,"fo",H2:H1989)
As above	R2017	=SUMIF(N2:N1989,"PAM only",H2:H881)	=SUMIF(N2:N1989,"PAM only",H2:H1989)
As above	P2024	=SUMIF(K2:K881,"4",H2:H881)	=SUMIF(K2:K1989,"4",H2:H1989)
On Survey Summary	N2019	=(N2018*100)/#REF!	=(N2018*100)/T2018
As above	Q2019	=(Q2018*100)/U2018	=(Q2018*100)/T2018

Worksheet	Cell #	Formula Error	Correct Formula
On Survey Summary	D552	='On Survey Effort'!#REF!	='On Survey Effort'!A556
On Survey Summary	D551	='On Survey Effort'!A556	='On Survey Effort'!A555

- The ability to use the tab key to move between cells and to type the first letter of a field entry instead of having to select from drop-down menus would make data entry quicker;
- It would be useful to not have restrictions on the number of characters in the animal description and general behaviour fields;
- A review of the 'family' and 'species' fields of the individual marine mammal detection worksheets would be useful. Ideally selecting a particular 'family' should reduce the possible 'species' to only those relevant. At present observers can choose species that do not relate to the 'family' selected;
- For each detection, the behaviour section appears repetitive (describe behaviour + first behaviour + predominant behaviour + last behaviour). Is this all necessary and can this be revised? Also, the fur seal worksheet requires similar information;
- For each detection, is the 'position of first detection' drag plot map necessary when a map with the waypoints plus the manual entry of waypoints is also required?;
- There appears to be inconsistency in how delays to soft starts are recorded. It would be useful to have more clarity on how delay soft starts need to be recorded in the ERFs. For example, a delay start (DS) may be entered as the 'Action taken' in a marine mammal detection worksheet, but that DS may not be recorded by some observers in the appropriate cell from K52 downwards in that same record. Further, the 'Array Status' DS may also not be entered into the 'On Survey Effort' worksheet for that detection. Rather 'Array Status' is often left as 'NG' and no new line was entered to reflect the beginning of a DS; and
- The ERFs appear to be designed so that one set of 'on-' and 'off-survey' ERFs should be completed for each swing. This causes significant issues when compiling a final report for a survey. It is not straightforward to combine data from several ERFs. It would be very helpful if this could be addressed.

4.5 Summarise details of shutdowns and delayed starts

AIM 4: Summarise details of shutdowns and delayed starts including:

a. Number;
b. Reason for shut down/delay start (e.g. species inside mitigation zone; PAM non-operational);
c. Geographic location;
d. Length of seismic downtime before restarting;
e. General review of which species were responsible for mitigation actions; and
f. Distances of marine mammal detections at which shutdown occurred.

The following section provides a breakdown of mitigation actions in response to the sighting of a cetaceans. Consistent with the ERF, we have reported all fur seals separately to cetaceans

With respect to fur seals, although there were 1550 sightings, there were only three mitigation actions undertaken. These were all delays to soft start when a seal was seen within the 200 m mitigation zone. The average time lost per fur seal mitigation event was only 12 (SE = 0.9) minutes with a total delay of 27 minutes over the three events.

Table 5:Summary of cetacean mitigation actions by Survey level (MBES: Multibeam Echo Sounder).

Action taken:	**Survey level**				**Total**
	1	**2**	**3**	**MBES**	
Shutdown	139	0	0	1	140
Delay soft start	28	0	0	0	28
Other	4	0	0	0	4
TOTAL	**171**	**0**	**0**	**1**	**172**

Table 6: Summary of taxa that caused cetacean mitigation actions by Detection type (i.e. MMO or PAMO). (Mitigation events: DSS – Delayed Soft Start; SD – Shut Down; O – Other)

Taxa	**MMO**				**PAM**				**Total**
	DSS	**SD**	**O**	**Total**	**DSS**	**SD**	**O**	**Total**	
Long-finned pilot whale	6	34		40	2	2		4	44
Dolphins and Toothed whales	1	4		5	5	23	1	28	33
Common dolphin[5]	4	18	1	22	2	6		8	30
Blue whale	1	18	2	19					19
Sperm whale	3	9		12					12
Whale (Unspecified)	1	7		8					8
Baleen whales	1	4		5					5
Pilot whale		2		2		1		1	3
Southern right whale		3		3					3
Bottlenose dolphin		2		2					2
Short-finned pilot whale		1		1		1		1	2
Beaked whales	1			1					1
Delphinidae					1			1	1
Fin whale		1		1					1
Minke whale		1		1					1
Southern bottlenose whale		1		1					1
Unidentified small cetacean						1		1	1
TOTAL	18	105	3	123	10	34	1	44	167

[5] Common dolphins are not defined as “species of concern” under the 2013 Code and therefore shut downs are not required for common dolphins (but delayed starts are required). However shutdowns are required for all marine mammals when operating in a Marine Mammal Sanctuary, which resulted in a number of shutdowns for common dolphins in the West Coast North Island Marine Mammal Sanctuary.

Table 7: Summary of cetacean mitigation actions by reason for mitigation (MMS: operating inside Marine Mammal Sanctuary; EMZ: operating with extended mitigation zone; unspecified: not clear which mitigation zone was applied (i.e. PAM detection without location).

Mitigation Action[6]	Shutdown	Delay soft start	Total
Within mitigation zone (unspecified)	56	19	75
Within 1000 m mitigation zone	31	2	33
Within mitigation zone (MMS)	27	2	29
Within 1500 m mitigation zone	12	3	15
Within 500 m mitigation zone (MMS)	6		6
Within mitigation zone (EMZ)	2		2
Within 1000 m mitigation zone (MMS)	1		1
Within 200 m mitigation zone		1	1
TOTAL	**135**	**27**	**162**

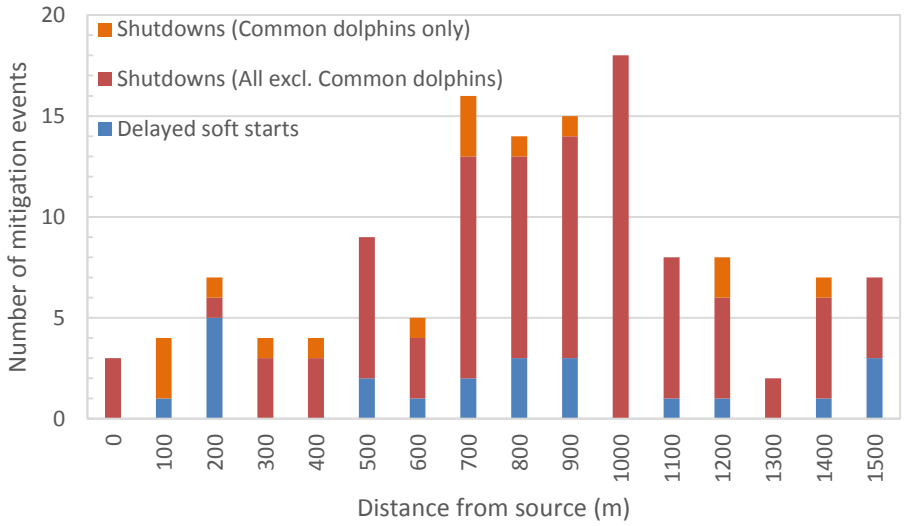

Figure 3: Number of mitigation events and the distance of cetacean detections from the source that triggered the event n=131.

[6] MMS – Marine Mammal Sanctuary; EMZ – Extended Mitigation Zone; Unspecified – Mitigation zone not defined

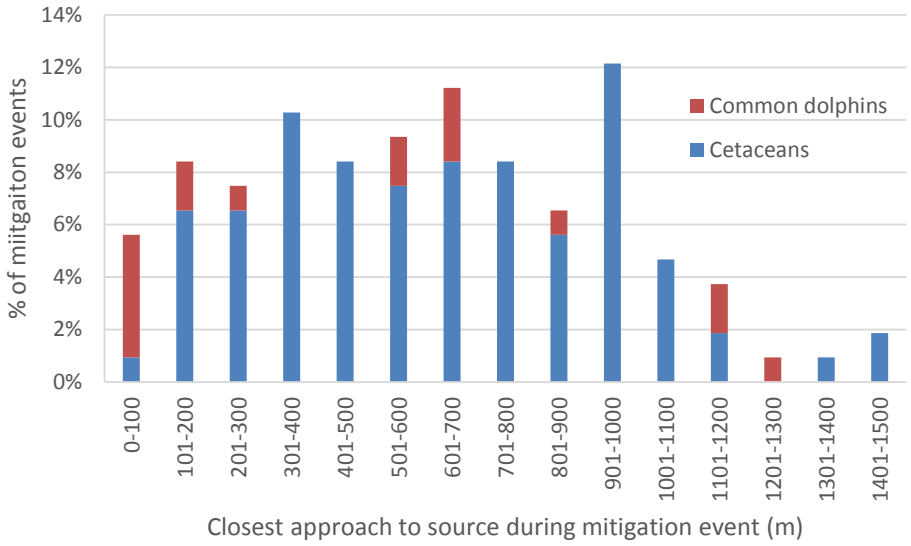

Figure 4: Summary of the closest approach by cetaceans to the source during mitigation events n=131[7].

Table 8: Summary of estimated time lost to cetacean mitigation events (NB. Estimate of time lost may be overestimated (e.g. includes time from operational as well as mitigation delays) or underestimated (e.g. time to complete infill lines lost to mitigation may not be included)

Hours lost (Rounded up to nearest hour)	Number of mitigation events				
	Shut Down during Full Power	Shut Down during Soft Start	Shut down during Testing	Delayed Start during soft start	Total
1	31	4	2	16	53
2	19	2	1	1	23
3	9	0	0	5	14
4	17	1	0	2	20
5	23	1	0	0	24
6	12	0	0	0	12
7	2	0	0	0	2
8	1	0	0	0	1
9	1	0	0	0	1
10	0	0	0	0	0
TOTAL no events	**115**	**8**	**3**	**24**	**150**
TOTAL time lost	**382 h**	**17 h**	**4 h**	**41 h**	**444 h**

[7] Common dolphins have been reported separated as mitigation actions for these species occur under rules for seismic operations in a Marine Mammal Sanctuary rather than under the Code.

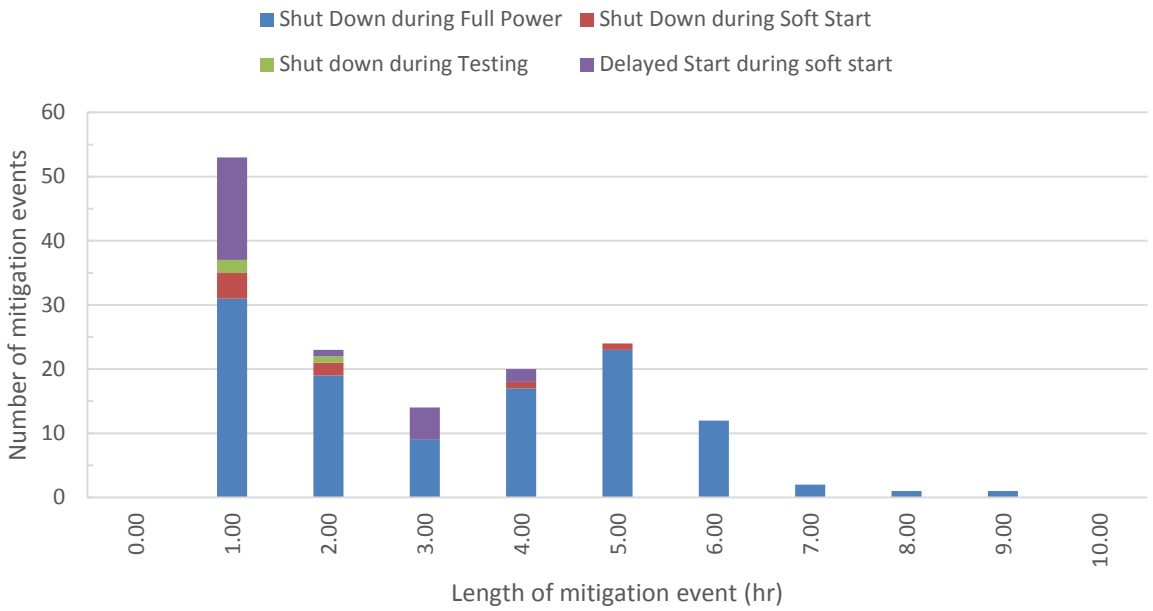

Figure 5: Summary of time lost to cetacean mitigation events by type of mitigation event n=150.

4.6 Summarise MMO and PAM survey effort and seismic acquisition

AIM 5: Summarise MMO and PAM survey effort and seismic acquisition

- ***a. Number of hours (and km wherever possible) for on- and off-effort monitoring; and***
- ***b. Breakdown by geographic area.***
- ***c. General review of marine mammal data including predominant behaviour***

It was not possible to provide estimates of km of survey effort as this information is not recorded in the standard ERFs, and so hours of effort was reported instead. There are several measures of effort that can be summarised. The most useful ones are:

- *Array Status*: which records the amount of time that the operation was in different operational states (e.g. full power, no guns, soft start, etc.); and
- *Monitoring Status*: which records the amount of time that each type of mitigation monitoring type was undertaken (e.g. 1 MMO, 2 MMOs, PAM only, etc.).

While both of these should be equal, it was noted that the total hours effort were different. The total effort in Table 9 and Table 10 is 18,499 hours and is estimated as total time in each Array Status category. Whereas total effort in Table 11 is 18,582 hours and is estimated as the total time in each of the Monitoring Status categories. The discrepancy is 353 hours or approximately 2%. This is likely due to variances in the way the data are reported and that they are reported separately and independently (i.e. array status vs. monitoring status).

Table 9: Summary of total effort in each Petroleum Basin for on- and off-effort combined by individual survey (hours).

	Total hours in each Petroleum Basin						
Survey ID	**Taranaki**	**Great South**	**Canterbury**	**Pegasus**	**East Coast**	**Reinga**	**TOTAL**
2013A	2,179	0	0	0	0	0	2,179
2013B	1,038	0	0	0	0	0	1,038
2013C	488	0	0	0	0	0	488
2013D	352	0	0	0	0	0	352
2013E	338	0	0	0	0	0	338
2013F	38	0	0	0	0	0	38
2013G	27	0	0	0	0	0	27
2013H	0	0	160	0	0	0	160
2014A	269	0	0	0	0	0	269
2014B	0	80	1,523	0	0	0	1,604
2014C	73	0	0	0	0	0	73
2014D	0	0	0	2,633	0	0	2,633
2014E	87	0	0	0	0	0	87
2014F	0	0	8	0	0	0	8
2014G	319	0	0	0	0	0	319
2014H	123	0	0	0	0	0	123
2014I	0	0	0	218	872	0	1,090
2014J	430	0	0	0	0	0	430
2014K	17	0	0	0	0	0	17
2014L	1,230	0	0	0	0	1,845	3,075
2014M	0	0	256	0	0	0	256
2015A	872	0	0	0	0	0	872
2015B	0	0	1,560	0	0	0	1,560
2015C	220	0	0	0	0	0	220
2015D	0	1,198	0	0	0	0	1,198
2015E	46	0	0	0	0	0	46
TOTAL	**8,147**	**1,278**	**3,507**	**2,851**	**872**	**1,845**	**18,499**

Table 10: Summary of monitoring status in each Petroleum Basin for on- and off-effort separately (hours).

Petroleum basin	ON-EFFORT		OFF-EFFORT		TOTAL EFFORT		Time at full power	
	n	%	n	%	n	%	n	%
Taranaki	6345	44%	1802	43%	8147	44%	3,533	44%
Great South	640	4%	638	15%	1278	7%	332	4%
Canterbury	2561	18%	946	22%	3507	19%	1,655	21%
Pegasus	2119	15%	731	17%	2851	15%	742	9%
East Coast	822	6%	50	1%	872	5%	521	7%
Reinga	1795	13%	50	1%	1845	10%	1,181	15%
TOTAL	14282	100%	4217	100%	18499	100%	**7,964**	100%

Table 11: Summary of total hours for all survey monitoring categories in each Petroleum Basin for on- and off-effort separately.

Petroleum basin	1 MMO		2 MMOs		3 MMOs		1 MMO & PAM		2 MMOs & PAM		3 MMOs and PAM		PAM only		No observations		TOTAL
	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	
Taranaki	675	761	175	124	9	4	78	2,692	24	378	0	54	95	2,320	753	397	8,539
Canterbury	520	108	53	11	0	0	90	1,383	12	94	0	0	70	912	201	15	3,471
Pegasus	142	271	29	49	3	3	99	603	22	122	0	2	100	771	334	298	2,848
Reinga	20	120	3	1	0	0	0	911	0	37	0	0	1	650	27	75	1,845
Great South	221	33	76	3	1	0	22	253	4	21	0	0	34	313	280	18	1,278
East Coast	9	41	1	3	0	0	5	290	1	36	0	0	0	412	35	39	872
SUB-TOTAL	1,587	1,334	336	193	12	7	294	6,132	64	687	0	56	299	5,378	1,630	843	
TOTAL	2,920		529		19		6,426		751		56		5,678		2,473		18,852

Table 12: Summary of number of cetacean detections[8] for all survey (i.e. on and off) effort by Petroleum Basin. (NB. Excludes total time with no observations so totals are different from those in Table 11)

Petroleum Basin	Summary of on- and off-effort (hours)				No. cetacean detections	Cetacean detection rate per hour per Basin	No. fur seal detections	Fur seal detection rate per hour per Basin
	MMO only	PAM only	Both MMO & PAM	TOTAL				
Taranaki	1747	2415	3226	7389	586	0.08	171	0.02
Canterbury	693	982	1579	3254	194	0.06	844	0.26
Pegasus	496	871	848	2215	78	0.04	224	0.10
Reinga	144	650	948	1743	126	0.07	0	0.00
Great South	334	346	300	980	42	0.04	143	0.15
East Coast	53	413	331	798	91	0.11	138	0.17
TOTAL	3468	5678	7233	16379	1117	0.07	1520	0.09

[8] This the number of groups detected and is not the total number of individuals

Table 13: Summary of detection rates (per hour) by effort type/monitoring type (i.e. MMO, PAMO, Both) by Petroleum Basin and Taxa groups (i.e. Cetaceans, Fur seals, All Marine Mammals)

Monitoring type	Taxa group	Effort	Petroleum basin						
			Canterbury	East Coast	Great South	Pegasus	Reinga	Taranaki	TOTAL
MMO only	MMs/hr	Off	0.55	5.00	0.19	0.04	0.18	0.22	0.32
		On	1.34	0.70	0.14	0.23	0.07	0.12	0.25
		TOTAL	0.69	1.46	0.19	0.16	0.09	0.17	0.29
	Cets/hr	Off	0.10	3.72	0.03	0.01	0.18	0.10	0.10
		On	0.11	0.23	0.03	0.04	0.07	0.10	0.09
		TOTAL	0.10	0.84	0.03	0.03	0.09	0.10	0.09
	Seals/hr	Off	0.45	1.28	0.16	0.03	0.00	0.12	0.22
		On	1.23	0.48	0.11	0.19	0.00	0.02	0.16
		TOTAL	0.58	0.62	0.16	0.13	0.00	0.07	0.20
PAM only	MMs/hr	Off	0.06	11.03	0.03	0.02	0.00	0.05	0.06
		On	0.02	0.01	0.02	0.02	0.00	0.04	0.03
		TOTAL	0.02	0.02	0.02	0.02	0.00	0.04	0.03
	Cets/hr	Off	0.06	11.03	0.03	0.02	0.00	0.05	0.06
		On	0.02	0.01	0.02	0.02	0.00	0.04	0.03
		TOTAL	0.02	0.02	0.02	0.02	0.00	0.04	0.03
	Seals/hr	Off	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		On	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MMO and PAM at same time	MMs/hr	Off	0.56	13.65	0.27	0.34	0.00	0.20	0.55
		On	0.32	0.22	0.38	0.24	0.12	0.11	0.19
		TOTAL	0.34	0.43	0.37	0.22	0.12	0.11	0.20
	Cets/hr	Off	0.09	3.56	0.00	0.05	0.00	0.18	0.14
		On	0.06	0.06	0.08	0.05	0.12	0.10	0.08
		TOTAL	0.06	0.11	0.07	0.05	0.12	0.09	0.08
	Seals/hr	Off	0.47	10.09	0.27	0.29	0.00	0.03	0.40
		On	0.26	0.17	0.30	0.18	0.00	0.01	0.10
		TOTAL	0.28	0.32	0.30	0.17	0.00	0.01	0.11
All	MMs/hr	Off	0.51	8.12	0.18	0.13	0.17	0.21	0.32
		On	0.26	0.14	0.19	0.14	0.07	0.08	0.13
		TOTAL	0.32	0.29	0.19	0.13	0.07	0.10	0.16
	Cets/hr	Off	0.10	3.89	0.03	0.02	0.17	0.10	0.10
		On	0.05	0.04	0.05	0.04	0.07	0.08	0.06
		TOTAL	0.06	0.11	0.04	0.03	0.07	0.08	0.07
	Seals/hr	Off	0.41	4.23	0.16	0.10	0.00	0.10	0.22
		On	0.21	0.10	0.14	0.11	0.00	0.01	0.07
		TOTAL	0.26	0.17	0.15	0.10	0.00	0.02	0.09

Table 14: Detection rate (per hour) of taxa (i.e. Cetacean, Fur seal, Marine Mammal) by array status at first sighting

Marine mammal	Deployment/ Retrieval of gear	Delayed start	Full power	No source/gear out	Source aboard	Shut down	Soft start	Steaming no gear	Testing	TOTAL
New Zealand fur seals	294	2	460	436	107	32	25	144	14	1514
Cetaceans	133	4	404	282	77	47	31	62	10	1050
Marine Mammals	427	6	864	718	184	79	56	206	24	2564
Total hours per array status	2686	24	7964	3844	1879	207	495	1276	125	18499
Cetacean detection rate per hour	0.05	0.16	0.05	0.07	0.04	0.23	0.06	0.05	0.08	0.06
Fur seal detection rate per hour	0.11	0.08	0.06	0.11	0.06	0.15	0.05	0.11	0.11	0.08
Marine mammal detection rate per hour	0.16	0.25	0.11	0.19	0.10	0.38	0.11	0.16	0.19	0.14

Table 15: Summary of Rate of detections by Array Status (i.e. Active = Full Power (FP); Inactive = Deployment/Retrieval (DR), No Gear out (NG), Source Aboard (SA), Steaming (ST))

	Source active (FP)	Source inactive (DR, NG, SA, ST)
Total hours	8,089	9,684
Total marine mammal detections	888	1,535
Rate of detections per hour	0.11	0.16

Table 16: Summary of behavioural states for cetacean detections[9]

Behaviour	1st Behaviour		Predominate Behaviour		Last Behaviour	
	n	%	n	%	n	%
Travelling (Cetaceans)	478	44.8%	469	44.0%	455	42.6%
Unable to observe (Cetaceans)	313	29.3%	316	29.6%	394	36.9%
Surface active (Cetaceans)	109	10.2%	86	8.1%	62	5.8%
Resting (Cetaceans)	42	3.9%	38	3.6%	28	2.6%
Milling (Cetaceans)	40	3.7%	61	5.7%	45	4.2%
Foraging (Cetaceans)	36	3.4%	38	3.6%	25	2.3%
Swimming	19	1.8%	21	2.0%	22	2.1%
Porpoising	16	1.5%	10	0.9%	12	1.1%
Stationary	4	0.4%	6	0.6%	4	0.4%
Milling	3	0.3%	2	0.2%	2	0.2%
Socialising (Cetaceans)	3	0.3%	10	0.9%	2	0.2%
Breaching	2	0.2%	1	0.1%	0	0.0%
Travelling (Pinnipeds)	2	0.2%	3	0.3%	10	0.9%
Bow riding	0	0.0%	4	0.4%	2	0.2%
Feeding (Pinnipeds)	0	0.0%	1	0.1%	0	0.0%
Other	0	0.0%	0	0.0%	2	0.2%
Resting (Pinnipeds)	0	0.0%	1	0.1%	0	0.0%
Unable to observe (Pinnipeds)	0	0.0%	0	0.0%	2	0.2%
	1067	100%	1067	100%	1067	100%

[9] Some of the behavioural states reported are noted as being specific pinniped behavioural states although this data is derived from cetacean sightings. We have used the categories as reported but would note that these require revision.

Table 17: Summary of behavioural states of fur seal upon first sighting

Behaviour at First Sight	Number	%
Resting	596	39%
Porpoising	441	29%
Head out of water	180	12%
Travelling	174	11%
Flippers up	46	3%
Diving	12	1%
Swim towards	12	1%
Looking around	11	1%
Porpoise towards	11	1%
Milling	7	0%
Looking at ship	6	0%
Swimming	5	0%
Unable to observe	5	0%
Feeding	4	0%
Porpoise away	4	0%
Swim away	2	0%
Crossing bow	1	0%
Stationary	1	0%
TOTAL	1518	

4.7 Development of database

AIM 6: Compile a Master database of all the collated data to be made available to DOC.

This work was completed and a copy of the data made available to DOC.

5. General Figures

The following figures are for illustrative purposes and are intended as being broadly informative rather than fully descriptive. Additional iterations and/or combinations can be developed upon request. Please note that none of the data in these figures have been weighted by relative effort in any way unless specifically stated.

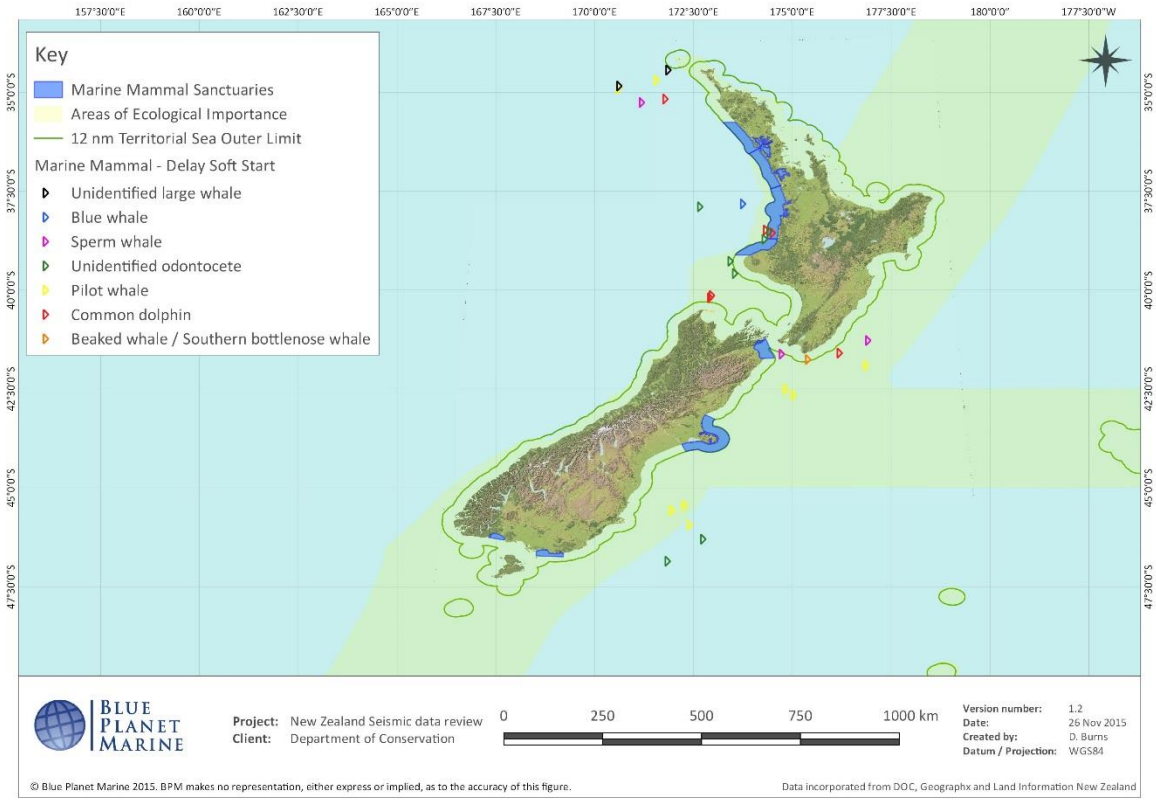

Figure 6: All Delayed soft start mitigation events by species responsible (all of New Zealand).

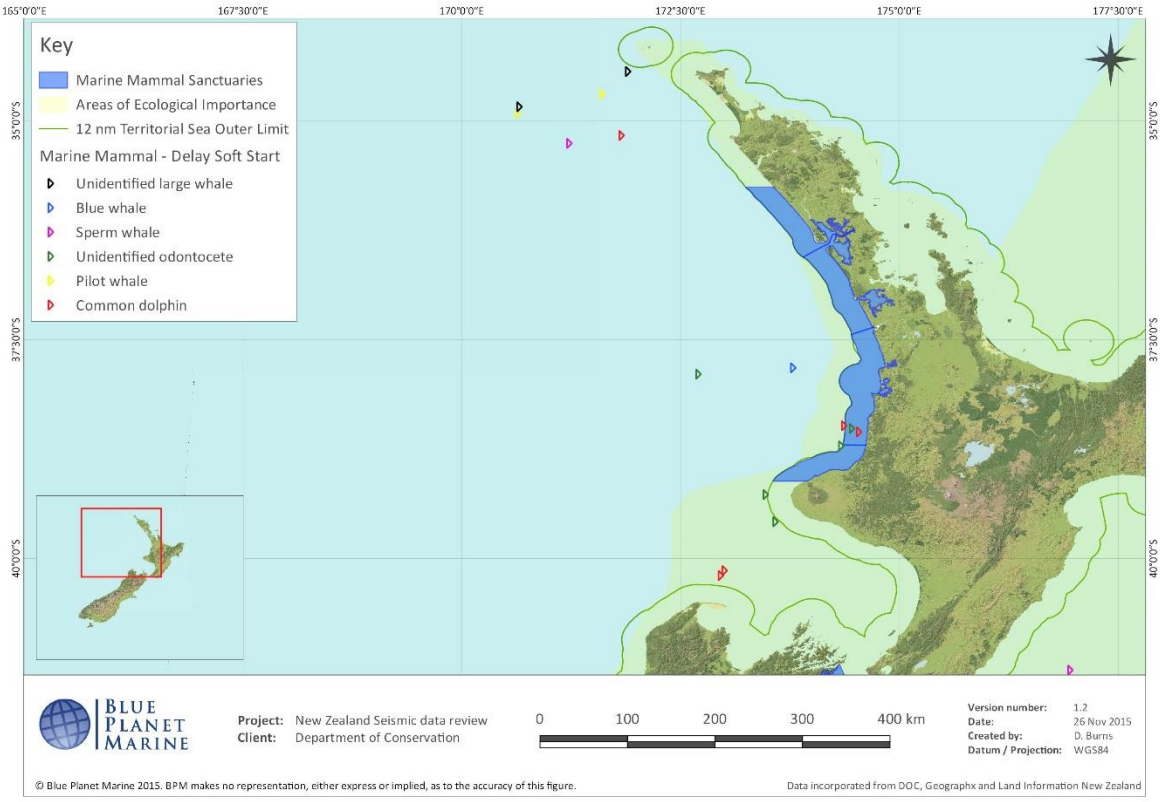

Figure 7: All Delayed soft start mitigation events by species responsible (North-west Region).

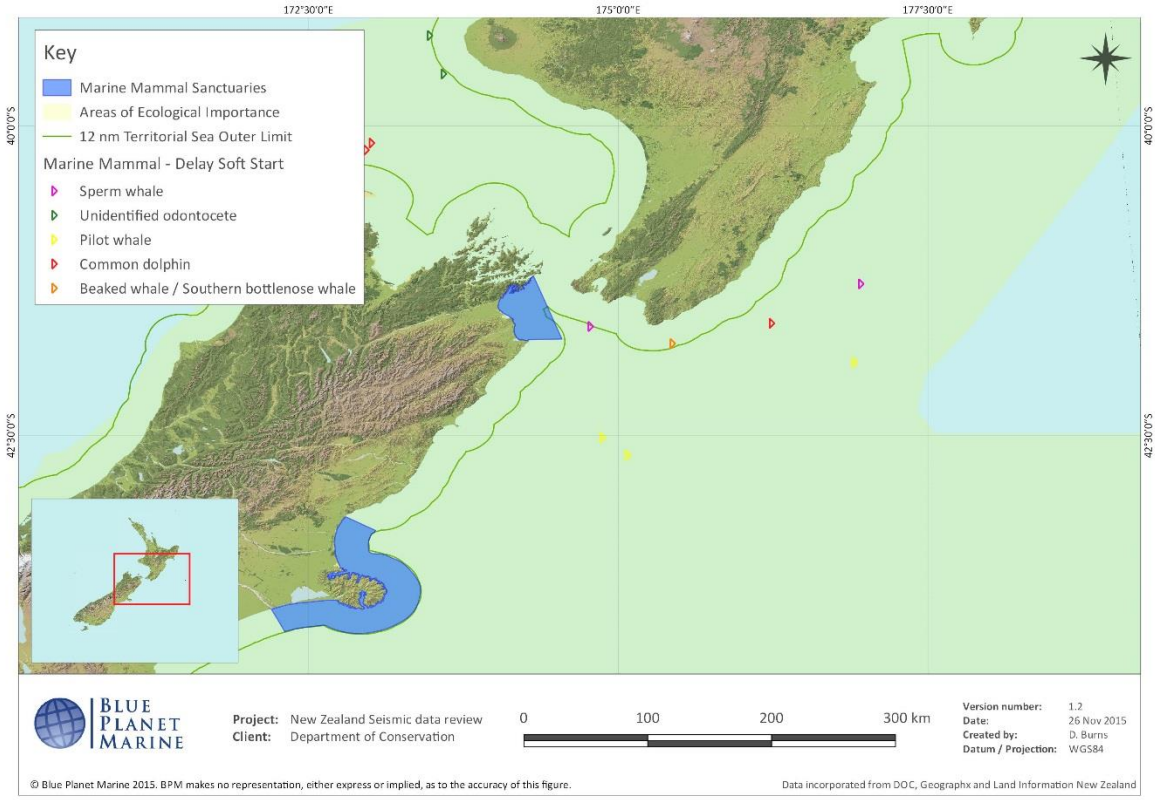

Figure 8: All Delayed soft start mitigation events by species responsible (Central Region).

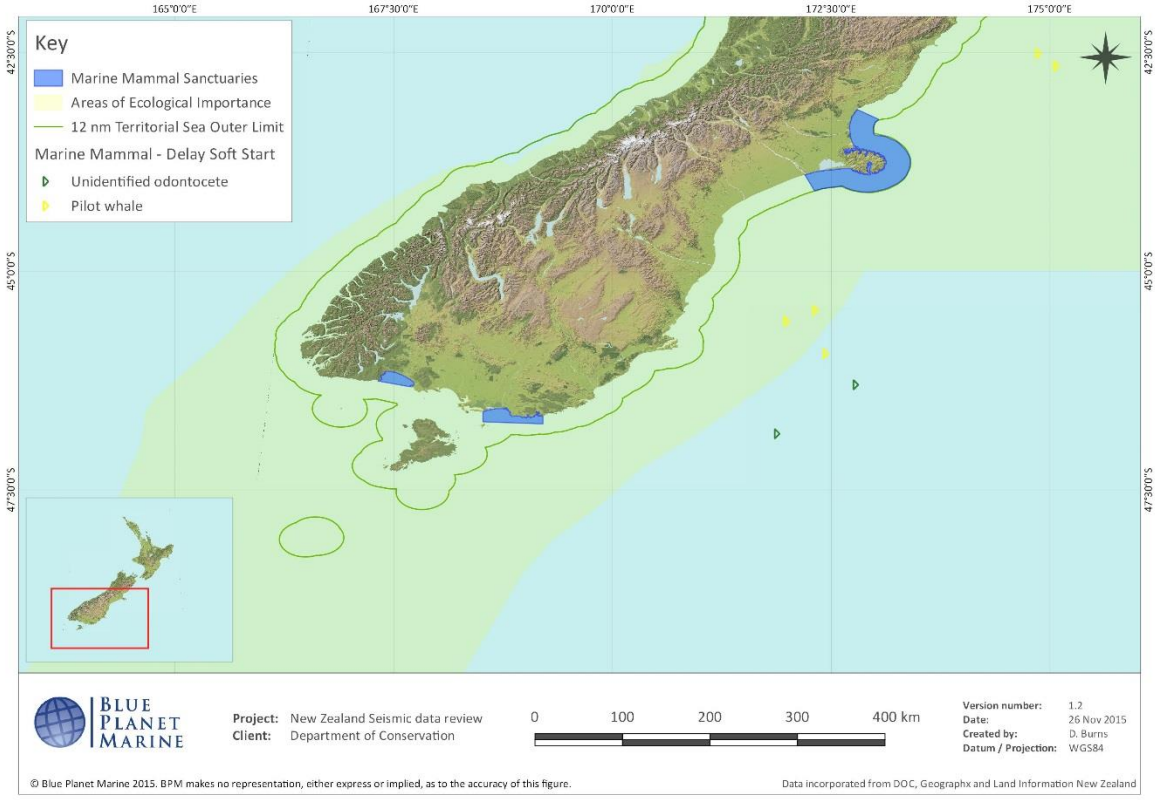

Figure 9: All Delayed soft start mitigation events by species responsible (South-east Region).

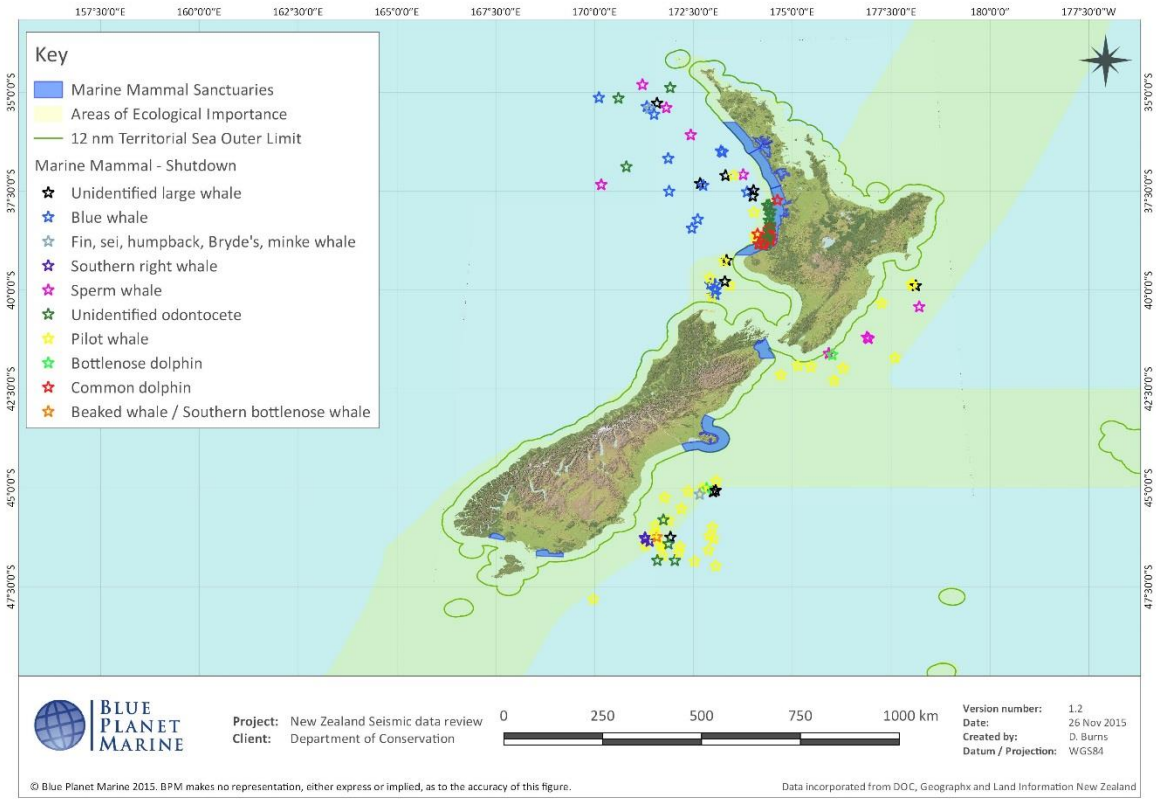

Figure 10: All Shut down mitigation events by species responsible (all of New Zealand).

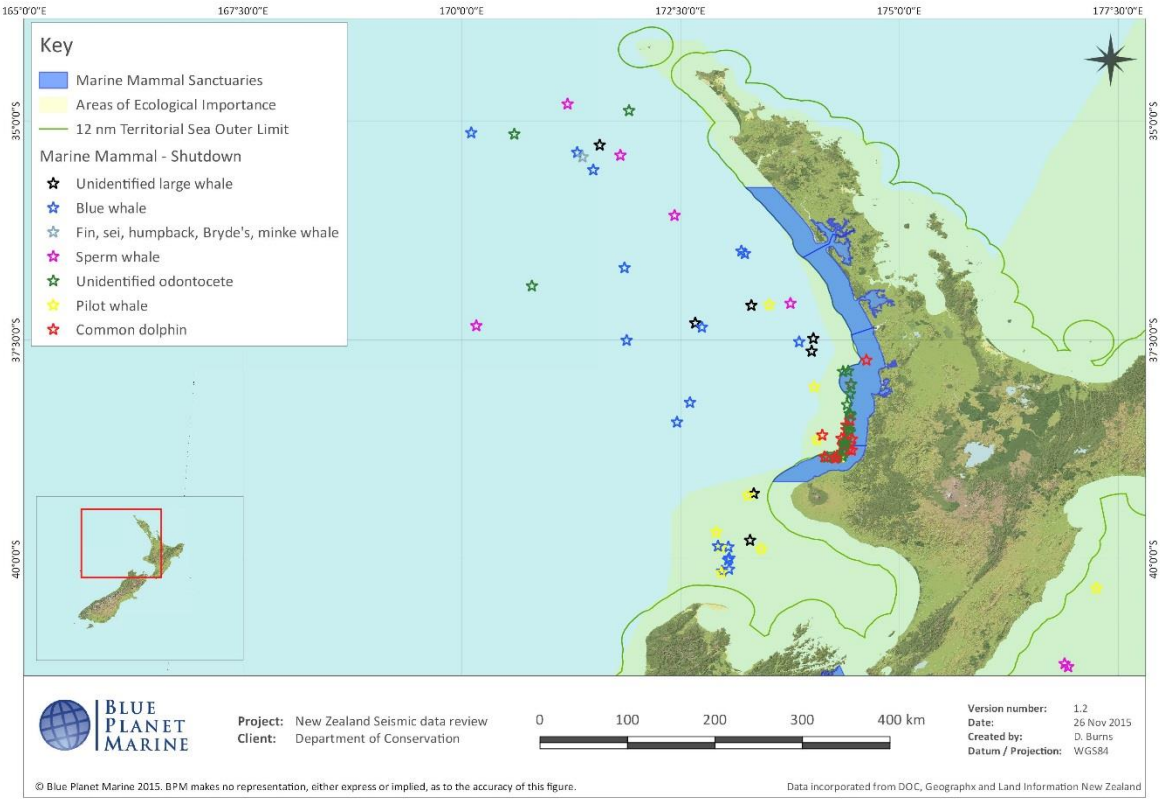

Figure 11: All Shut down mitigation events by species responsible (North-west Region).

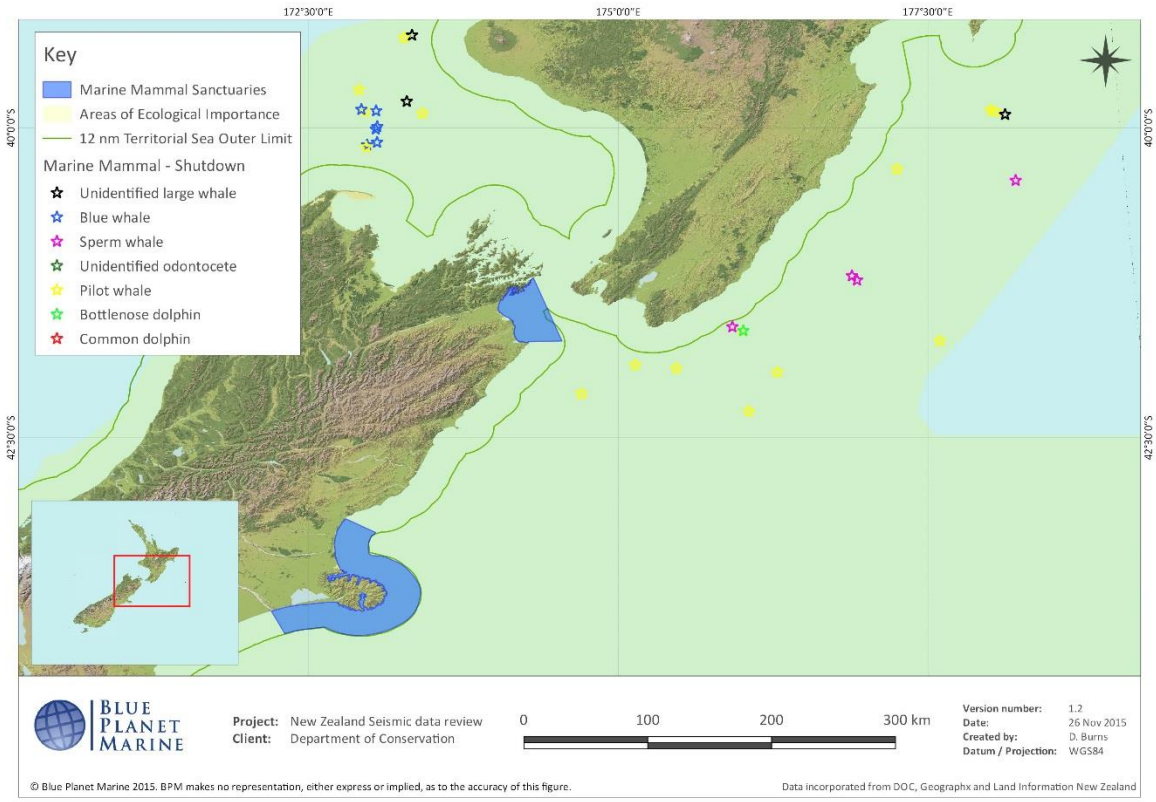

Figure 12: All Shut down mitigation events by species responsible (Central Region).

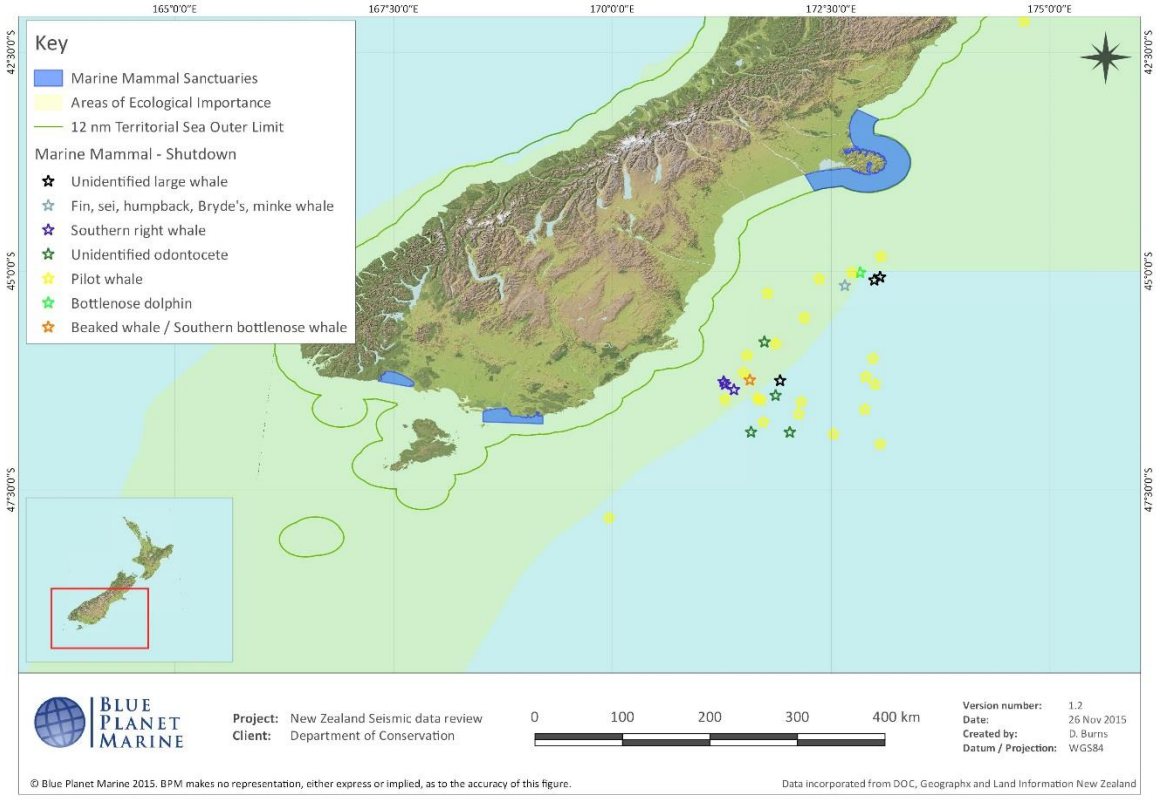

Figure 13: All Shut down mitigation events by species responsible (South-east Region).

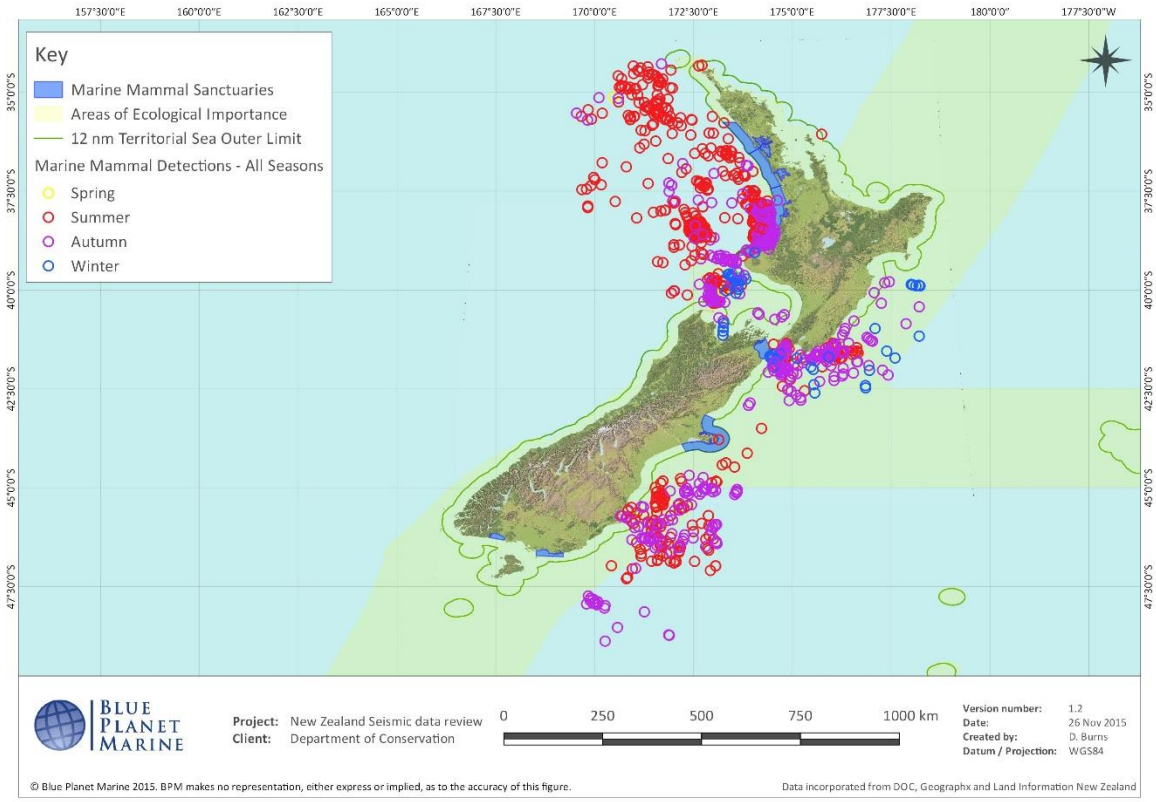

Figure 14: All cetacean detections by season (all of New Zealand).

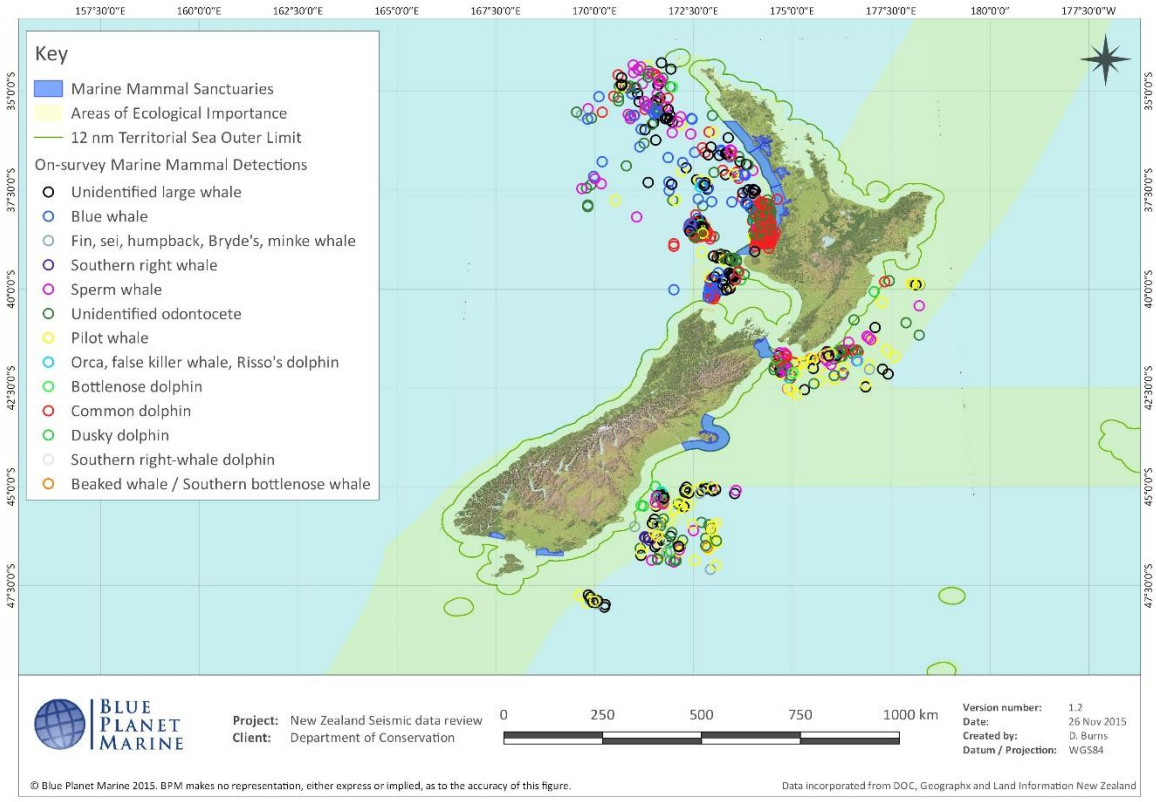

Figure 15: All cetacean detections for on-effort observations (all of New Zealand).

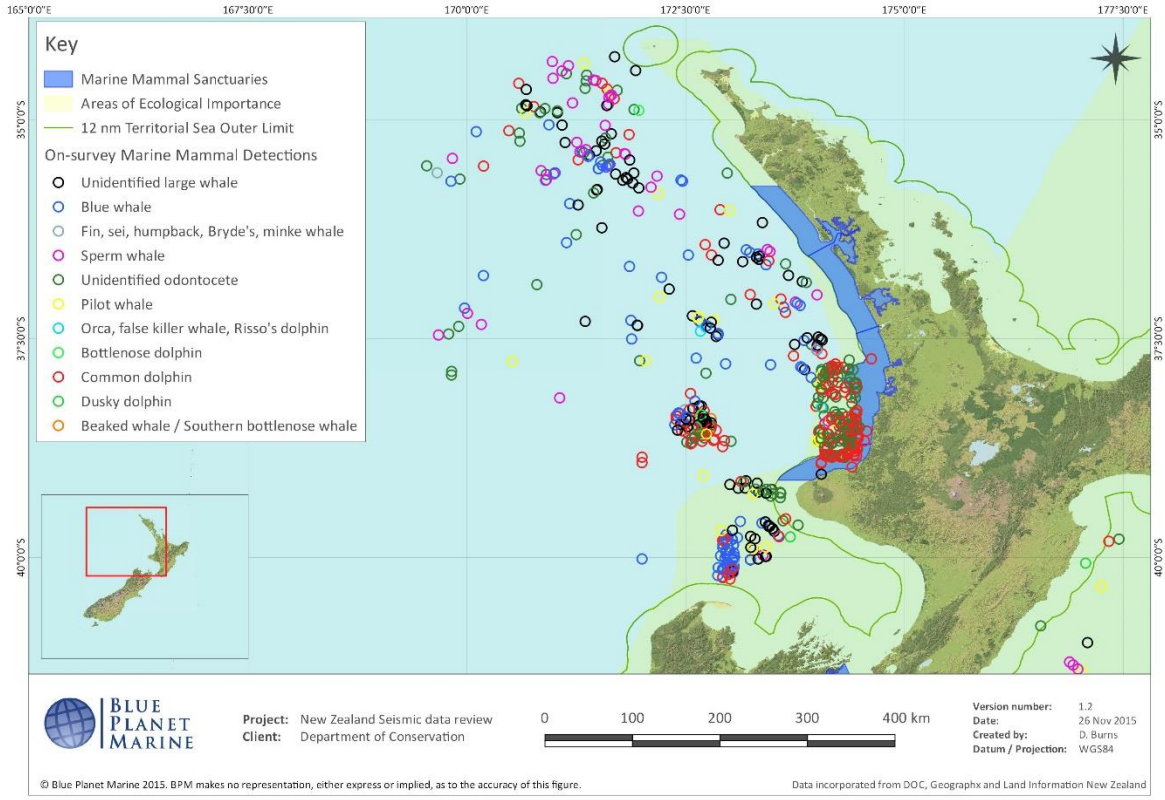

Figure 16: All cetacean detections for on-effort (North-west Region).

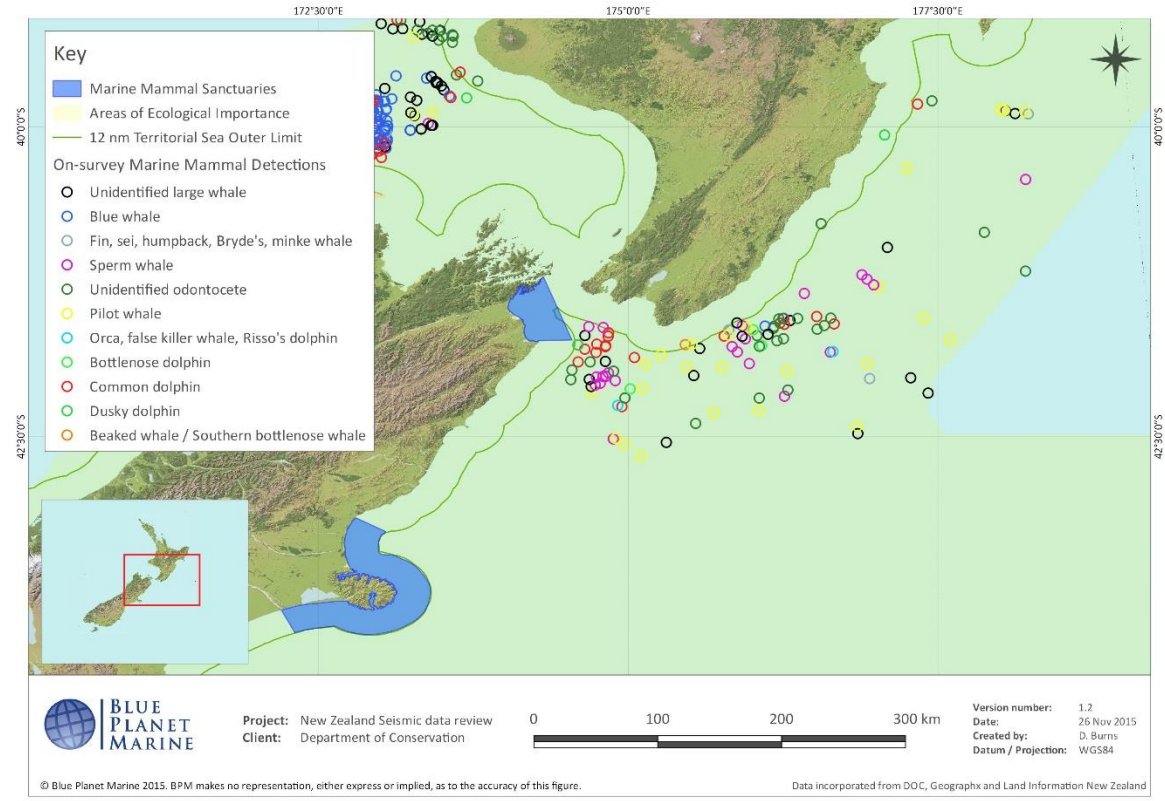

Figure 17: All cetacean detections for on-effort observations (Central Region).

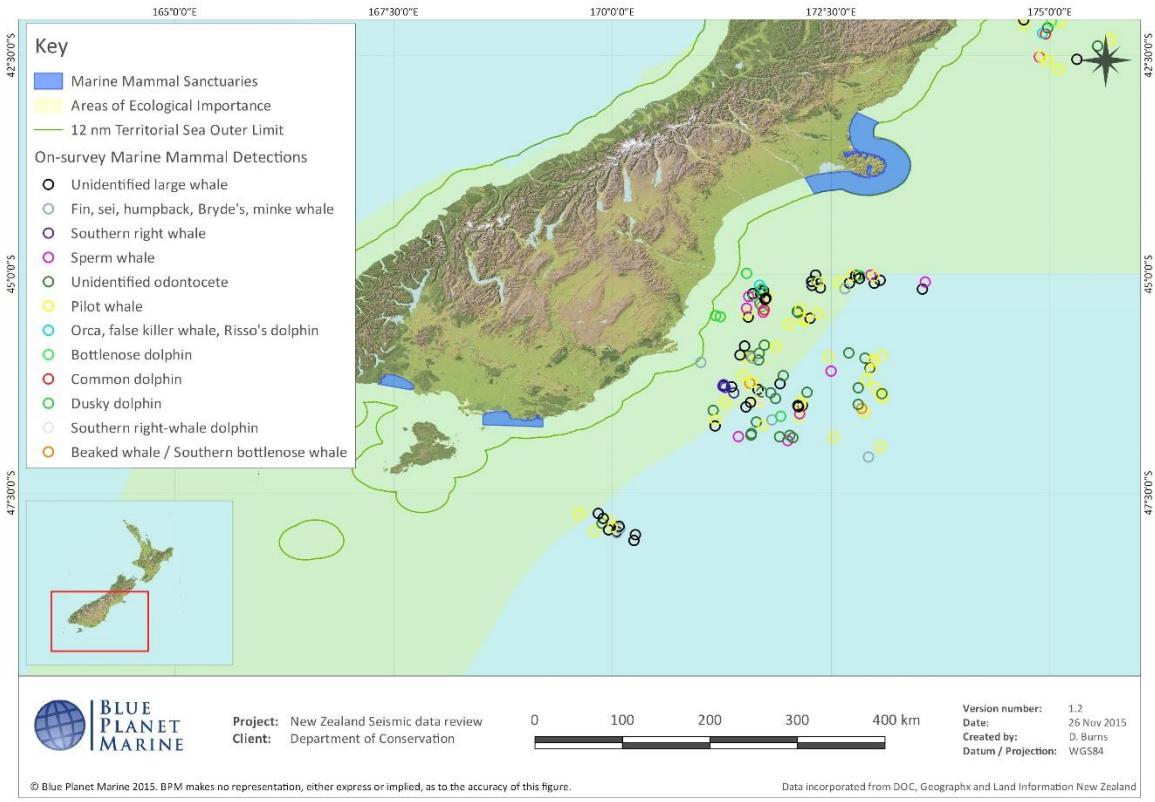

Figure 18: All cetacean detections for on-effort (South-east Region).

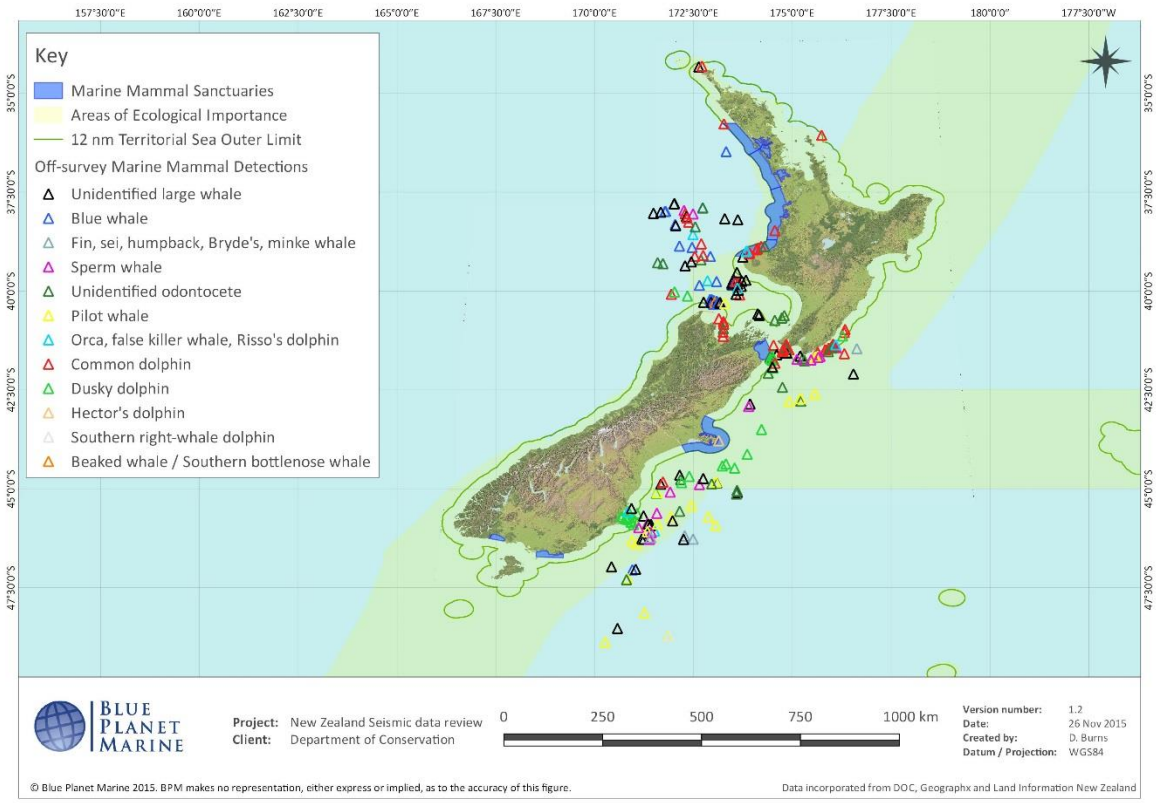

Figure 19: All cetacean detections for off-effort observations (all of New Zealand).

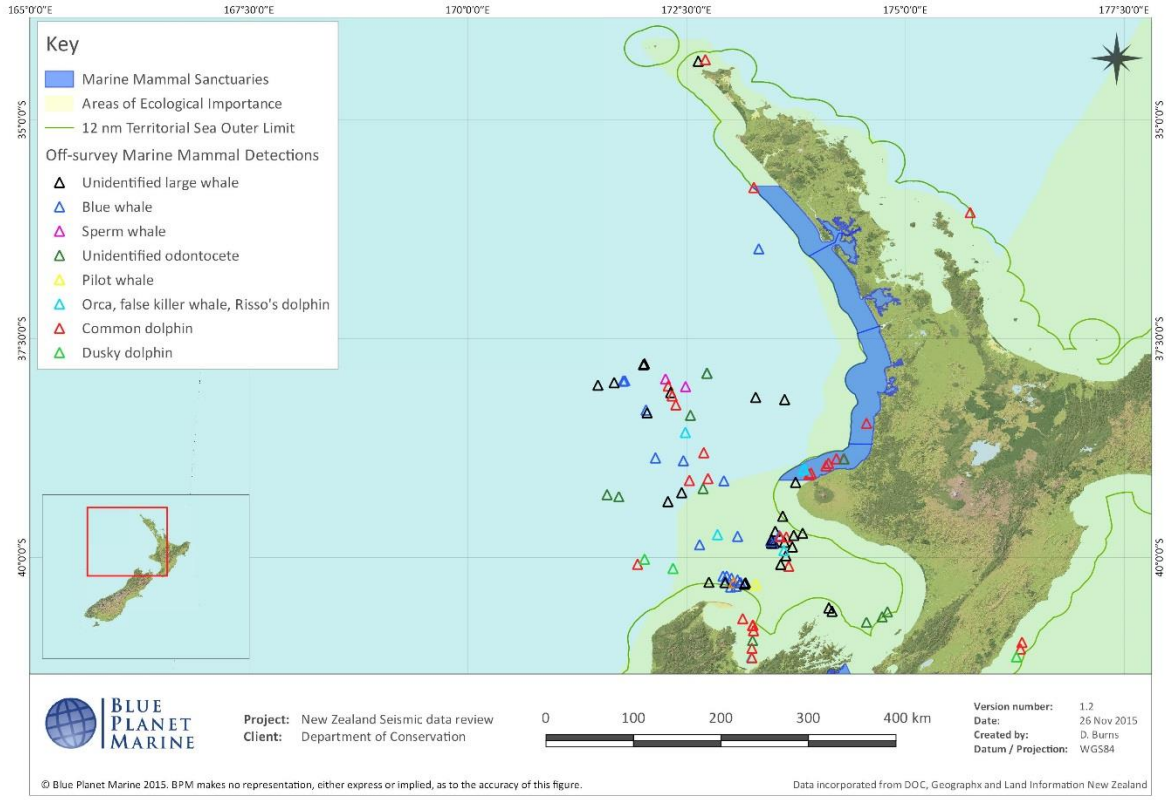

Figure 20: All cetacean detections for off-effort (North-west Region).

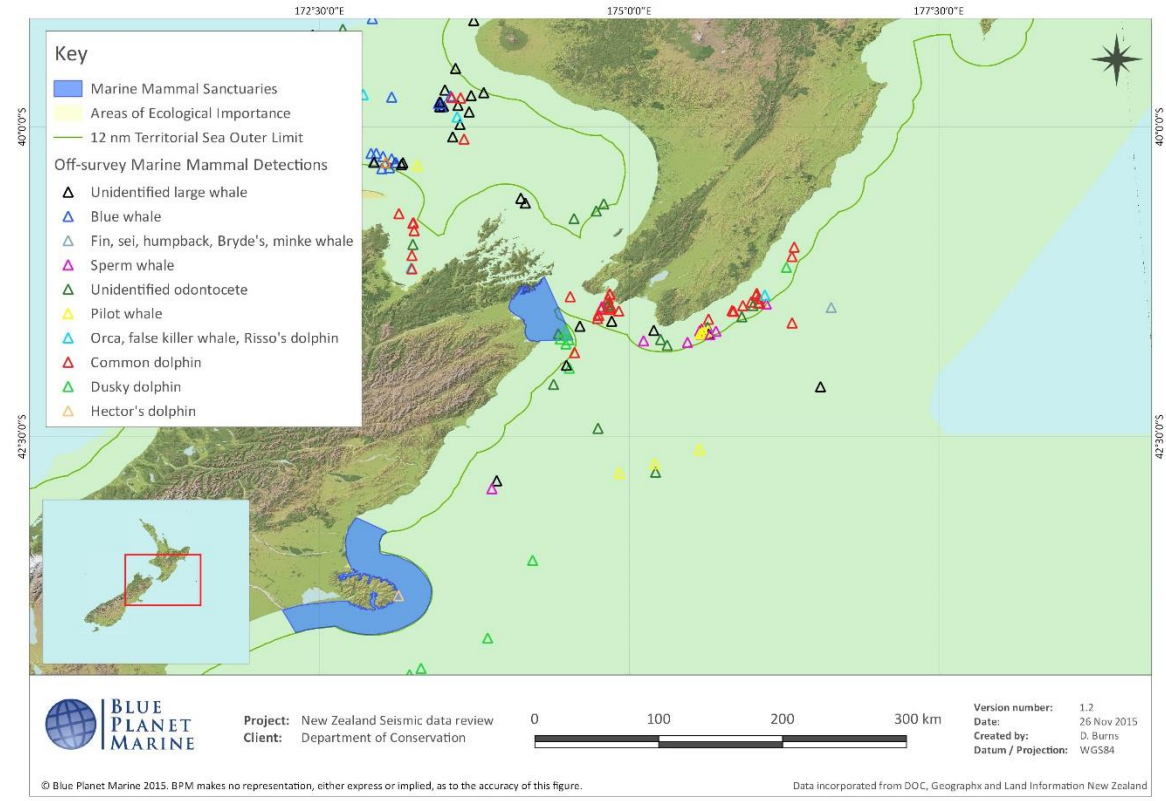

Figure 21: All cetacean detections for off-effort observations (Central Region).

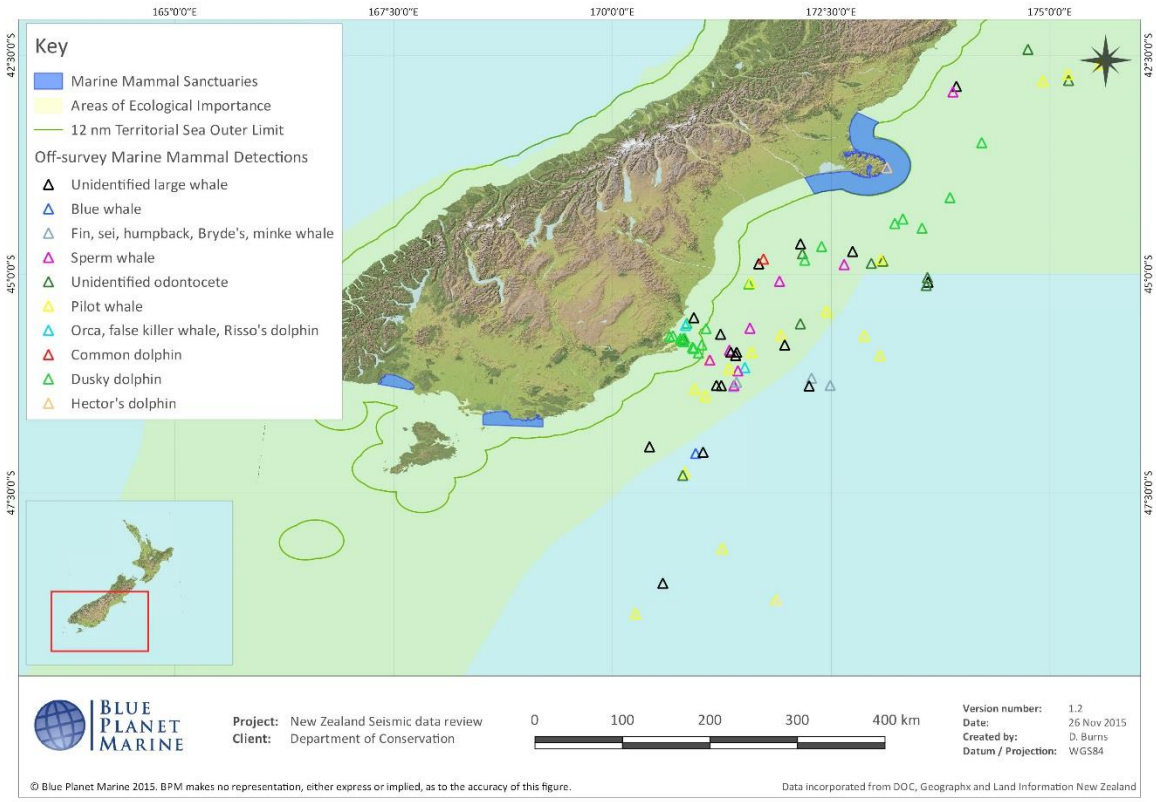

Figure 22: All cetacean detections for off-effort observations (South-east Region).

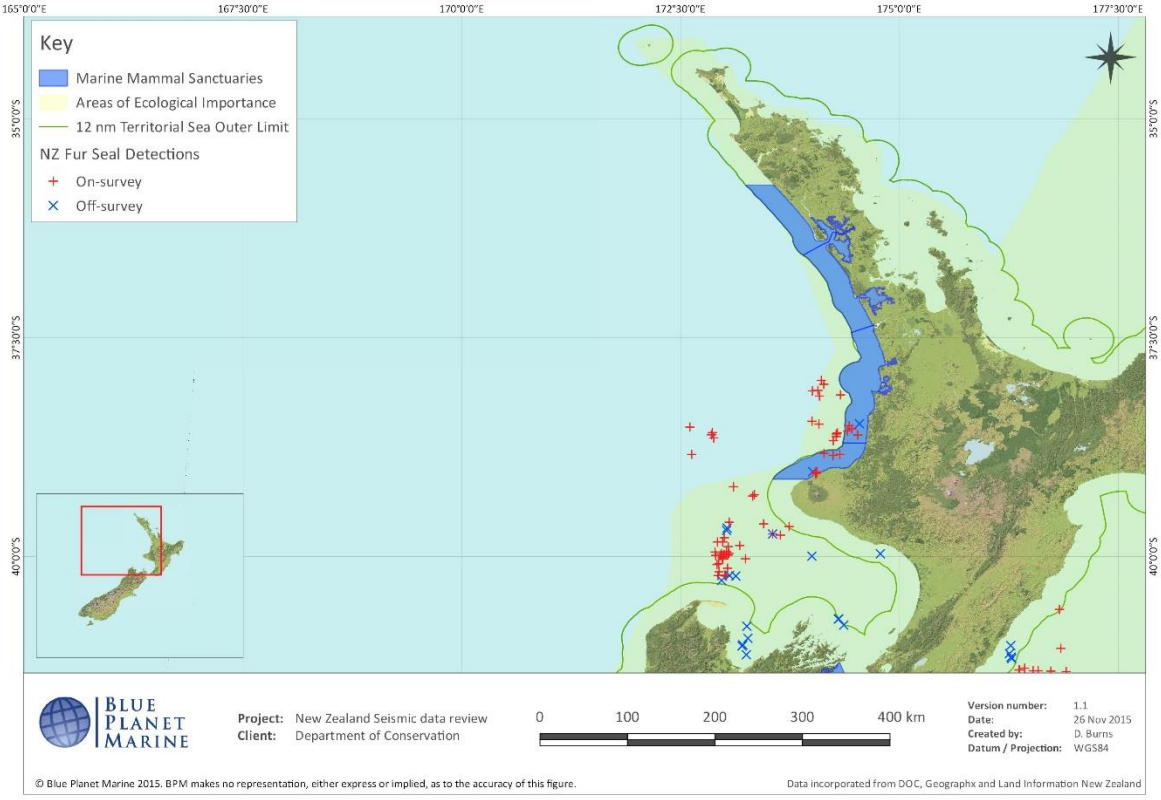

Figure 23: All NZ fur seal detections (North-west Region).

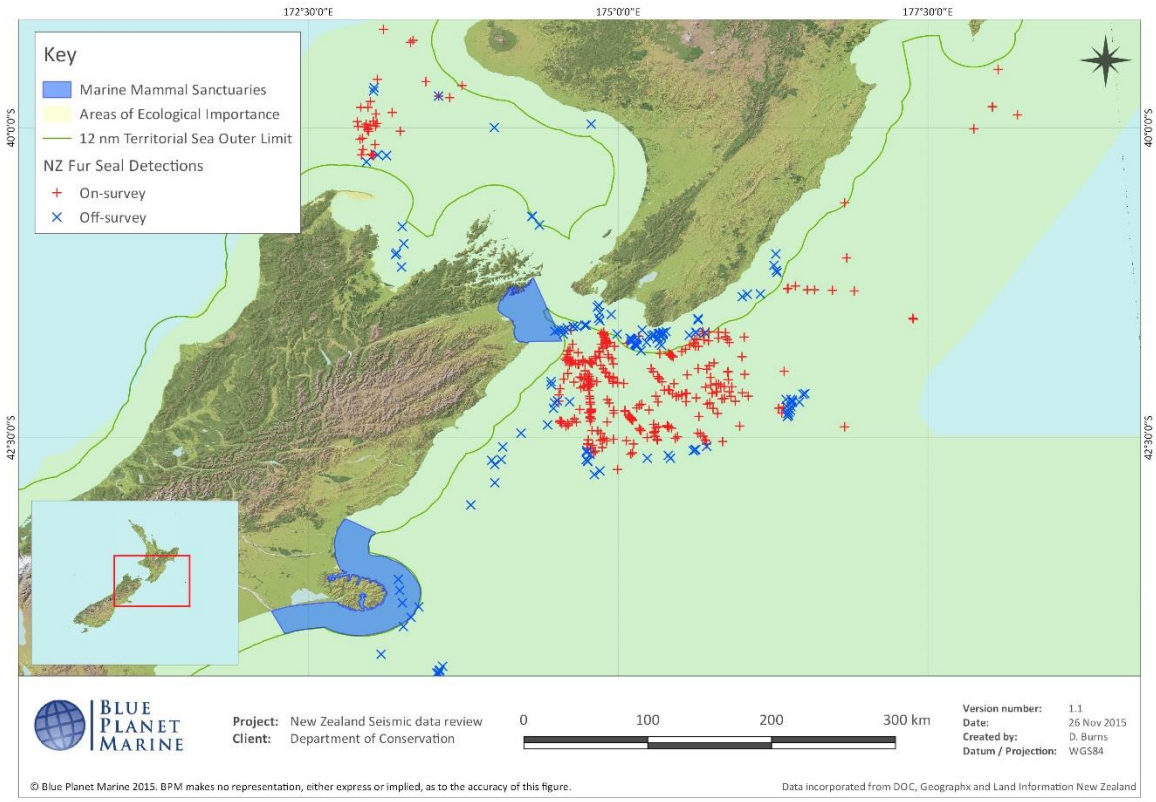

Figure 24: All NZ fur seal detections (Central Region).

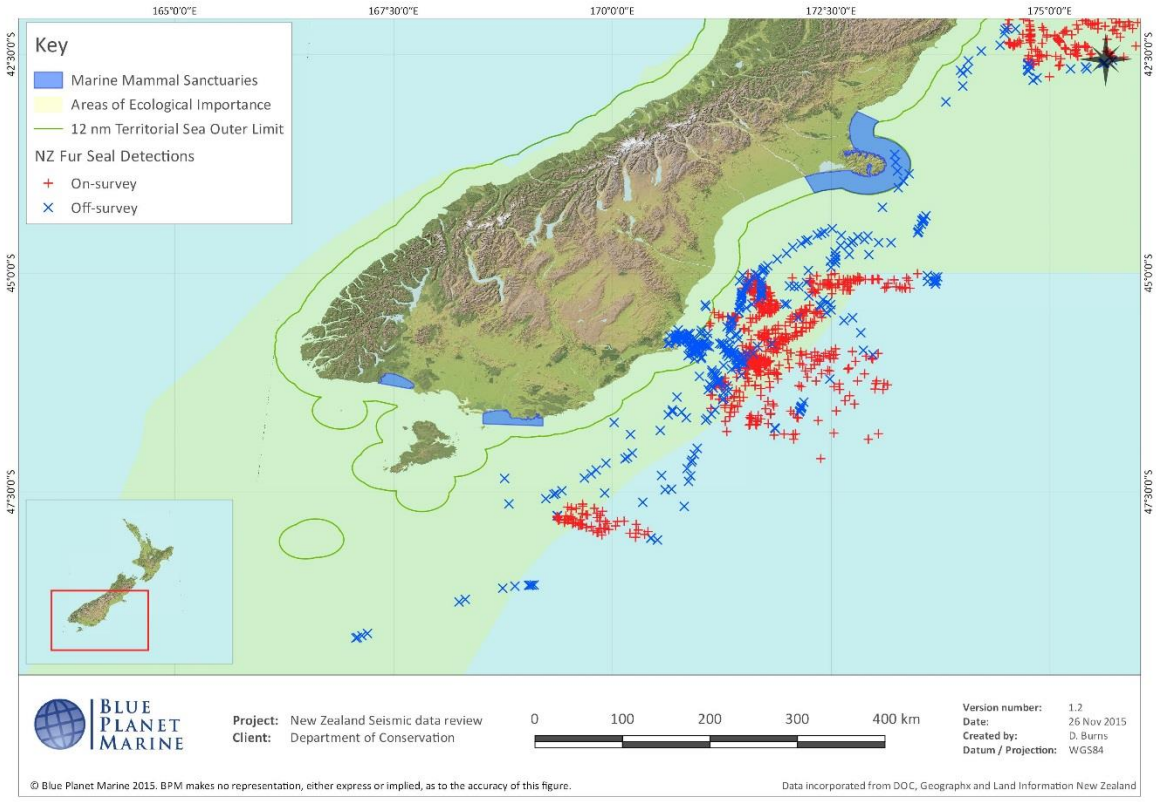

Figure 25: All NZ fur seal detections (South-east Region).

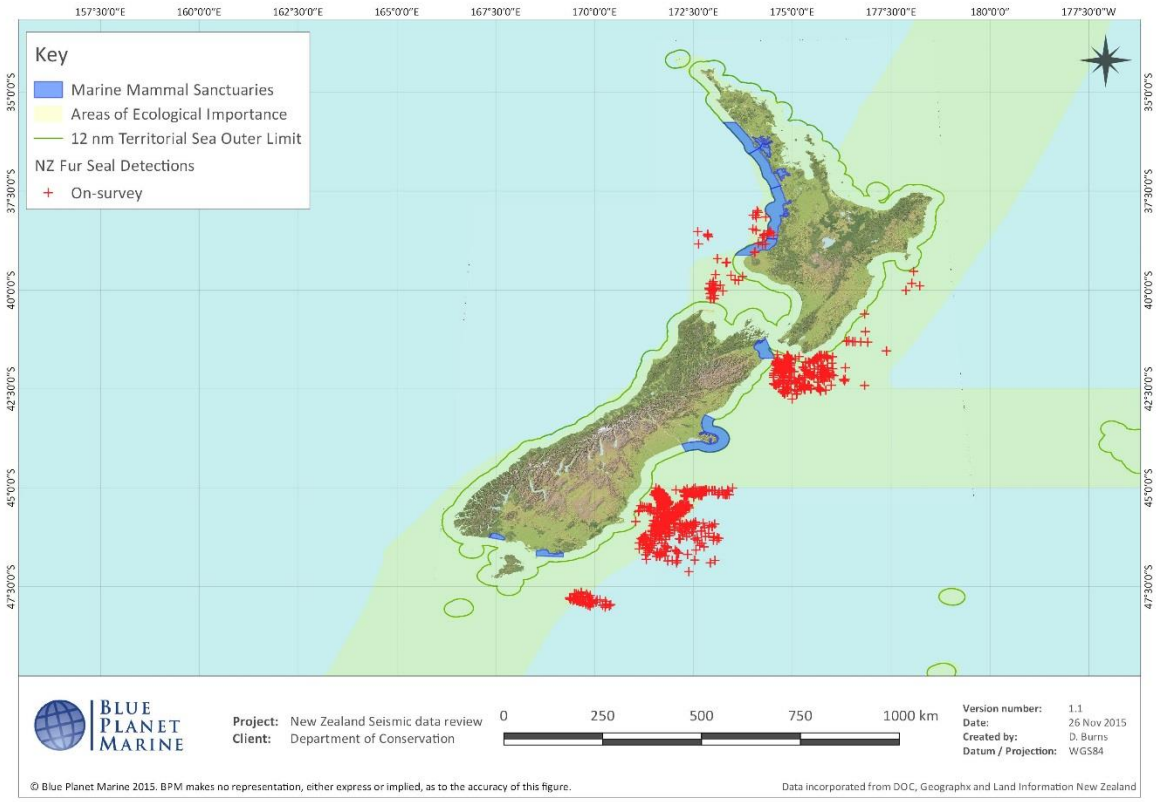

Figure 26: All NZ fur seal detections during on-effort observations (all New Zealand).

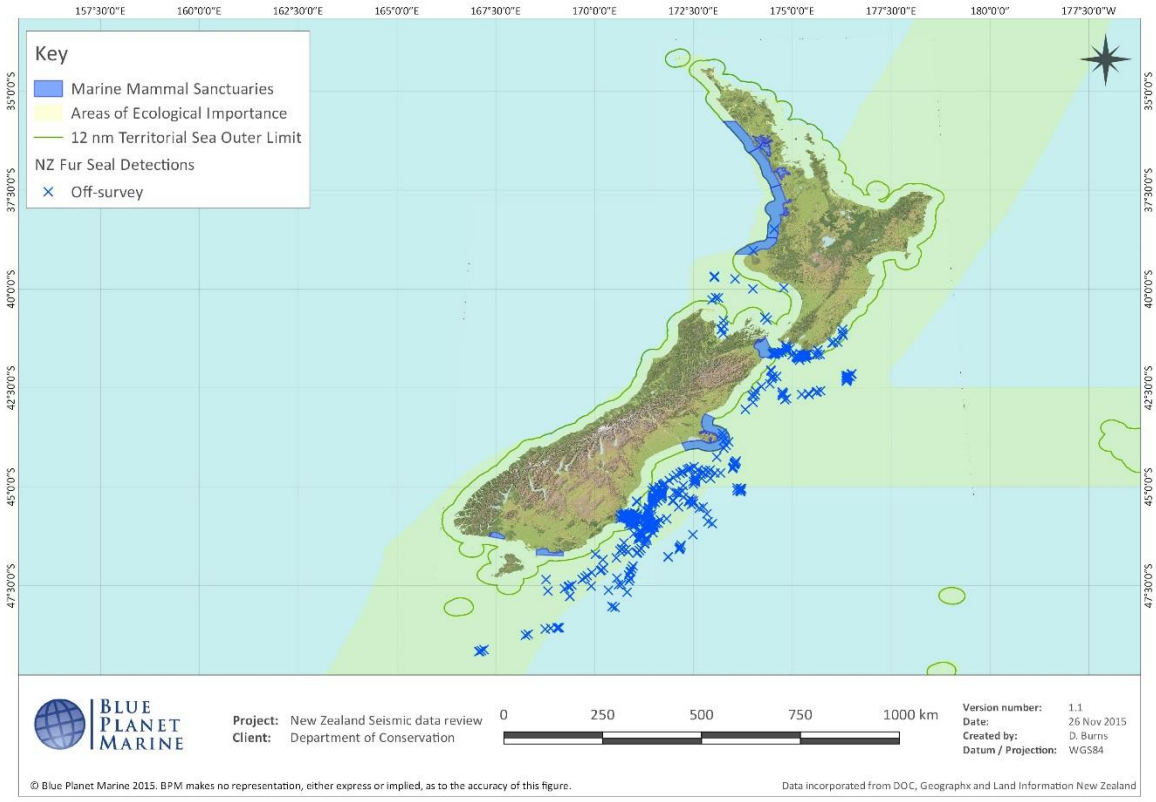

Figure 27: All NZ fur seal detections during off-effort observations (all of New Zealand).

Figure 28: All mitigation actions as a result of NZ fur seal interactions (all of New Zealand).

6. Acknowledgements

We would like to acknowledge the work and commitment of the MMOs and PAMOs who worked long hours at sea with dedication and diligence in collecting this data.

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