Identifiable individuals, behavioural responses to vessel activity and calf survival of bottlenose dolphins (*Tursiops truncatus*) in Far North waters, New Zealand

0800 TRIOCEANS
info@trioceans.org
www.trioceans.org

February 2022
Peer-reviewed in July 2023

Submitted to:
Bronwyn Bauer-Hunt
Operations Manager | Pou Matarautaki
Department of Conservation | Te Papa Atawhai
Mobile: +64 0272584103
Email: (bbauerhunt@doc.govt.nz)

Pewhairangi | Bay of Islands Area Office
34 Landing Road, Kerikeri 0230 | PO Box 128, Kerikeri 0245
T: +64 9 4070300
Cc: Adrian Walker (awalker@doc.govt.nz)

Submitted by:
Tangaroa Research Institute of Oceanographic Studies (TriOceans)

Investigation leader contact information:
Thibaud Guerin
Field Director
32/10 Klinac Lane
Waipapa 0295
New Zealand
Email: thibaud@trioceans.org
Phone: 02108139057

Statement of Confidentiality & Non-Disclosure

This document contains proprietary and confidential information. All data submitted to any receiving party are provided in reliance upon its consent not to use or disclose any information contained herein except in the context of its business dealings with the Tangaroa Research Institute of Oceanographic Studies (TriOceans). The recipient of this document agrees to inform its present and future employees and partners who view or have access to the document's content of its confidential nature.

The recipient agrees to instruct each employee that they must not disclose any information concerning this document to others except to the extent that such matters are generally known to, and are available for use by, the public. The recipient also agrees not to duplicate or distribute or permit others to duplicate or distribute any material contained herein without TriOceans express written consent.

TriOceans retains all title, ownership, and intellectual property rights to the material and trademarks contained herein, including all supporting documentation, files, marketing material, and multimedia.

BY ACCEPTANCE OF THIS DOCUMENT, THE RECIPIENT AGREES TO BE BOUND BY THE AFOREMENTIONED STATEMENT.

Contents

List of Figures

List of Tables

1. Executive summary

The present report describes the outcomes of a dedicated continuous study carried out in Far North waters, Doubtless Bay to Whangarei harbour, between June 2019 and November 2021, which resulted in a total of 6291.1 km of track surveyed whilst on effort (296.2hrs). The 2019-2021 dataset presented here is also consolidated with additional data collected under contract or independently by TriOceans (2017-2019), to provide a comprehensive summary for management. Most effort occurred within Bay of Islands waters (76.9%), where common bottlenose dolphins (referred to hereafter as bottlenose dolphins) were the most encountered species (n=70 sightings, 114hrs encounter effort), with another 8 species of marine mammals recorded (n=62 sightings).

Results indicate a continued decline in bottlenose dolphin identifiable individuals in the Bay of Islands. Eighty-five individuals were identified over the study period, compared to 278 individuals identified in 1997-1999 (Constantine 2002), although we note variations in level and type of effort between studies make direct comparisons difficult. Those variations are however unlikely to affect the numbers of frequent users (> seven monthly resights) and occasional visitors (two to seven monthly resights) identified in each study, which showed a decrease since Constantine 2002 of 74.6% and 95.6%, respectively. 81.4% of bottlenose dolphin resights in the Bay of Islands were accounted for by one group of 15 identifiable individuals (frequent users). Results suggest that bottlenose dolphins' use of the Bay of Islands is changing, with only one group of frequent users seen regularly and fission-fusion examples rarely observed within this group. The near-loss of occasional visitor individuals brings concerns to the status quo of bottlenose dolphin presence in the Bay of Islands, should the one group of frequent users shift its preferred area of use to a different location.

Significant effects on bottlenose dolphin behavioural budget, bout length, transitions, and time to return to behaviour were detected in the "Presence" state, considered initiated whenever at least one vessel of any type is within 300m of a focal group (additional to the research vessel). Vessel presence effects were consistent with Peters & Stockin 2016, indicating an overall reduction in energy acquisition behaviours (foraging and resting) and increase in energy expenditure behaviours (socialising and milling) in the presence of vessels, as well as a reduction in group mobility (traveling). These changes are still occurring in a context of reduced boat traffic (30% of daylight hours vs 86% for Peters & Stockin 2016), however a strong seasonality in the behavioural change is observed: in Winter, no significant differences were observed for traveling, foraging and socializing, while in Summer (peak calving season) most behavioural states were affected (traveling, socializing, milling and resting). Low sample sizes in Winter for milling, resting and diving did not allow for further seasonal comparison of these behavioural states. Most vessels recorded entering within 300m of dolphins were private vessels (85%, n=1180), and highest vessel traffic was observed in Summer (62% of daylight hours, maximum new vessels/hour = 107). Vessel traffic during this study takes place in the context of permitted vessel restrictions implemented by the Department of Conservation, COVID-19 restrictions, and increased public awareness to dolphin-vessel interactions through the Bay of Islands Marine Mammal Sanctuary implementation process.

Second year calf mortality (50%) was reduced from Peters & Stockin 2016 (75%), although still high and similar to Tezanos-Pinto 2009 (52%). Fewer calves were also documented with the total number of calves whose survival rates could be determined (n=5), a reduction of 70.6% from Constantine 2002 (n=17).

Bottlenose dolphins remain the economic core of dolphin-watch operations in the Bay of Islands and a taonga species for local Hapū. While the Bay of Islands represents only a part of the range of bottlenose dolphins along the North-East coast, it is one of only two areas (Great Barrier Island, Dwyer et al, 2014) where year-round presence and high resight rates have been reported. As such, the decline reported here raises questions both about the viability of the Bay of Islands as bottlenose dolphin habitat and the health of the wider North-East coast bottlenose dolphin population. Management decisions aiming at 1. Improving ability to produce viable offspring, including by reducing observed behavioural changes, 2. Continuing to investigate other population parameters which may take part in the observed decline and 3. Monitoring the effectiveness of the Bay of Islands Marine Mammal Sanctuary, with a goal of attaining no significant changes observed in any seasons, are recommended.

As top-predators, easily detected and highly mobile, cetacean species are considered reliable environment sentinels (Fossi et al., 2018) giving early indications of changes in marine ecosystems. Other species have been the topic of studies in the Bay of Islands, including identification of changes in subtidal seagrass beds (Booth 2019) or of rodolith beds harbouring high diversity of invertebrate taxa

(Nelson et al, 2012, Meill et al, 2015). In some cases, protection measures have been taken, including closure of Kūtai /Mussels in the Te Puna Mātaitai since March 2020 and Temporary Fishing Closure (except Kina) in Maunganui Bay since December 2010. A reduction in cetacean numbers such as the one reported here represents a potential warning sign for the Bay of Islands' rich ecosystem, and offers an opportunity to investigate other elements in time to promote conservation efforts.

2. Introduction

Over the past few decades, sustainable use of resources and environmental conservation has become a strong focus worldwide. As the largest biome on the planet, marine ecosystems represent a key element of this process, providing nutritional, recreational and cultural resources. While ocean studies and conservation carry inherent complexities for data collection, marine scientific publication numbers continue to increase (Global Ocean Science report 2020), particularly in a global context of climate change concerns.

The use of cetaceans as a resource is an illustration of this context, with a global shift from whaling to whale-watching, as a more sustainable practice (Hoyt 1995; Cunningham et al., 2012). Supported by the fascination of the general public towards marine mammals (Bejder et al., 2022), the industry has grown exceptionally since its start in the 1950s, and is now present in over a hundred countries, welcoming millions of visitors and generating billions in expenditures (O'Connor et al., 2009). Cetacean focused tourism offers the potential for economically viable operations, with additional conservation benefits such as fostering public stewardship towards marine ecosystems (Parsons et al., 2003) and improved access to marine environments. As cetacean-focused tourism grows, so does independent seeking of marine mammal interactions from private vessels.

However, whale watching (whether commercial or private) has also been shown to have the potential for detrimental effects on targeted populations. As common practices become more interactive, (Spradlin et al., 2001), cetaceans are placed at a higher risk of harassment or injury. With more long-term data available on the possible effects of vessel interactions, it is becoming apparent that such activities have the potential for both short-term effects, such as vessel strike and changes in behaviour or vocalisations (Buckstaff 2004; Guerra et al., 2014; Pirotta et al 2015; Peters & Stockin 2016), and longer-terms effects at the population level such as displacement from habitats (Nishiwaki & Sasao 1977; Lusseau 2005; Rako et al., 2013). The rise of these concerns has triggered the exploration of new ways to manage the industry (Bejder et al., 2002), including the introduction of the concept of maximum sustainable tourism yield (MSTY) in 2020 (WSAS 2020) for southern resident killer whales.

In New Zealand (NZ), such effects have been measured across several areas and species, including Hector's dolphins (*Cephalorhynchus hectori*) (Bejder et al., 1999; Martinez et al., 2011), dusky dolphins (*Lagenorhynchus obscurus*) (Markowitz et al., 2009; Lundquist at al., 2012), and common dolphins (*Delphinus sp.)* (Neumann & Orams 2005, 2006; Stockin et al., 2008a; Martinez & Stockin 2013; Meissner et al., 2015).

The *nationally endangered* bottlenose dolphin is a particularly well studied species worldwide and in New Zealand, with three genetically distinct populations (Tezanos-Pinto et al., 2009, Figure 1) and new hotspots recently described (Great Barrier Island, Dwyer et al., 2014; Stewart Island, Brough et al., 2015; Kermadec Islands, Baker et al., 2016). Studies on vessel interactions were carried out in two out of those populations. Research in Fiordland identified changes in dive behaviour and habitat displacement (Lusseau 2003, 2004) as a result of tour activities, as well as changes in residency patterns (Lusseau 2005). Within the North-East coast population range, dolphins using Bay of Islands (BOI) waters (referred to hereafter as "local BOI population") have shown similar changes over several decades. A decrease in resting and increase in milling in the presence of permitted vessels was detected in 1997-1999 (Constantine 2002). Further concerns were raised by Tezanos-Pinto (2013; et al., 2013; 2015) with the detection of a population decline and high calf mortality. Those concerns were confirmed by Peters & Stockin 2016, with a further decline in identifiable individuals in the BOI and disruption in survival critical behaviours year-round and by all vessel types.

As a result, several actions were taken by the Department of Conservation (DOC) of NZ in the Bay of Islands:

- In 2016 an on-the-water public education campaign took place over the busier Summer months, and was carried on for several years. This included a combination of TriOceans and DOC vessels interacting with boaties directly during an encounter with bottlenose dolphins. Soft-sided vessels were used to approach vessels and discuss marine mammal biology and regulations. A total 2000 “boatie bags” specifically designed for this purpose, containing DOC brochures around national marine mammal regulations, a floating key ring stating the main national rules, and other marine conservation topics were distributed between 2016 and 2018, both on the water during direct interactions and at public events. The use of this boatie bag continues to date, with and additional 4000 printed by January 2022. A maritime radio add on “Russell Radio” ran from December 2015 to December 2018, including information on the Marine Mammals Protection Regulations (1992) (MMPR), and a newly introduced voluntary 100m no approach zone for mothers and calves. The same information was displayed on new boat ramp signage. Additional information pertaining to the marine mammal permits, scientific findings and conservation messages were published on the DOC social media pages.

- In July 2019, the DOC implemented changes in permitted vessel activities around marine mammals in the BOI, including encounter times reduced to 20 minutes, removal of static “no-go” zones to implement new no-interaction zones that would be reviewed on a 3-year basis, and a ban on morning encounters and swim-with activities with bottlenose dolphins.
- A feasibility assessment for a Bay of Islands Marine Mammal Sanctuary (MMS) was carried out in 2019, which resulted in a public consultation process taking place in April/May 2021.

This resulted in the need for a comparative study to quantify the effects of the permit management changes and re-evaluate the status quo of the local BOI bottlenose dolphin population to ensure the most up-to-date information was continually available.

The DOC contracted this research to obtain as solid as possible scientific evidence on the effectiveness of management decisions and an update on the status of the local BOI bottlenose dolphin population. Furthermore, this report and associated data now constitute a pre-MMS establishment dataset that can be used as a comparison point for future research.

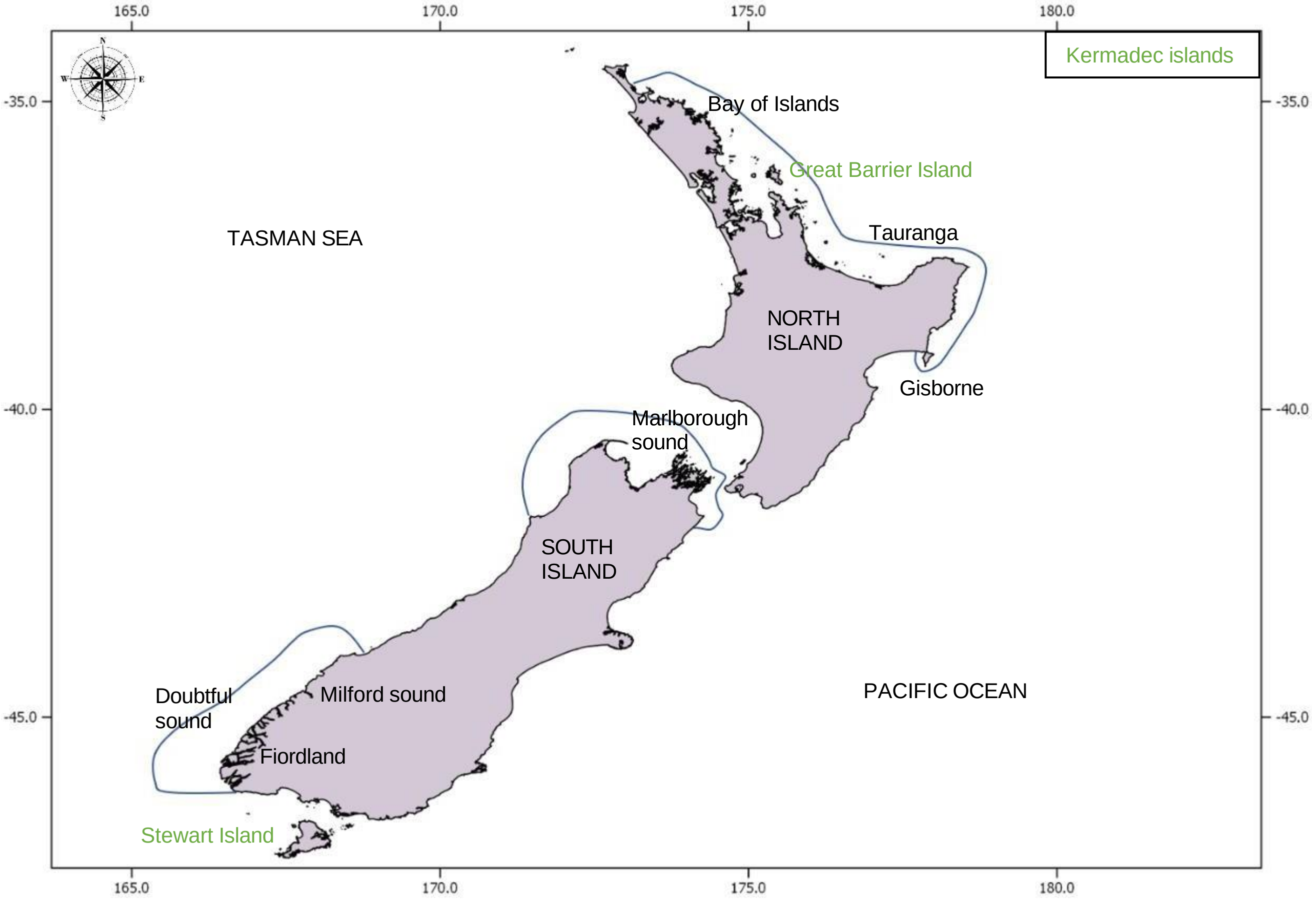


Figure 1: Presumed discontinuous distribution of coastal bottlenose dolphins (*Tursiops truncatus*, inside blue line) from live sighting data, New Zealand. Newly described hotspots are shown in green (adapted from Peters, 2018).

3. Objectives

The DOC is tasked with the management protection and conservation of marine mammals under the Marine Mammals Protection Act (1978), primarily achieved through the Marine Mammals Protection Regulations (1992). In the Bay of Islands, the DOC has used scientific findings (Peters & Stockin 2016) to make management decisions on the local BOI bottlenose dolphin population due to the unique pressures faced in that area. The DOC commissioned this study to assess the effectiveness of those decisions, as well as obtain an update on the status of the local BOI population. Specifically, this study aims to:

1. Determine the range extent of bottlenose dolphins in Far North (Doubtless Bay to Whangarei harbour) and Bay of Islands waters
2. Provide an update of the number of identifiable individuals and usage patterns in Far North and Bay of Islands waters.
3. Quantify post management changes variation in vessel effort around bottlenose dolphins in the Bay of Islands.
4. Determine the potential effects of interacting with bottlenose dolphins as currently permitted for both commercial operations and private vessels in the Bay of islands. This includes describing behavioural responses of dolphin groups to allow comparison with Peters & Stockin (2016).
5. Provide an update of bottlenose dolphin calf survival in the Bay of Islands
6. Provide an update of other marine mammal species occurrence in the Bay of Islands and Far North waters.
7. Integrate present and historical research results to produce statements and recommendations regarding existing and future anthropogenic activities around bottlenose dolphins in the Bay of Islands and Far North waters.

More explicitly:

1. How does the number of identifiable bottlenose dolphin individuals compare with previous studies? How does this vary across different user groups?
2. What is the current level of vessel action [permitted, commercial (un-permitted) and private] around bottlenose dolphins? Does the current level of vessel action correlate with any significant effects on dolphin behaviour? How does the current level of vessel action differ from levels identified in Peters & Stockin 2016?
3. What are the short-term behavioural responses of dolphins in relation to viewing by tourists? Are these activities significant for the local BOI population? Should these activities be reduced, remain at current levels, or could the level of activity be increased? Do current behavioural responses differ from what was previously reported?
4. How many calves were observed in Far North and Bay of Islands waters? What is the current 1st year and 2nd year calf mortality rate? How does this rate differ from previous studies?
5. What further conditions (if any) could be considered to minimise any identified effects? These conditions should address the following questions:
    What are the occupancy patterns of bottlenose dolphins? Are the locations of no-interaction zones put in place in July 2019 still relevant? Are there other areas that should be considered? Is the limit on the length of time each permitted operator spends with the dolphins for viewing, once an interaction is established, still appropriate?
6. What is the potential long-term significance of the current level of tourism activities on bottlenose dolphins in the BOI?
7. Once the previous questions have been answered: what are the implications of current vessel effort for the local BOI population, and in Far North waters? What recommendations could be suggested for managing vessel effort in these areas?

4. Materials and methods

4.1. Data collection

4.1.1 Survey methods

Data were collected in Far North waters, Doubtless Bay, to Whangarei Harbour, (Latitude 34.85° to 35.90° S, Longitude 173.35° to 174.70° E), on the North East coast of the North Island, New Zealand (Figure 2), within inshore limits, between June 2019 and November 2021 (included), with a particular focus on the Bay of Islands. The survey area was reduced to the Bay of Islands (Tikitiki Island to Cape Brett) for analytical purposes in some sections of this report. Survey methods combined systematic transect following a zigzag equal angle transect design (Figure 2) and random survey. The systematic zigzag transects were designed using the software Distance 7 to evenly cover the complex zones of the study area.

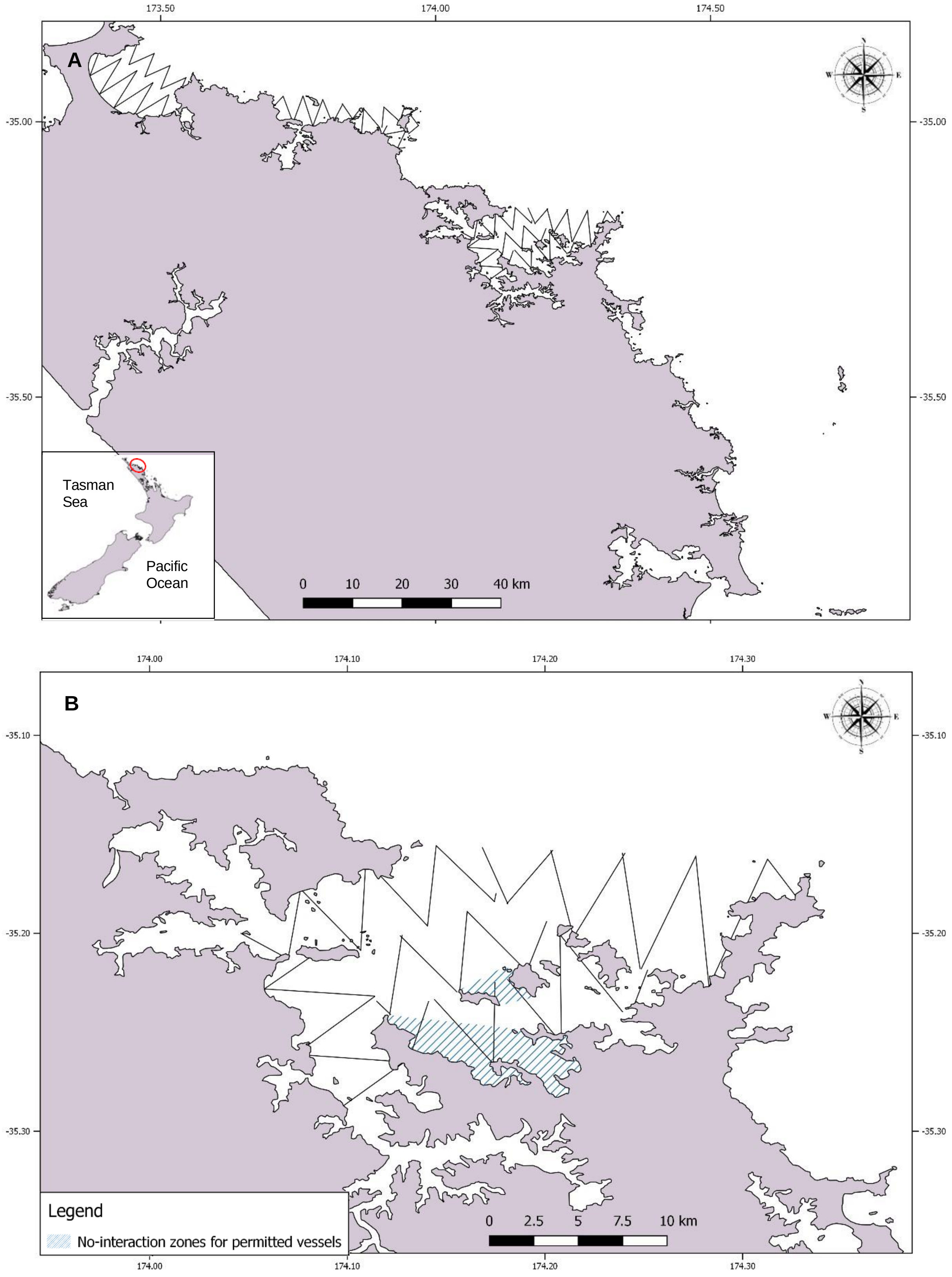


Figure 2: Entire study area (A) and Bay of Islands only (B) and transect lines, New Zealand. The dashed zones represent the current no-interaction zones for permitted vessels, and safe 5 knots zones as part of the Bay of Islands Marine Mammal Sanctuary.

Data were collected from the research vessels RV Wavelength (June – October 2019) and RV Kekeno (October 2019 – March 2020), respectively a 5.5m STRATA 550 (Smuggler Marine) vessel powered by a 90 hp engine and a 6.6m Highfield Patrol 660 powered by a 115hp engine (Figure 3). Owing to the eye height of both vessels, (~2m above sea level), surveys were conducted in good weather conditions (Beaufort sea state (BSS), ≤3) and in good visibility (≥1 km)) (Dwyer et al., 2014; Peters & Stockin 2016). In fog, precipitation or BSS >3, surveys were discontinued. Survey transects were selected on the day depending on sea conditions and already realised survey effort, with the aim to evenly cover all areas (Dwyer et al., 2014; Peters & Stockin 2016).

Environmental and observational data were collected using a Samsung SM-T335 tablet computer equipped with CyberTracker (CyberTracker Conservation, Version 3.505+). The software was programmed to record continuous GPS tracks (with GPS recordings every 30s).

Figure 3: TriOceans research vessels RV Wavelength (left) and RV Kekeno (right) (Photographs: C. Peters).

To allow direct comparison of results, survey methods followed Peters & Stockin 2016. At the onset of each survey, environmental data including cloud coverage, glare, swell height and BSS were recorded. The vessel was then operated at survey speed and *On survey mode* commenced.

On survey mode: Paired observers scanned an allocated vessel side from directly ahead to 90° abeam (Mack et al, 2002). Travel direction was decided based on sea conditions and vessel speed maintained at 10-13 knots (Constantine 2002; Cañadas & Hammond 2008; Dwyer et al., 2014; Peters 2018). Dolphin groups were detected by naked eye and/or binoculars. Observer positions were rotated every hour to prevent fatigue. Standard dolphin detection cues included splashing, fins breaking surface waters, behaviour of other vessels and presence of birds (Constantine 2002; Lusseau 2006; Peters & Stockin 2016).

Once a group was detected, all observers stopped scanning and focused on data collection on the focal group encountered (Mann 1999; Stockin et al., 2008a; 2008b). As such, no further effort was undertaken to detect new groups during this time and *On survey mode* was discontinued. *On encounter mode* commenced.

On encounter mode: the research vessel was operated following the Marine Mammals Protection Regulations (1992, Part 3) to not disrupt the normal movement or behaviour of any marine mammal. When within 300m of any marine mammal, the vessel was manoeuvred at a constant idle or no wake speed in such a way that no animal was separated from the focal group. Groups were approached from the side or behind, as far as possible (Stockin et al., 2008b).
Once within 300 m of the group, environmental parameters including water depth (± 0.1 m) and SST (sea surface temperature) (± 0.1o C) were recorded using an on board depth sounder and Simrad Go7 chart plotter.

Species and ecotype were confirmed at the onset on data collection based on external morphological criteria (Visser et al., 2010; Zaeschmar 2015; Peters 2018; Zaeschmar et al., 2020).

4.1.2 Group size and composition

Groups were considered independent if separated by more than 5km, sighted more than 30min after the previous group, or where feasible as confirmed by photo-identification (Stockin et al., 2009; Peters & Stockin 2016). Group sizes were recorded using the absolute minimum, absolute maximum and best estimate for the number of individuals in the group (Dwyer et al., 2014; Peters & Stockin 2016). Groups were further categorised in any combination of adults, juveniles, calves and neonates present (Table 1) (Constantine et al., 2003).

Table 1: Age class definitions of bottlenose dolphins based on Constantine et al. (2003) in Far North waters, New Zealand.

Age class	**Definition**
Neonate	Classified by the presence of white dorso-ventral foetal folds down their sides (Cockcroft & Ross 1990, Kastelein et al., 1990). Typically displayed poor motor skills and were often uncoordinated upon surfacing to breathe (Mann & Smuts 1999). The neonate stage usually lasts up to 3 months of age.
Calf	Defined as dolphins that were approximately one-half or less the size of an adult and were closely associated with an adult, often swimming in 'infant position' (i.e., in contact under the mother) (Mann & Smuts 1999).
Juvenile	Approximately two-thirds the size of an adult and were frequently observed swimming in association with their mothers but were never observed swimming in 'infant position' (i.e., in contact under the mother; Mann & Smuts 1999), suggesting they had been weaned (Mann et al., 2000).
Adult	All dolphins (including assumed mothers) that were fully-grown, i.e., equal or greater than 3m in total body length.

When dolphin behaviour and sea state allowed it, photo-identification of individual bottlenose dolphins was conducted using either a Sony α2000 camera fitted with a FE 4.5-5.6/100-400GM OSS lens, a Canon 5D camera fitted with a EF 100-400mm 1:4.5-5.6L, or a Canon 7D camera fitted with a EF 28-300mm 1:3.5-5.6L following previously outlined methods on bottlenose dolphins in the Bay of Islands (Constantine 2002; Tezanos-Pinto et al., 2013; Peters & Stockin 2016; Peters 2018). For each sighting, effort was made to randomly photograph all individuals in a group. Photos were taken of the dorsal fin as primary identifiers and flanks and/or any other areas with identifiable marks as secondary identifiers.

4.1.3 Behavioural data collection

Methods followed Peters & Stockin 2016 and Peters 2018, as summarised below:
Every three minutes, the predominant behaviour of the group was recorded, following mutually exclusive and cumulatively inclusive categories (Table 2). When determining the predominant behavioural state of the focal group, all dolphins were scanned from left-to-right. This ensured inclusion of all individuals in the group and avoided potential biases caused by specific individuals or behaviours (Mann 1999). In cases where not all group members behaved in a uniform manner, the 50% rule was applied (Lusseau 2003), where the behavioural state was determined as the category in which more than one-half of the group was involved. If an equal percentage of the group was engaged in different behaviours, all behavioural states were logged.

In addition to predominant behaviour, the number of vessels present within 300m, number of vessels interacting with the dolphins, and vessel traffic type (Table 3) were recorded every three minutes. The distance of 300m was chosen to follow MMPR (1992), where all vessels must slow to idle or no wake speed (Regulation 18(1)) (Peters & Stockin 2016).

The distance was estimated by eye by trained observers, and whenever possible confirmed by laser range finder (Kogan 5-600P). Daily checks of distance estimation using laser range finders on fixed objects/slow moving vessels or chart plotter data were additionally conducted to help with initial distance estimation.

Table 2: Definitions of behavioural states of bottlenose dolphin groups in Far North waters, New Zealand, with abbreviations for each state given in parentheses (Neumann 2001; Constantine 2002; Lusseau 2003; Constantine et al., 2004).

Behavioural state	Definition
Travel (T)	Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing
Foraging (F)	Dolphins involved in any effort to pursue, capture and/or consume prey, as defined by observations of fish chasing (herding), co-ordinated deep and/or long diving and rapid circle swimming. Diving may also be performed, i.e. arching their backs at the surface to increase their speed of descent. Dolphins show repeated unsynchronised dives in different directions in a determined location. High number of non-coordinated re-entry leaps; rapid changes in direction and long dives are witnessed. Presence of prey observed.
Socialising (S)	Dolphins observed in inter-individual interaction events among members of the group such as social rub, aggressiveness, chasing, mating and/or engaged in any other physical contact with other dolphins (excluding mother-calf pairs). Aerial behavioural events such as horizontal and vertical jumps are frequent
Resting (R)	Dolphins observed in a tight group (<1 body length apart), engaged in slow manoeuvres with little evidence of forward propulsion. Surfacing appears slow and are generally more predictable (often synchronous) than those observed in other behavioural states.
Milling (M)	Dolphins exhibit non-directional movements; frequent changes in bearing prevent animals from making headway in any specific direction. Different individuals within a group can swim in different directions at a given time, but their frequent directional changes keep them together. Milling can be associated with feeding and socialising
Diving (D)	Dolphins engaged in persistent, non-directional movements; frequent periods sub-surface with short surfacing's. Different individuals within a group can dive in different directions at a given time, but their frequent directional changes keep them together.

Table 3: Definitions of vessel traffic types in Far North waters, New Zealand (Peters & Stockin 2016)

Vessel traffic type	Definition
Absence	Research vessel present with all other vessel types absent within 300m
Presence	Research vessel present with other vessel types present. Considered initiated whenever at least one vessel of any type is within 300m of a focal group (additional to the research vessel)

Additionally, each individual vessel was recorded upon entering within 300m of the dolphins according to vessel type: Permitted (commercial operation with dolphin-watch permit), Commercial (without dolphin-watching permit), Private (non-commercial vessels) and DOC/research.

Once all data were recorded, the research vessel returned to on survey mode to search for further independent groups.

4.1.4 Calf survival

Data collection and analysis were designed to allow comparison with Tezanos-Pinto (2009) and Peters & Stockin (2016).

Upon first sighting of a female-neonate pair, an approximate indication of date of birth was made. As per age group definitions (Table 1), a neonate could have been born between one and three months from first sighting. Calf resights where subsequently recorded by using photographs (taken as per section 4.1.2) of the calf flanking the presumed mother and/or secondary (or primary where available) identifying markers on the calf. Additional datasets were included for analysis of calf survival (October

2017 to May 2019, Guerin, unpublished data) and photogrammetry (December 2018 to May 2019, Guerin, unpublished data), following the same data collection methods.

To assess calf growth, photogrammetry was used as per van Aswegen et al, 2019: a stereo-laser system was used in combination with a Canon 7D camera fitted with an EF 28-300mm 1:3.5-5.6L lens. The laser system (designed, manufactured and supplied by Barnacle Electronics, Scotland) consisted of two Beamshot (Quarton USA Inc, USA; 5mW; 532nm) laser modules mounted 10cm apart on an aluminium block housing. The housing was attached to the camera lens using a tripod mount (Figure 4). An on-off switch allowed to disable the system to improve both human and animal safety (van Aswegen et al., 2019).

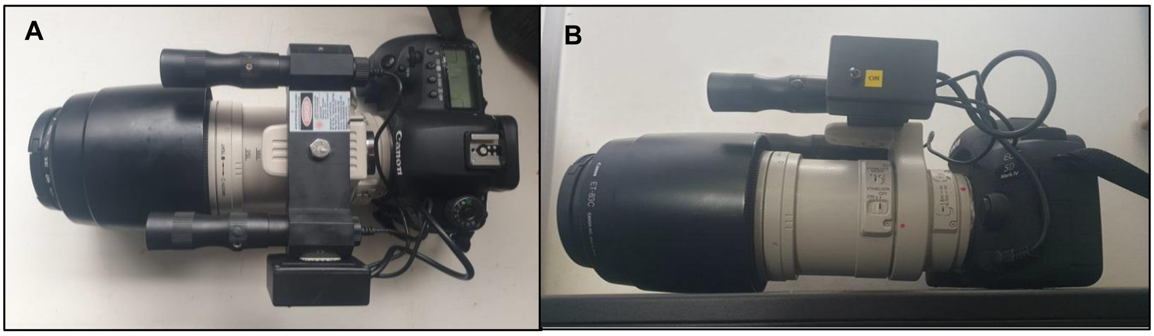


Figure 4: Laser stereo-photogrammetry rig with A) Top view and B) Side view

A calibration method was applied before and after every survey to ensure the lasers dots remained 10cm apart and parallel: calibration photographs were taken at five incremental distances (5-25m) from the calibration sheet. If before survey, the lasers were found to not align with the reference points, the vertical and horizontal grub screws were used to re-align the system (van Aswegen et al., 2019). If the laser dots were found to not align after survey, i.e. a de-alignment occurred during the survey, data from that particular survey was removed from the analysis.

Photogrammetry data were collected while conducting photo-identification (section 2.1.2) data collection. The laser system was switched on only if dolphins were within 5-25m of the vessel, with no other vessels around. Using the camera autofocus point and the view finder, the lasers were placed on the dorso-lateral surface of the dolphin (van Aswegen et al., 2019) (Figure 5).

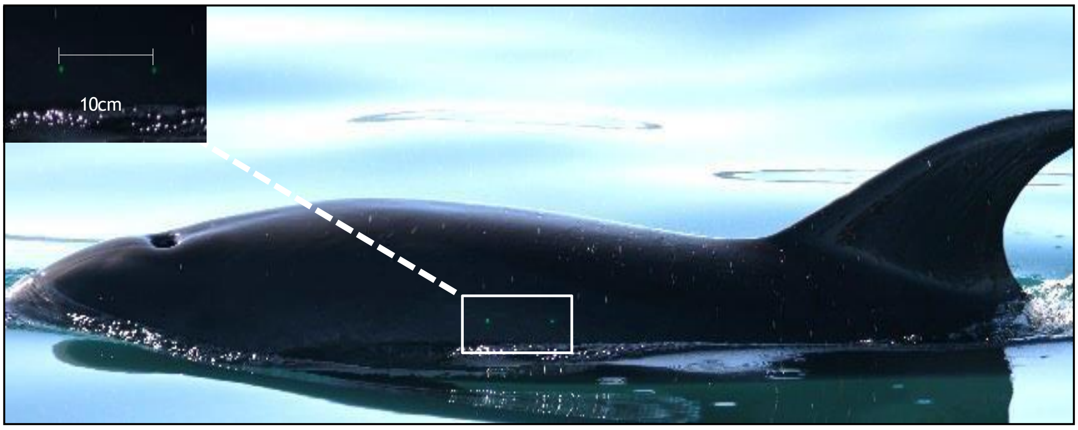


Figure 5: Example of a bottlenose dolphin photograph with calibrated laser dots visible on the flank (Photograph: T. Guerin)

4.2 Data analysis

Data analysis replicated key methodologies from previously published work (particularly that of Constantine et al., 2003; 2004; Tezanos-Pinto et al., 2013; Peters & Stockin 2016). Statistical analyses were conducted using R i386 (Version 3.4.3), with the significance threshold set at 0.05.

4.2.1 Distribution

Vessel effort and marine mammal sightings were plotted using a Geographic Information System (GIS), created using QuantumGIS version 2.18.3. All effort data were gridded as km effort covered / km^2 to allow trends to be analysed in the context of unevenly distributed effort.

4.2.2 User type and site fidelity

Data analysis replicated key methodologies from previously published authors (Tezanos-Pinto 2009, Peters & Stockin 2016): digital photo-identification photographs were renamed with information on area, species, photographer, camera, date, frame number, vessel, survey number and encounter number. Data were then processed as follows:

1- All photos were graded according to a quality scale (as per Tezanos-Pinto et al., 2013).
2- For each encounter, unique individuals were identified based on a combination of long-term markings, nicks and notches on the trailing edge of the dorsal fin, with secondary features such as scarring (including rake marks due to the short length of study relative to mark loss rate) and fin shape (Würsig & Jefferson 1990). Dolphins were considered marked if there was at least one primary and two secondary features. Fin images were grouped per individual.
3- For each encounter, all photos of the same individual were matched to a temporary catalogue. Before adding a new individual or resight of a previously identified individual in the temporary catalogue, all images were independently checked by three researchers (Tezanos-Pinto 2009). After an addition or confirmed match, the data were entered into a database.

To assess the minimum number of individuals using BOI waters, images of the dorsal fin of each identified individual were compared across encounters. A ‘resight’ refers to an individual identification photograph obtained during an encounter with a unique individual (ID) and the associated data collected during each encounter (Dwyer et al., 2014). Once a fin was identified on a specific day, all other resights of that fin on the same day were removed from analysis, resulting in a maximum of one sighting per day for each individual.

User type was based on sighting frequency (number of resights) and grouped into three categories: frequent users, occasional visitors and infrequent users of the BOI (Constantine 2002; Tezanos-Pinto 2009; Peters & Stockin 2016). This was achieved by fitting a Poisson distribution to test the null hypothesis that individuals were sighted randomly with regards to monthly frequency. This distribution was selected given that it expresses the probability of a number of events occurring in a period of time (e.g., months) with a known average rate (e.g., resights). The point at which the number of resights exceeds the expected frequency of the Poisson distribution was considered to indicate ‘frequent users’. The variation between observed and expected frequencies was tested using a chi-square goodness-of-fit test. Results from this study were compared with Peters & Stockin 2016, Tezanos-Pinto et al., 2013 and Constantine 2002.

4.2.3 First behavioural data processing

Methods followed Peters & Stockin 2016. Behavioural distribution was calculated as a proportion of all behavioural states observed within each 1km/1km grid cell. To examine the behavioural states in which more than one-half of the group was involved, any recording with two behavioural states was removed. Consecutive behavioural observations are not likely to be statistically independent, and as such they were analysed as a series of time-discrete first-order Markov chains (Markov 1906; Lusseau 2003; Lundquist 2012; Bas et al., 2017). Data were investigated and first order behavioural chains constructed at the following levels:

- Diurnal (morning vs afternoon). To match Bay of Islands permitted vessel regulations, morning was defined as before 12:00PM and afternoon as after 12:00PM for all seasons
- Seasonal
- Absence vs presence (as described in Table 3)
- Absence vs whole database, seasonally and year-round

When switching from one chain to another (successive 3min observations), the transition between the two succeeding behavioural states was discarded (Lusseau 2003). Sequences of more than 15min (or five transitions) were considered for Markov chain analyses (Stockin et al., 2008a; Meissner et al., 2015). No assumption is made that the research vessel had no effect on dolphin behaviour. To minimise any potential effect, the vessel was consistently driven by the same skipper in accordance with best practice.

For each level of investigation, the behavioural budget (proportion of time spent in state) is presented as a proportion of all observations within first-order Markov chains, for each state. Standard errors are 95% confidence intervals.

Seasonal Absence vs whole database was investigated as a way to account for amount of vessel interactions directly.

4.2.4 Probability matrices

Assumptions described in Lusseau (2003), including 1) the probability that a transition will occur remains the same over time and 2) annual variation had no effect on the outcome were met here.

For each level of investigation, transition probabilities from preceding to succeeding behavioural states were calculated by:

$$P_{ij} = \frac{a_{ij}}{\sum_{j=1}^{6} a_{ij}} \; ; \; \sum_{j=1}^{6} P_{ij} = 1 \qquad (1)$$

where *i* and *j* refer respectively to the preceding and succeeding behavioural state with *i* and *j* ranging from 1 to 6 (six behavioural states), a_{ij} is the number of transitions recorded from the behaviour *i* to *j* and P_{ij} corresponds to the transition probability between behaviour *i* and *j* in the chain. Therefore, each calculated P_{ij} corresponds to the proportion of time the specific succession was observed in the chain. Pairs (each P_{ij} to its counterpart, depending on level investigated) were tested to detect effects of vessel presence on the behavioural transitions with a Z-test for proportions (Fleiss 1981).

The mean length of behavioural bouts was calculated. Bout length represents the mean length of time spent in a behavioural state before changing to a different state (Lusseau 2003; Lundquist et al., 2012):

$$\bar{t}_{i\,i} = \frac{1}{1 - P_{ii}} \qquad (2)$$

where P_{ii} is the probability of transitioning from state *i* to state *i*, i.e. remaining in the same state. This was also used to calculate the continuous minutes spent in the absence of vessels.

Standard errors for behavioural bout length were calculated using 95% confidence intervals (Lundquist; 2012):

$$SE = \sqrt{\frac{P_{11} * (1 - P_{ii})}{n_i}} \qquad (3)$$

where n_i is the number of times the behavioural state *i* was counted as the preceding behaviour. Pairs (each absence $\bar{t}_{i\,i}$ to its presence counterpart) were tested with a Z-test for proportions (Fleiss 1981).

For presence/absence chains, the mean time (i.e. number of transitions) for the dolphins to return to each behavioural state after change was also assessed:

$$E(T_j) = \frac{1}{\pi_j} \qquad (4)$$

where T_j is the number of time (i.e. number of transitions) it took the dolphins to return to a behaviour j given that behavioural state changed and π_j the probability to be in the behavioural state j in the chain. T_j was multiplied by the length of the transition unit (three minutes, section 2.1.3) to convert the results in minutes. Pairs (each absence T_j to its presence counterpart) were tested to detect the effect of vessel presence on time to return to behavioural state with a Z-test for proportions (Fleiss 1981).

4.2.5 Vessel effort

To allow comparison with Peters & Stockin 2016, diurnal categories were created to consider daylight variations across the year, using a time of day index (Lundquist et al., 2012). Both datasets of vessel traffic recorded every 3min and individual vessel type approaching within 300m of the dolphins were investigated at the seasonal and time of day level.

A desktop exercise was carried out to give an indication of the effect of the Bay of Islands Marine Mammal Sanctuary on local commercial operations. Marine mammal encounter probability was calculated for the core commercial area, as well as average marine mammal travel speed. Average distance travelled per trip by commercial operators and time needed for marine mammals to exit a 300m zone was estimated. The calculations above were used to give an estimate of average time required to stop for commercial operations in the Bay of Islands under the Bay of Islands Marine Mammal Sanctuary rules (REF). Several assumptions are made in this process, and as such the result should be used as an idea of scale rather than exact values.

4.2.6 Calf survival

Analysis was designed to allow comparison with Tezanos-Pinto (2009) and Peters & Stockin (2016). Date of Birth was approximated based on the first sighting of an identifiable female accompanied by a neonate (born 1 – 3 months prior to first sighting date). Only data from dolphins known to be neonates or very young calves were used to avoid potential error in date of birth estimation. Due to COVID-19 lockdown occurring partway through the study, calves observed immediately after lockdown (up to 6 months old) were included. If unmarked, the identity of the calf was inferred from the close association with the identified mother.

A calf was assumed to have survived its second year of life at 24 months (18-20 months being the minimum weaning age, Smolker et al., 1992; Wells & Scott 1999). A calf was assumed to have not survived if it was less than 18 months of age and the presumed mother was resighted in two consecutive encounters without the calf (Steiner and Bossley 2008). First -year calf mortality was calculated as the number of calves assumed to not have survived over one year divided by the number of calves whose fate could be documented over one year. Second-year calf mortality was calculated as the number of calves assumed to not have survived over two years divided by the number of calves whose fate could be documented over two years.

All photogrammetry-based measurements were made using the image processing software ImageJ. To reduce horizontal angle error, only photos of very high quality, considering focus, clear display of laser dots, parallel positioning of the dolphin and visibility of the dorsal fin and blowhole were selected (van Aswegen et al., 2019).

Using the software ImageJ (http://rsbweb.nih.gov/ij/), the 10cm scale provided by the laser dots was converted into number of pixels. The number of pixels between the medial point of the blowhole (BH) and the anterior origin of the dorsal fin (DF, BH-DF) were then converted back into centimetres (van Aswegen et al., 2019).

Sampled individuals were identified using markings on the flanks and dorsal fin if available, or association with an identified mother. If any uncertainty existed around the identity of the calf, the photograph was excluded.

5. Results

5.1 Effort

Data collection between June 2019 and November 2021 comprised 130 vessel-based surveys, over 27 survey months (note: survey effort did not occur during three survey months, due to COVID-19 restrictions (April-May 2020) and/or weather (August 2020)). A total of 6291.1km of track were surveyed whilst on effort (296.2hrs) (Figure 6). The proportion of survey effort that occurred within Bay of Islands waters was 76.9% (n=4841.1km).

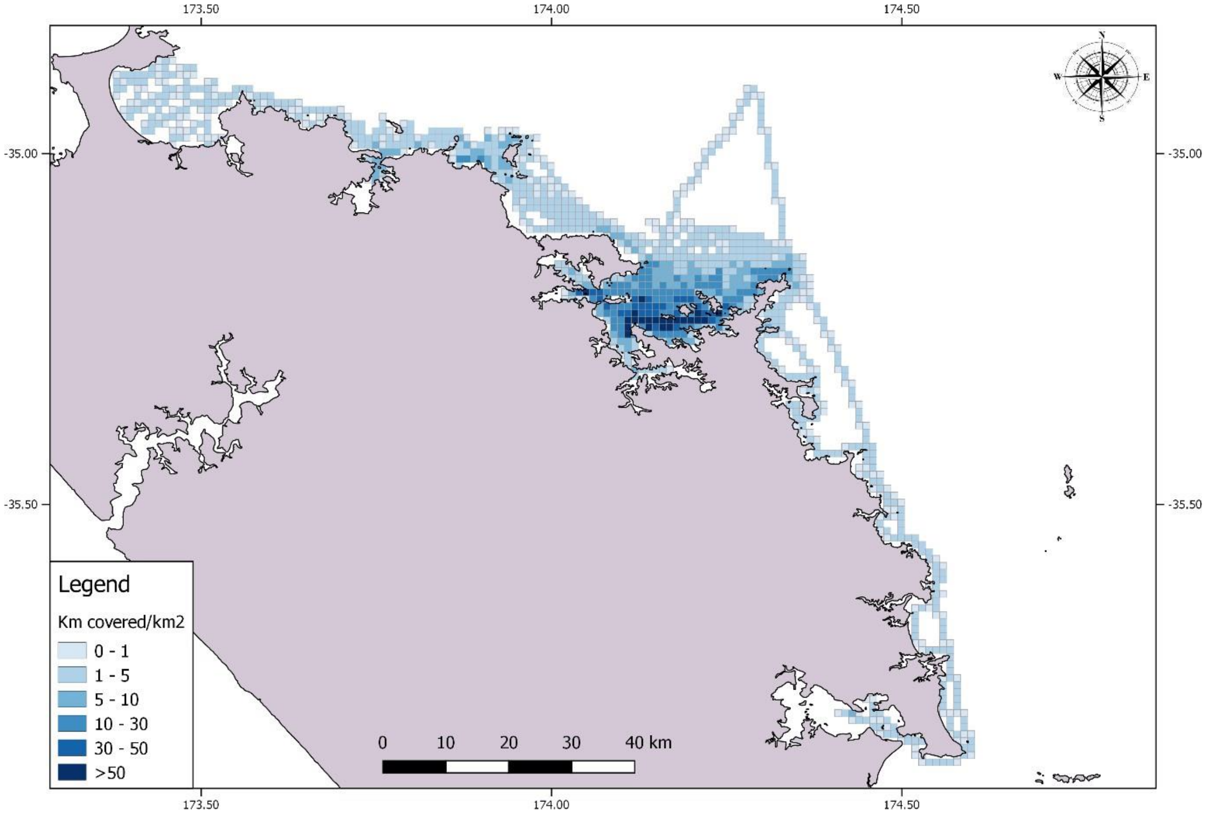


Figure 6: Research vessel survey effort between June 2019 and November 2021 in Far North waters, New Zealand, coloured according to the proportion of kilometres (km) travelled while on survey within each grid cell (1km x 1km).

Surveys were conducted in every season of the study period, with highest numbers in Spring/Summer due to good weather conditions, and lowest in Winter and Autumn due to weather conditions and interruption of data collection (New Zealand COVID-19 quarantine, March-May 2020) (Table 4).

Table 4: Surveys per season between June 2019 and November 2021, in Far North waters, New Zealand.

Seasons	**Winter**	**Spring**	**Summer**	**Autumn**
No. of surveys	16	42	53	19

5.2 Sightings

Out of a total of 137 marine mammal encounters, bottlenose dolphins were the most recorded marine mammal species within the study area (54.7%, n= 75), with almost all sightings being of the coastal ecotype (94.7 %, n= 71) and the remaining 5.3 % (n= 4) being of the oceanic ecotype (Table 5). For the coastal ecotype, this includes 62 sightings while *On survey*, and an additional 9 sightings while *Off survey.*

The remaining sightings were of New Zealand fur seals (*Arctocephalus forsteri*) (29.2 %, n= 40), common dolphins (*Delphinus sp.*) (6.6 %, n= 9), killer whales (*Orcinus orca*) (2.9 %, n= 4), Bryde's/fin/sei whales (*Balaneoptera edeni/physalus/borealis*) (2.2 %, n= 3), humpback whales (*Megaptera novaeangliae*) (2.2 %, n= 3), false killer whales (*Pseudorca crassidens*, referred to hereafter as pseudorca) (1.5 %, n= 2) and long-finned pilot whales (*Globicephala melas*) (0.7 %, n= 1). Pseudorca and pilot whales were always observed in association with oceanic bottlenose dolphins. Oceanic bottlenose dolphins were only observed once without association with either pseudorca or pilot whale.

Table 5: Mean group size (number of individuals) of marine mammal encounters, between June 2019 and November 2021, in Far North waters, New Zealand. (SE=Standard Error, TT = bottlenose dolphin, *Tursiops truncatus*).

Species	N	Group size		
		Mean	SE	Range
Coastal TT	71	18.1	1.0	1-32
Fur seals	40	3.6	0.4	1-12
Common dolphin	9	32.2	4.35	20-50
Oceanic TT	4	21.3	13.6	2-60
Orca	4	9.5	1.5	6-12
Bryde's/fin/sei	3	1.3	0.33	1-2
Humpback	3	1	0	1
Pseudorca	2	55	15.0	40-70
Pilot whale	1	30	NA	NA

Depth and sea surface temperature mean, standard error and range for each species are presented in Table 6. Fur seals were observed in the deepest (181m) and coldest (17.1) waters; however, most sightings occurred on land (no depth recorded). Pseudorca were observed in the mean warmest waters (21.8 °C, SE=0.2). Following fur seals, killer whales had the widest depth range (2.8m to 101m). Coastal bottlenose dolphins had the widest temperature range (15.2 to 23.7 °C).

Table 6: Mean sea surface temperature (SST) and water depth (m) of marine mammal encounters, between June 2019 and November 2021, in Far North waters, New Zealand. (SE=Standard Error, TT = bottlenose dolphin, *Tursiops truncatus*).

Species	N	Depth (m)			SST (°C)		
		Mean	SE	Range	Mean	SE	Range
Coastal TT	71	22.9	1.4	5-63	19.7	0.3	15.2-23.7
Fur seals	40	101.5	31.8	22.4-181	17.1	0.3	14.5-21.2
Common dolphin	9	51	5.4	29.7-87.6	18	0.6	15.1-20.7
Oceanic TT	4	53.1	9.5	34.1-78	19.8	1.2	17.4-22
Orca	4	43.3	21.6	2.8-101	18.5	0.6	17.4-20.2
Bryde's/fin/sei	3	29.8	5.7	20.3-40.1	17.7	0.2	17.2-18
Humpback	3	23.1	0.9	21.4-24.4	18	0.2	17.7-18.4
Pseudorca	2	50.1	6.9	43.2-57	21.8	0.2	21.6-22
Pilot whale	1	34.1	NA	NA	18.1	NA	NA

Marine mammals were observed across the whole study area, in all seasons (Figure 7A). Most sightings occurred in the Bay of Islands, where 76.9% of survey effort occurred (Figure 7B).

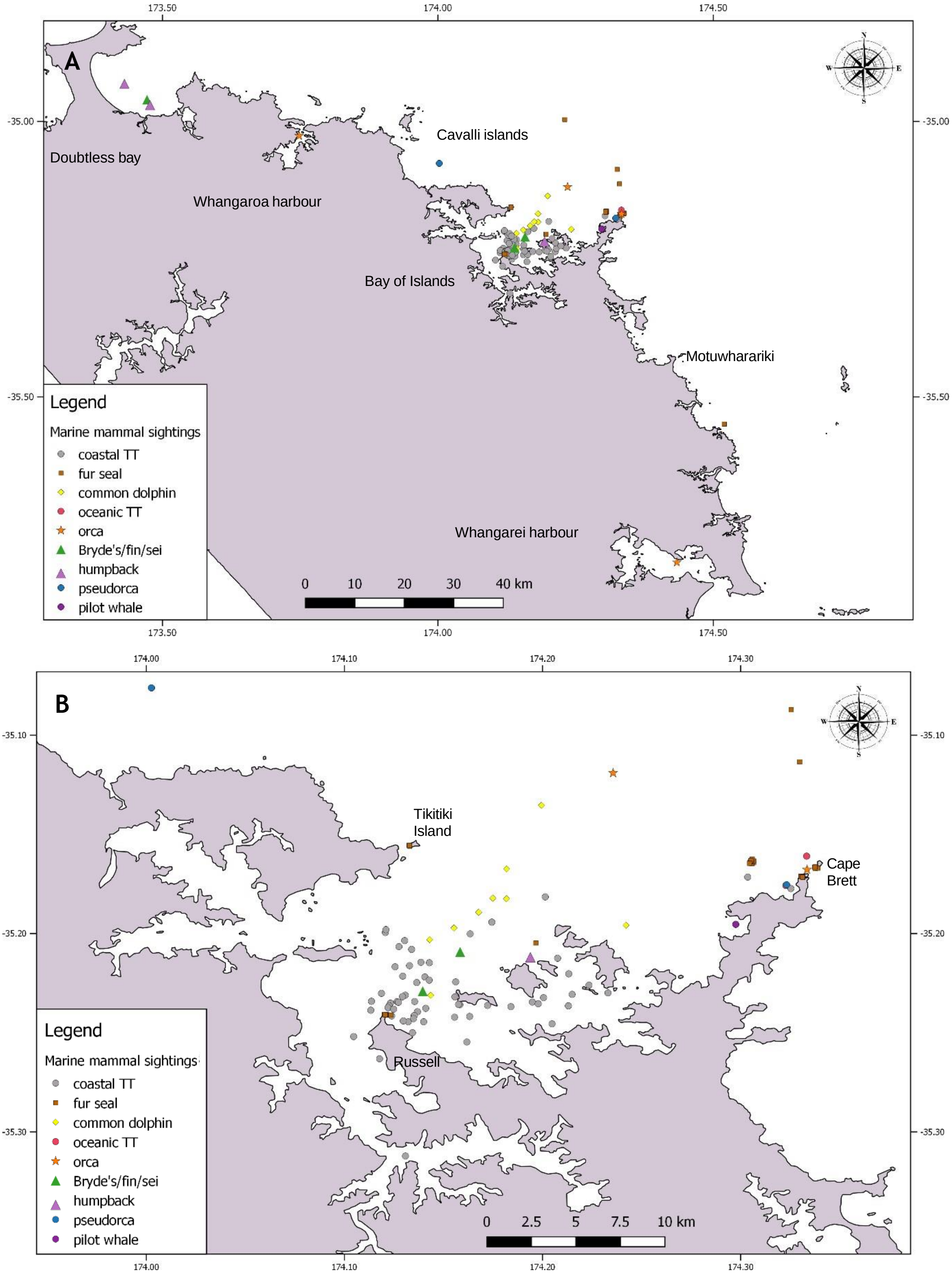


Figure 7: Marine mammal sightings while on survey between June 2019 and November 2021 in A) Far North waters and B) zoomed in on Bay of Islands waters, New Zealand (TT = bottlenose dolphin, *Tursiops truncatus*).

The following results include coastal bottlenose dolphins only, referred to hereafter as bottlenose dolphins.

5.3 Bottlenose dolphin spatial distribution

While on encounter, bottlenose dolphins were followed for a total of 114.7hrs (639.3 km) (Figure 8). Of 71 sightings, one occurred outside Bay of Islands waters (off survey sighting due to weather conditions, located on the east shore of Stephenson Island, n=0.7hrs).

Bottlenose dolphins were mostly observed in the inner Bay of Islands, with highest densities North of the Russell Peninsula and in the Eastern islands (Figure 8). Dolphins were observed in high density in the current permitted vessel no interaction and MMS safe zones.

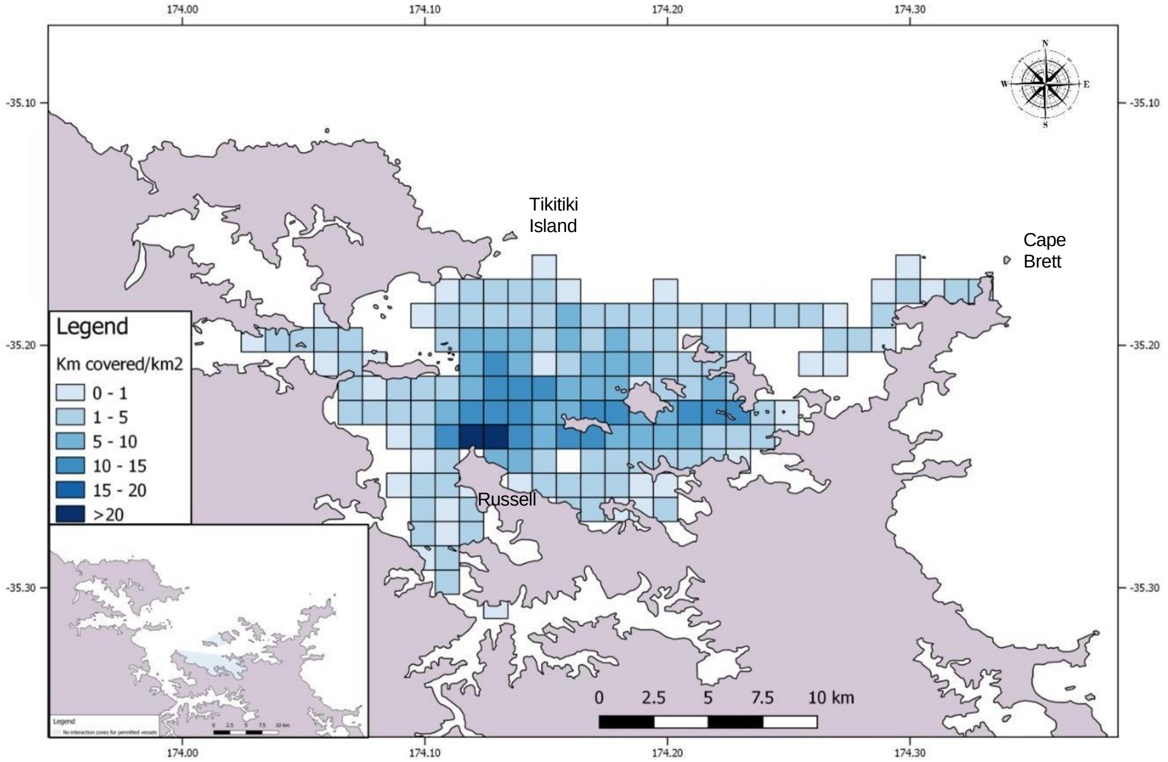


Figure 8: Research vessel coastal bottlenose dolphin encounter effort between June 2019 and November 2021 in Bay of Islands waters, New Zealand, coloured according to the proportion of kilometres (km) travelled while on encounter within each grid cell (1km x 1km). Current permitted vessel no interaction zones are represented on the bottom left.

The following results include coastal bottlenose dolphin data collected in the Bay of Islands only.

Spatial distribution of bottlenose dolphins according to seasons and time of day are presented in Appendix 1 and 2, respectively.

5.4 Group composition

Of the 70 sightings of coastal bottlenose dolphin groups within Bay of Islands waters, four group categories were recorded (Figure 9). The predominant category recorded was Adult-Juvenile-Calf (42.9%, n=30), followed by Adult-Calf (24.3%, n=17), Adult-Juvenile-Neonate-Calf (17.1%, n=12) and Adults only (11%, n=4). Five sightings were recorded as Unknown group size and composition due to short observation time. Mean group size overall was 18.3 (SE=1.0, n=65).

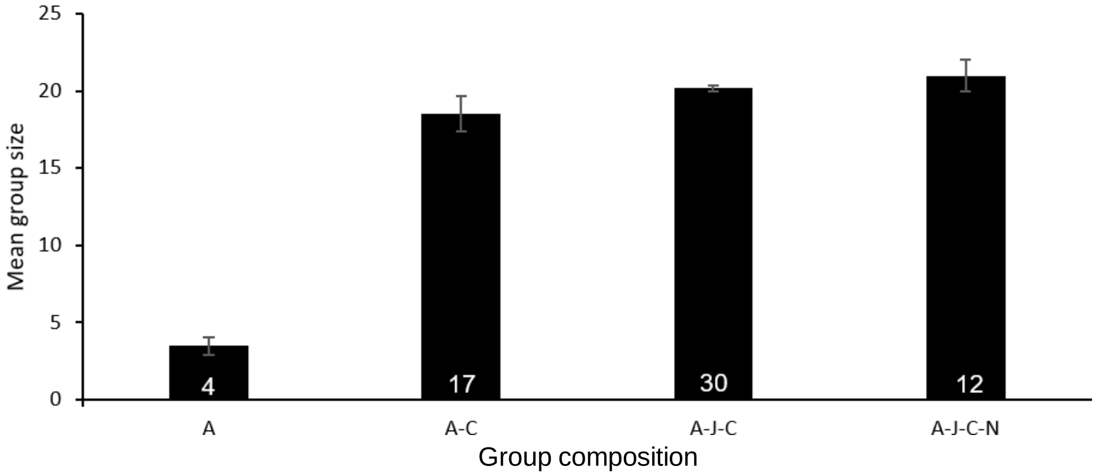


Figure 9: Mean group size vs Group composition between June 2019 and November 2021, in Bay of Islands waters, New Zealand. N numbers are displayed on the bars. Error bars represent standard error. Note: A=Adults, J=Juvenile, C=Calf and N=Neonate

5.5 Unique individuals and site fidelity

Coastal bottlenose dolphins were encountered in 74.1% of survey months (n=20) over 70 encounters in Bay of Islands waters. Photo-identification effort resulted in 603 resights of 85 uniquely identifiable bottlenose dolphins. Of the 85 individuals identified, 64 were only identified once, and as such may not be included in mark-recapture modelling. The remaining 21 (24.7%) were sighted more than once, forming the core local population. In this study's timeframe, nine months of 27 survey months brought new individual identifications. Seasonal survey and encounter effort and number of individuals identified are presented in Table 7. Over all seasons, the number of individuals identified per survey kilometre varied between 0.025 and 0.036.

Table 7: Summary of survey/encounter effort and number of identifiable dolphins sighted per season between June 2019 and November 2021 in Bay of Islands waters, New Zealand.

	Winter	**Spring**	**Summer**	**Autumn**
Number of surveys	16	37	52	11
Survey effort (km)	700.4	1653.4	1945.9	541.4
Encounter effort (hr)	11.3	24.1	64.1	14.5
Number of encounters	12	16	30	12
Number of individuals identified	25	50	49	16
Number of individuals identified/survey km	0.036	0.030	0.025	0.029

The discovery curve (Figure 10) showed several plateaus reached throughout the study, including from the first month (June- October 2019) and during the last 11 months (December 2020-November 2021). Three of five months with the highest survey effort (over 300km) did not bring any new identifications.

5.6 Resight rates

Resight rates of the 85 identified individuals varied considerably during the study period (Figure 11). The 15 individuals categorised as frequent users accounted for 81.4% (n=491) of resights. Resights were categorized into months to avoid bias due to pseudo-replication, resulting in a total of 316 monthly resights.

Monthly resights ranged from 1 – 17 (mean= 3.7). Patterns of use significantly differed from the Poisson distribution (Figure 12) (chi-square goodness-of-fit test, $x^2 = 95.7$, df=2 pvalue = 0.05). The point at which the observed monthly resights exceeded expectation (i.e., ≥ 14) was considered to indicate frequent users of the BOI. Infrequent users and occasional visitors were arbitrarily defined as the individuals with one and 2-8 observed monthly resights, respectively.

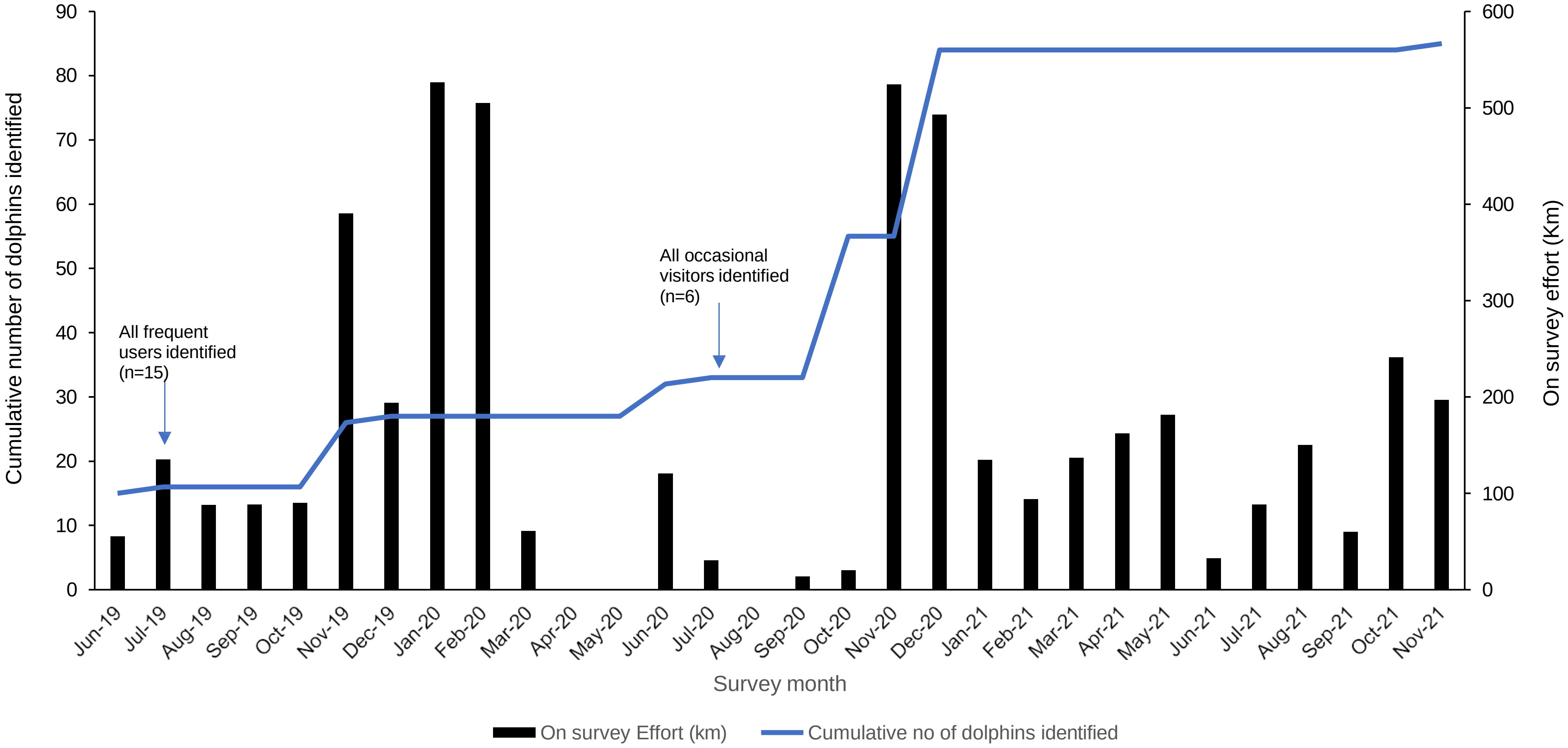


Figure 10: Discovery curve of bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, with cumulative number of individuals photo-identified per survey day. Individuals identified only once are included. Bars represent the number of kilometers (km) spent on effort.

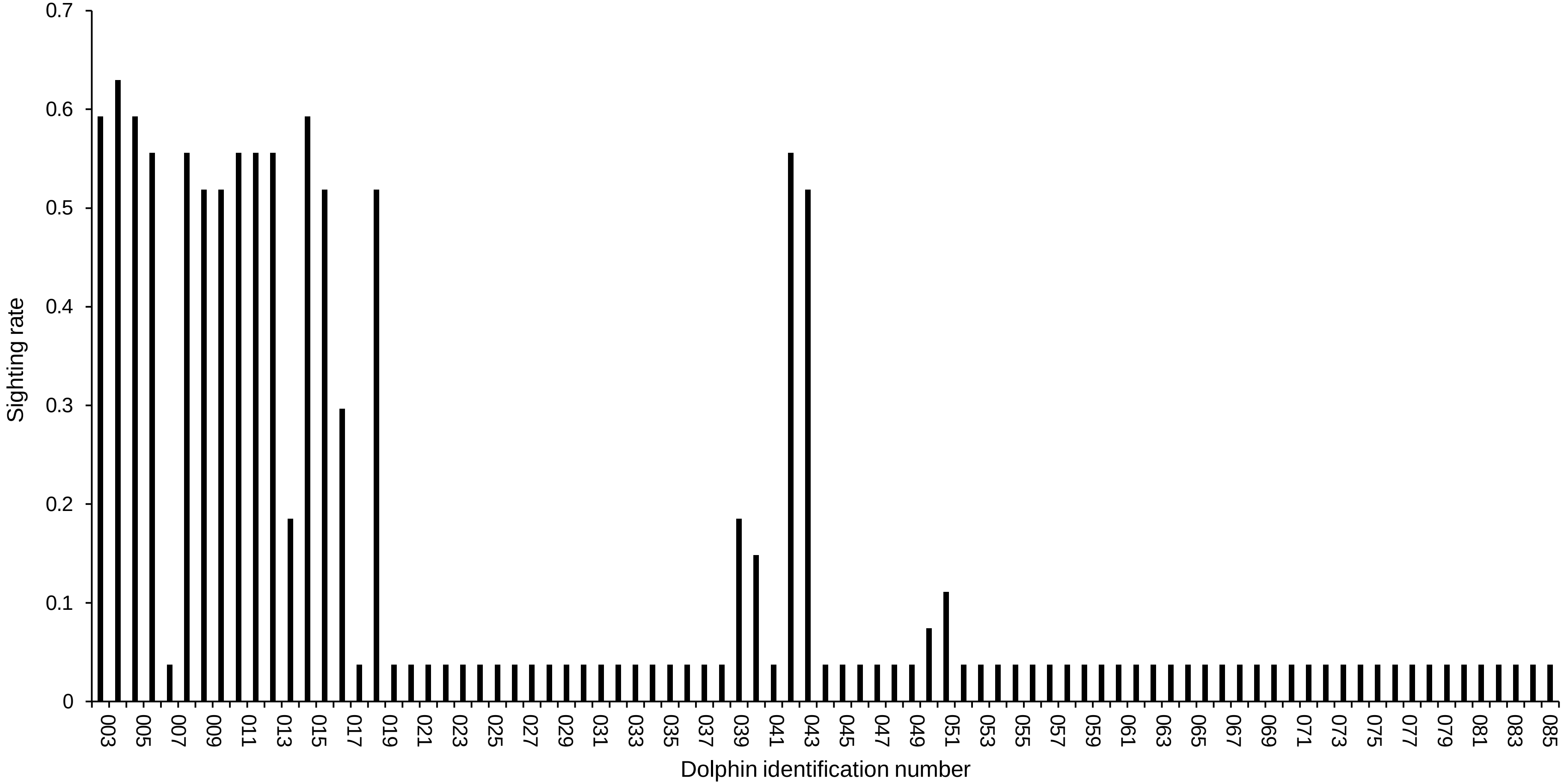


Figure 11: Monthly sighting rates of identifiable bottlenose dolphins between June 2019 and November 2021, in Bay of Islands waters, New Zealand

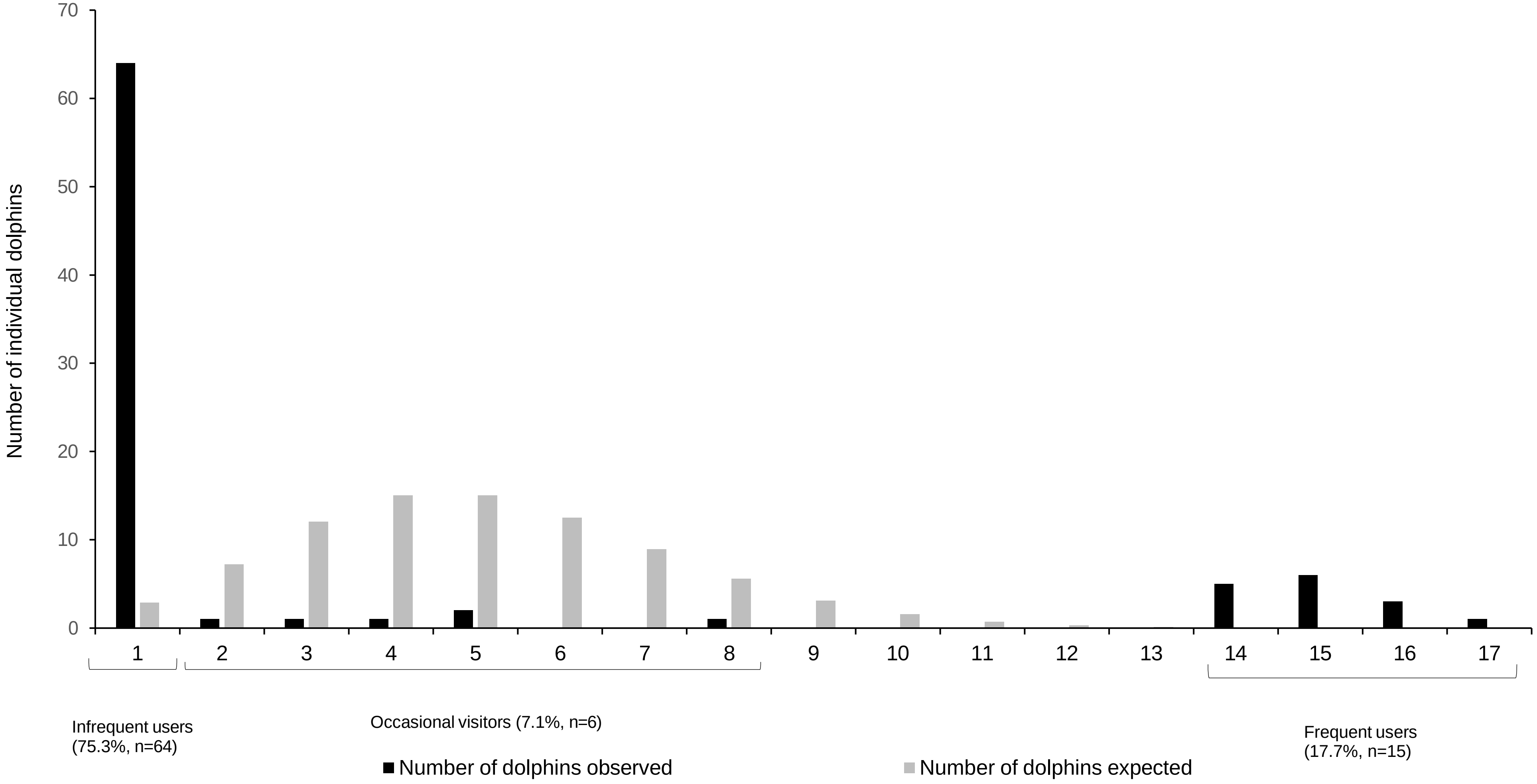


Figure 12: Observed (black) vs. expected (grey) Poisson distribution of number of times individual bottlenose dolphins were identified between June 2019 and November 2021, in Bay of Islands waters, New Zealand. The proportion of different user types (infrequent users, occasional visitors and frequent users) are also indicated.

Infrequent users formed the majority group (75.3%, n=64). Occasional visitors represented another 7.1% (n=6). Frequent users represented 17.7% (n=15) of identified individuals.

Frequent users represented 71.2% of monthly resights (n=225). All 15 frequent users were identified alongside other frequent users throughout the study period, with consistent group size for all encounters (mean group size = 20, SE = 0). One frequent user individual was an exception, and was identified on two occasions (8% of this individual's resights) alongside an occasional visitor individual.

Five of six occasional visitors had between two and five monthly resights. The remaining individual (n=8 monthly resights) was recorded as a frequent user until September 2020, which was the last time it was recorded.

Infrequent users (one monthly resight) were observed with calves on three encounters of seven. No calves or neo-nates were recorded alongside occasional visitors.

The highest number of individually identified dolphins per encounter was 29 dolphins (range=0-29; mean=7.5; SE=0.8). No singletons were observed during the study period.

Data collected from October 2017 to May 2019 by the TriOceans team (3312.9km on survey effort) also reported 30 identifiable individuals, including the same 15 frequent users reported here for June 2019-November 2021 and four individuals with one resight only.

5.7 Behavioural observations

A total of 2108 behavioural observations of coastal bottlenose dolphins were recorded within Bay of Islands waters between June 2019 and November 2021. Number of observations and transitions after data processing into 1st order Markov chains (section 2.2.4) are presented in Table 8.

Final observations and transition numbers are presented in Table 8 and 9. Observations occurred within both a pre-COVID-19 (June 2019-March 2020) and COVID-19 context (March 2020-November 2021). Data were deemed insufficient to conduct pre-COVID-19 vs COVID-19 analysis.

Table 8: Count of observed behavioural observations and transitions by time of day, season and vessel traffic types between June 2019 and November 2021 in Bay of Islands waters, New Zealand.

	Behavioural observations	**Total**	**Behavioural transitions**	**Total**
Morning	675	2037	643	1950
Afternoon	1362		1307	
Winter	243	2059	234	1980
Spring	424		410	
Summer	1124		1080	
Autumn	268		256	
Absence	808	1459	745	1346
Presence	651		601	
Winter-Absence	182	803	172	740
Spring-Absence	263		244	
Summer-Absence	200		177	
Autumn-Absence	158		147	

The summary of behaviour count values recorded is shown in Table 9. Travelling was the most observed behaviour overall and diving the least observed.

Table 9: Counts of behavioural observations by state and level investigated between June 2019 and November 2021 in Bay of Islands waters, New Zealand.

Behavioural state	**Time of day**			**Seasons**					**Vessel traffic type**			**Seasons - Absence**				
	Morning	**Afternoon**	**Total**	**Winter**	**Spring**	**Summer**	**Autumn**	**Total**	**Absence**	**Presence**	**Total**	**Winter**	**Spring**	**Summer**	**Autumn**	**Total**
Travelling	344	523	867	122	219	434	106	881	420	156	576	97	134	115	71	417
Foraging	99	154	253	46	45	110	58	259	116	66	182	31	22	27	36	116
Socialising	116	367	483	66	55	331	30	482	97	281	378	47	24	18	6	95
Milling	54	114	168	4	11	142	12	169	12	119	131	2	2	4	4	12
Resting	52	153	205	2	50	100	55	207	116	27	143	2	38	36	40	116
Diving	10	51	61	3	44	7	7	61	47	2	49	3	43	0	1	47
Total	675	1362	2037	243	424	1124	268	2059	808	651	1459	182	263	200	158	803
Travelling	331	503	834	119	215	420	98	852	391	140	531	92	127	105	64	388
Foraging	95	148	243	43	43	107	57	250	105	61	166	29	18	24	34	105
Socialising	105	354	459	65	52	316	29	462	89	265	354	46	21	14	6	87
Milling	52	108	160	4	10	137	11	162	12	110	122	2	2	4	4	12
Resting	51	147	198	1	48	95	54	198	104	23	127	1	35	30	38	104
Diving	9	47	56	2	42	5	7	56	44	2	46	2	41	0	1	44
Total	643	1307	1950	234	410	1080	256	1980	745	601	1346	172	244	177	147	740

5.7.1 Spatial distribution of behaviours

All six behaviours were recorded across Bay of Islands waters (Figures 13 to 18). No areas of high density for a specific behaviour were observed. Traveling (Figure 13) was observed with the widest range across the study area.

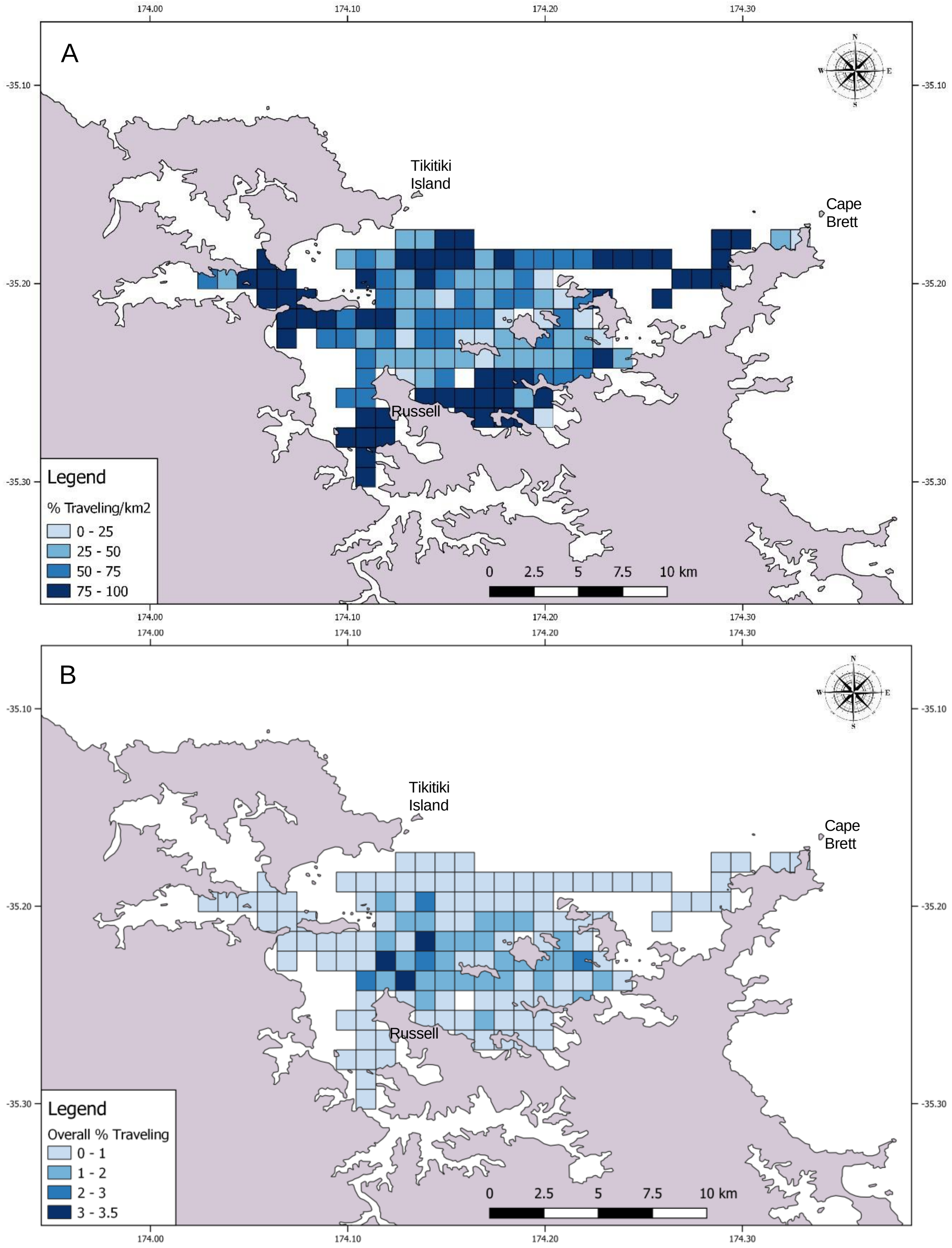


Figure 13: Bottlenose dolphin traveling behaviour between June 2019 and November 2021, in Bay of Islands waters, New Zealand, with 1km x 1km grid cells coloured according to A) proportion of traveling observations relative to all other behaviours within each cell and B) proportion of traveling observations relative to all traveling observations across the study area.

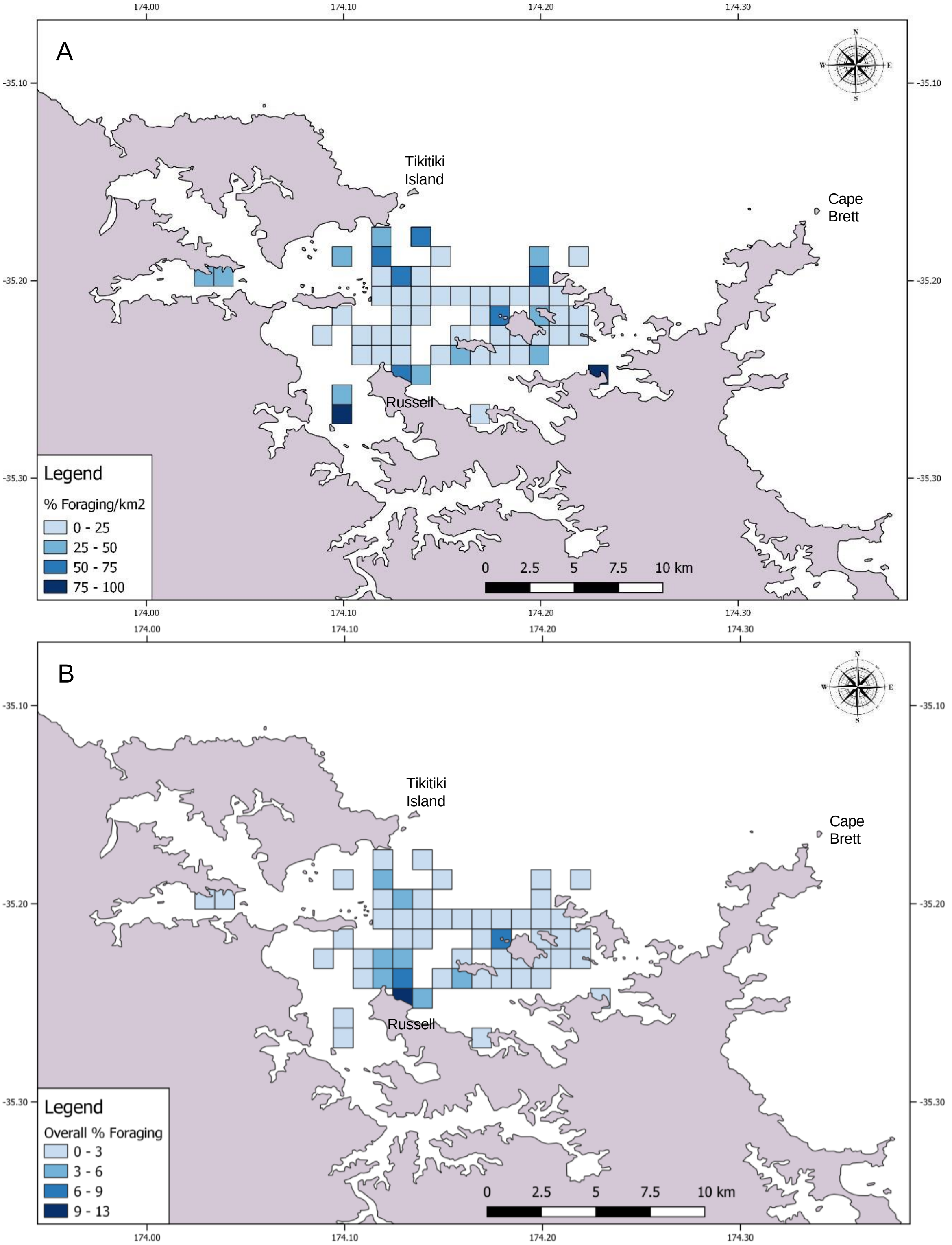


Figure 14: Bottlenose dolphin foraging behaviour between June 2019 and November 2021, in Bay of Islands waters, New Zealand, with 1km x 1km grid cells coloured according to A) proportion of foraging observations relative to all other behaviours within each cell and B) proportion of foraging observations relative to all foraging observations across the study area.

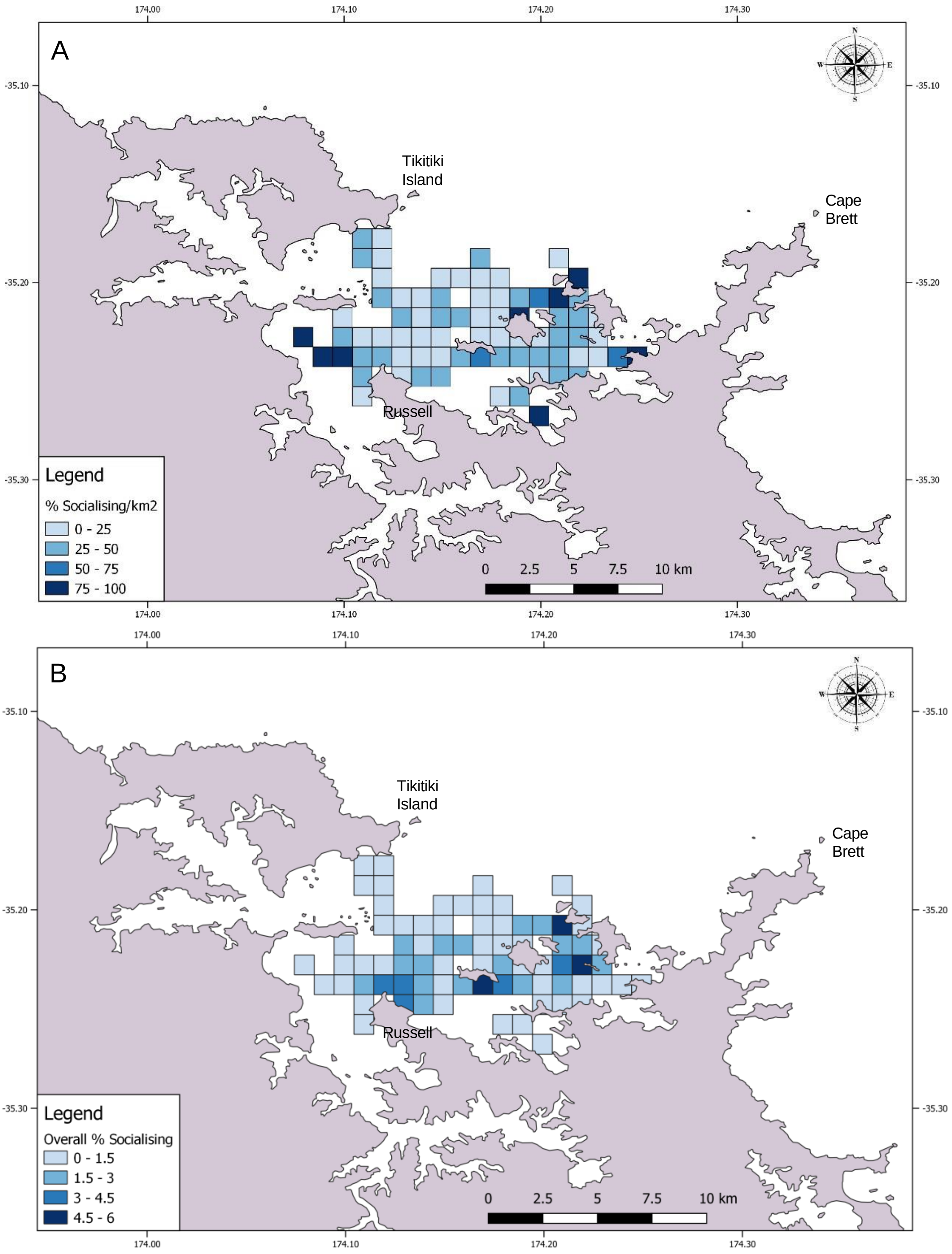


Figure 15: Bottlenose dolphin socialising behaviour between June 2019 and November 2021, in Bay of Islands waters, New Zealand, with 1km x 1km grid cells coloured according to A) proportion of socialising observations relative to all other behaviours within each cell and B) proportion of socialising observations relative to all socialising observations across the study area.

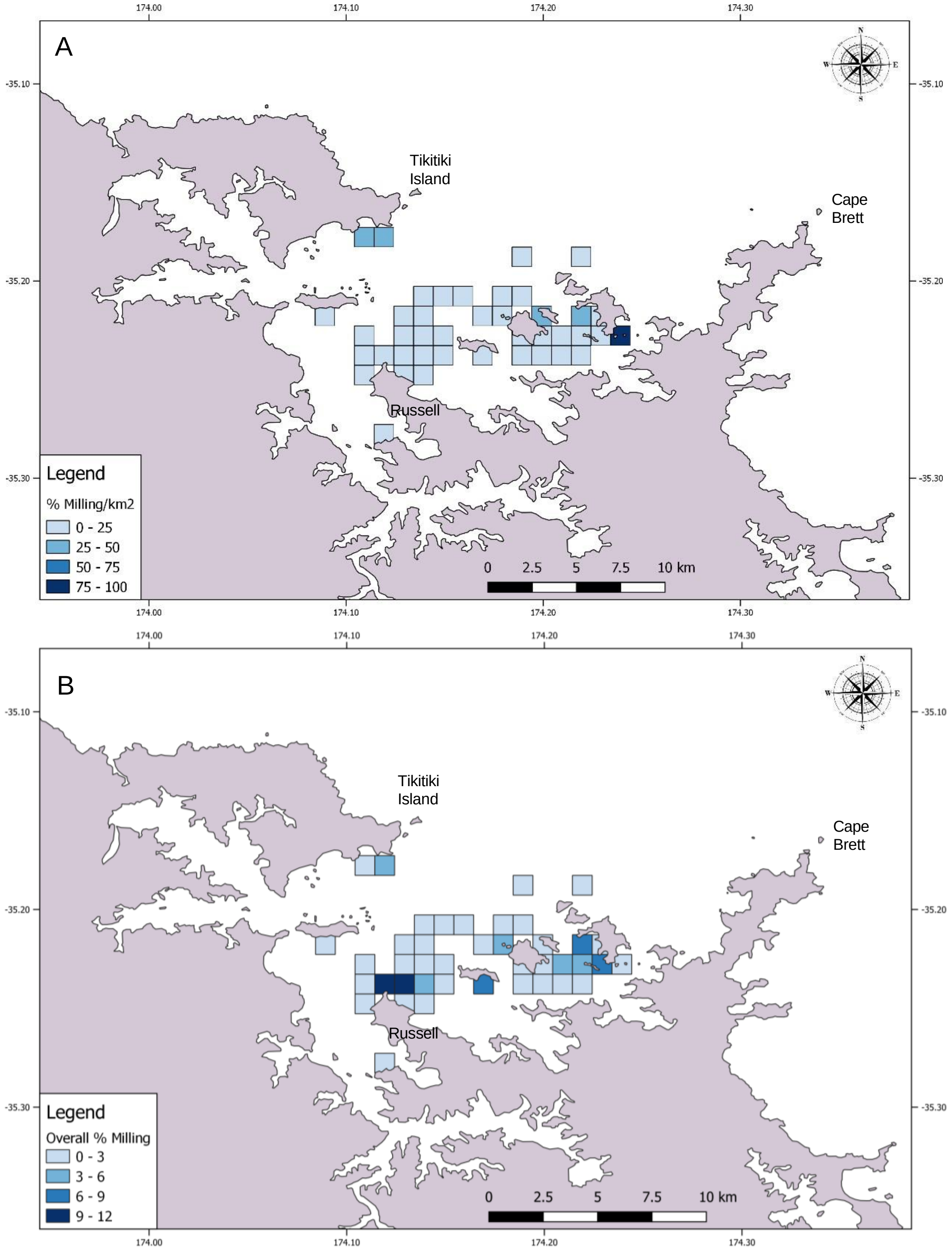


Figure 16: Bottlenose dolphin milling behaviour between June 2019 and November 2021, in Bay of Islands waters, New Zealand, with 1km x 1km grid cells coloured according to A) proportion of milling observations relative to all other behaviours within each cell and B) proportion of milling observations relative to all milling observations across the study area.

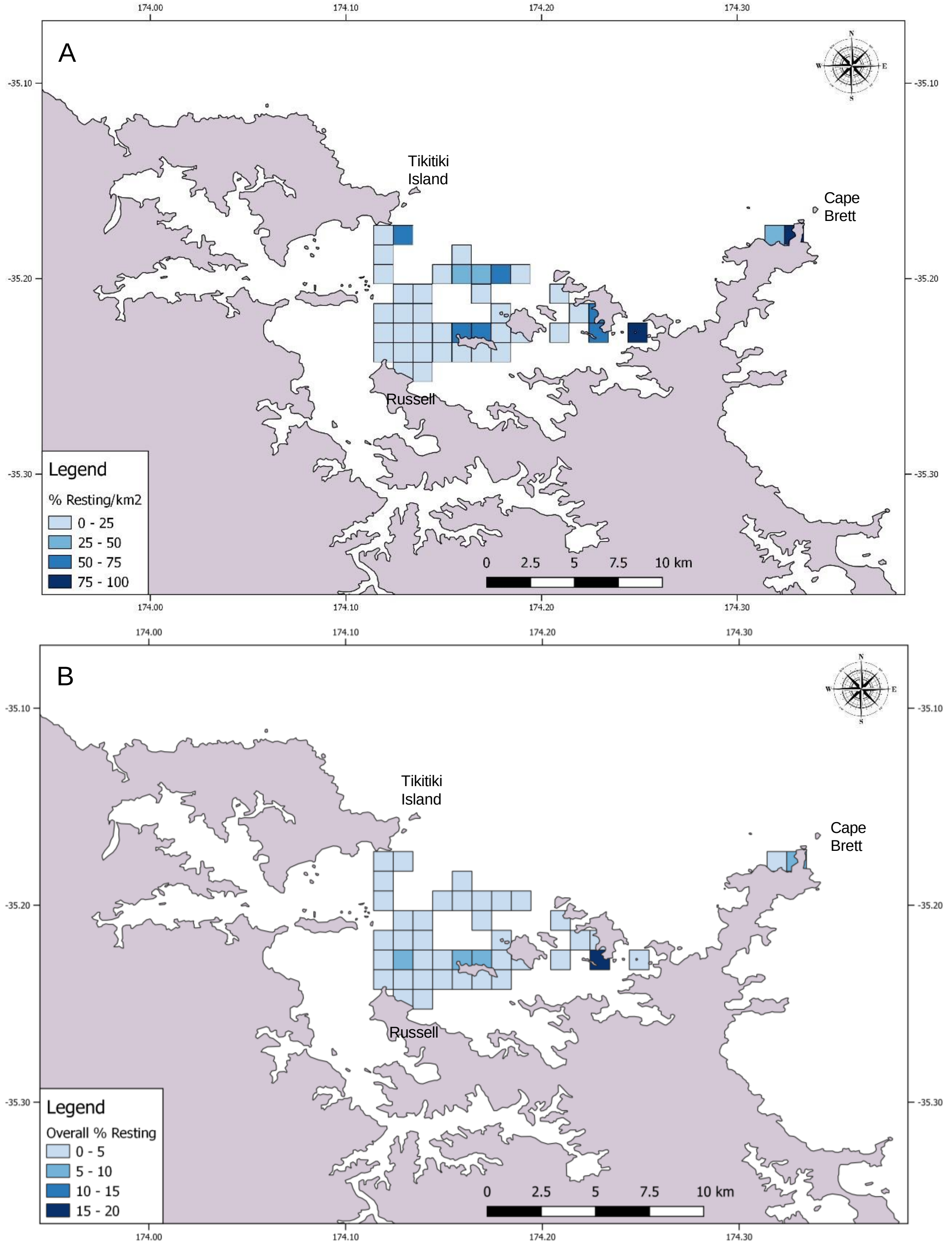


Figure 17: Bottlenose dolphin resting behaviour between June 2019 and November 2021, in Bay of Islands waters, New Zealand, with 1km x 1km grid cells coloured according to A) proportion of resting observations relative to all other behaviours within each cell and B) proportion of resting observations relative to all resting observations across the study area.

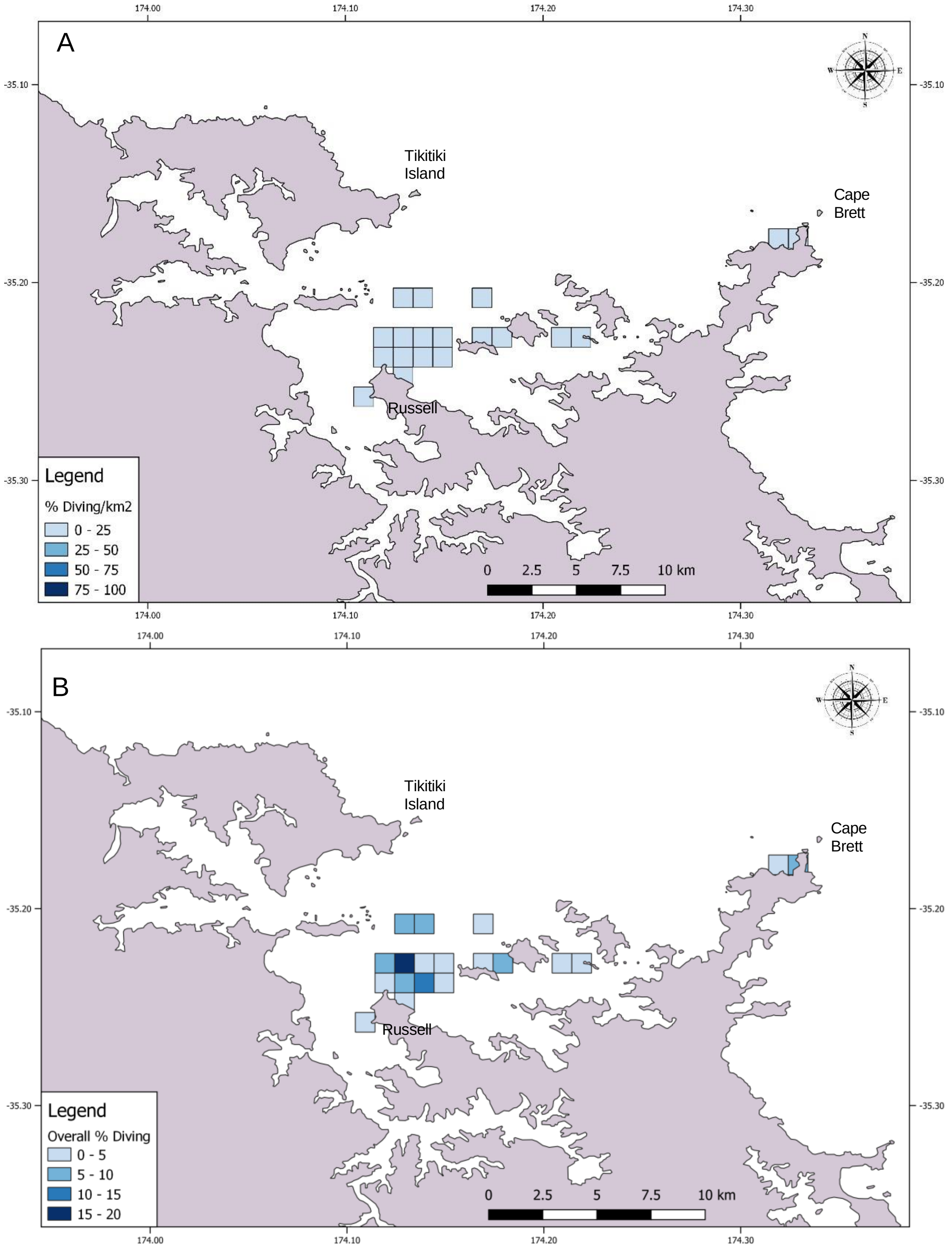


Figure 18: Bottlenose dolphin diving behaviour between June 2019 and November 2021, in Bay of Islands waters, New Zealand, with 1km x 1km grid cells coloured according to A) proportion of diving observations relative to all other behaviours within each cell and B) proportion of diving observations relative to all diving observations across the study area.

5.7.2 Seasonal and diurnal variation in behaviour

5.7.2.1 Behavioural budget

Both season and time of day (Figure 16) had a significant effect (z-test p<0.05) on the behavioural budget of bottlenose dolphins. Traveling (p=<0.001) and foraging (p=0.03) budgets showed a significant decrease in the afternoon of 24.6% and 23.1%, respectively. Socialising, resting and diving showed a significant (p=<0.001, p=0.01 and p=0.01, respectively) increase in the afternoon of 56.6%, 45.5% and 146.7%, respectively. Higher proportions of traveling were observed in Winter Spring, and higher proportions of socializing in Winter and Summer (p<0.01). The highest proportions of milling were observed in Summer, of resting in autumn, and of diving in spring (p<0.01).

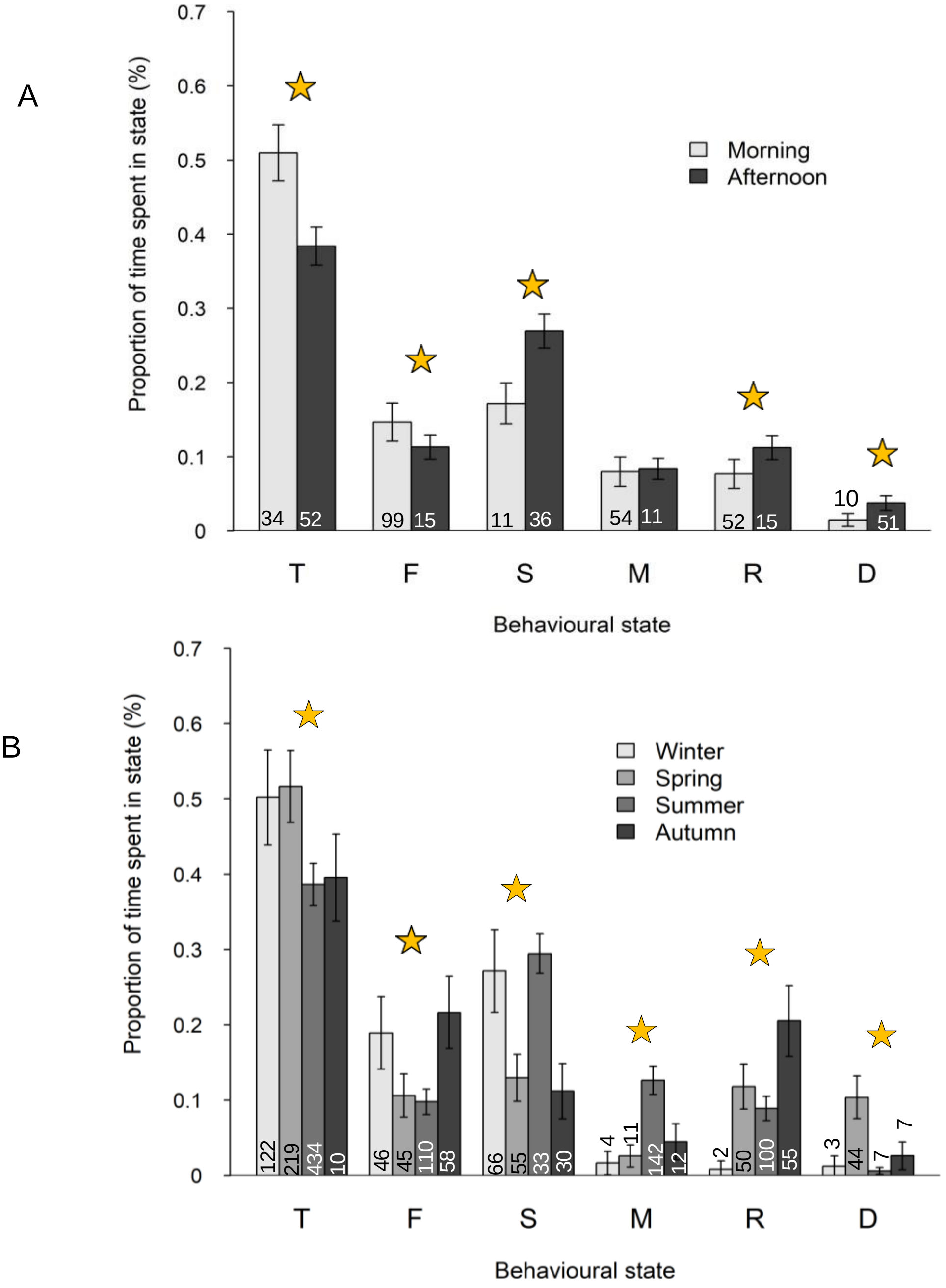


Figure 19: Overall behavioural budget of each behavioural state for bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, by time of day (A, before and after 12:00PM) and seasons (B). Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant differences between categories (z-test p=0.05) are marked with a yellow star. Error bars represent standard error. N values for each category are displayed on the bars.

5.7.2.2 Mean behavioural bout length

Both time of day and season (Figure 17) had a significant effect (z-test $p<0.05$) on the behavioural bout length of bottlenose dolphins. Socialising ($p=0.02$) and diving ($p=0.01$) showed an increase in the afternoon of 35.5% and 184.4%, respectively. The longest bout length of foraging was observed in Winter, of socializing in Winter and Summer, and of diving in Spring.

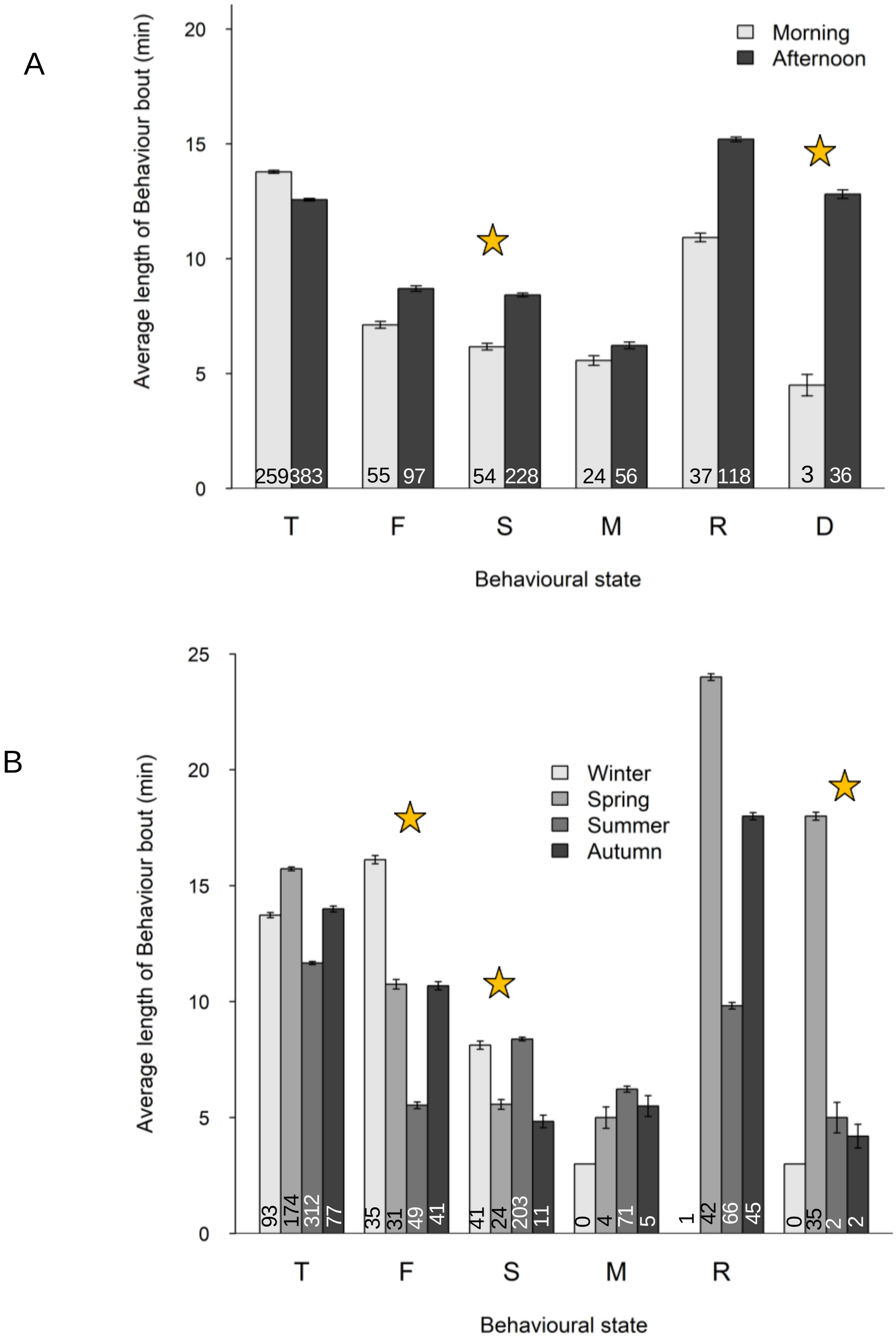


Figure 20: Mean bout length (minutes) of each behavioural state for bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, by time of day (A, before and after 12:00PM) and season (B). Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant differences between categories (z-test $p=0.05$) are marked with a yellow star. Error bars represent standard error. N values (same state transitions) for each category are displayed on the bars.

5.7.3 Effects of vessel presence on behaviour

5.7.3.1 Behavioural budget

All six states' behavioural budgets were significantly affected by the presence of vessels (Figure 18). Dolphins spent significantly less time travelling ($p<0.001$), foraging ($p=0.02$), resting ($p<0.001$) and diving ($p<0.001$) in the presence of vessels within 300 m of the dolphin group, which decreased by 53.8%, 29.9%, 71.5% and 94.8% respectively. In contrast, dolphins spent more time socialising ($p<0.001$) and milling ($p<0.001$) in the presence of vessels, which increased by 258.3% and 1207.1%, respectively.

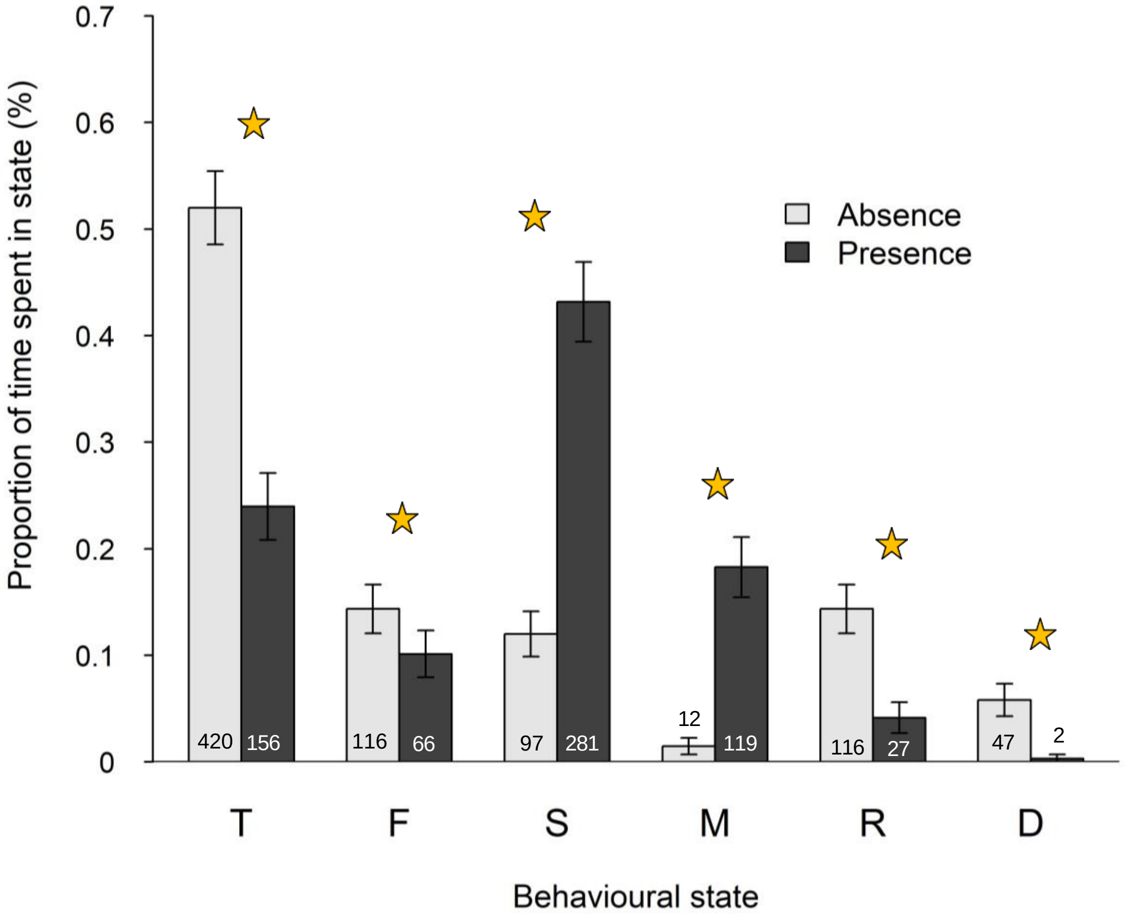


Figure 21: Overall behavioural budget of each behavioural state for bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, in absence and presence of vessels. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant differences between categories (z-test $p<0.05$) are marked with a yellow star. Error bars represent standard error. N values for each category are displayed on the bars.

5.7.3.2 Mean behavioural bout length

The mean behavioural bout length varied significantly in presence of vessels for five states (Figure 19). In the presence of vessels, travelling(p<0.001), foraging (p=0.01) and resting (p<0.001) bouts were shorter (65.6%, 46.3% and 71.3% decrease, respectively), while milling (p=0.01) bouts were longer in the presence of vessels (8.3.3% increase). No diving bouts were observed in the presence of vessels.

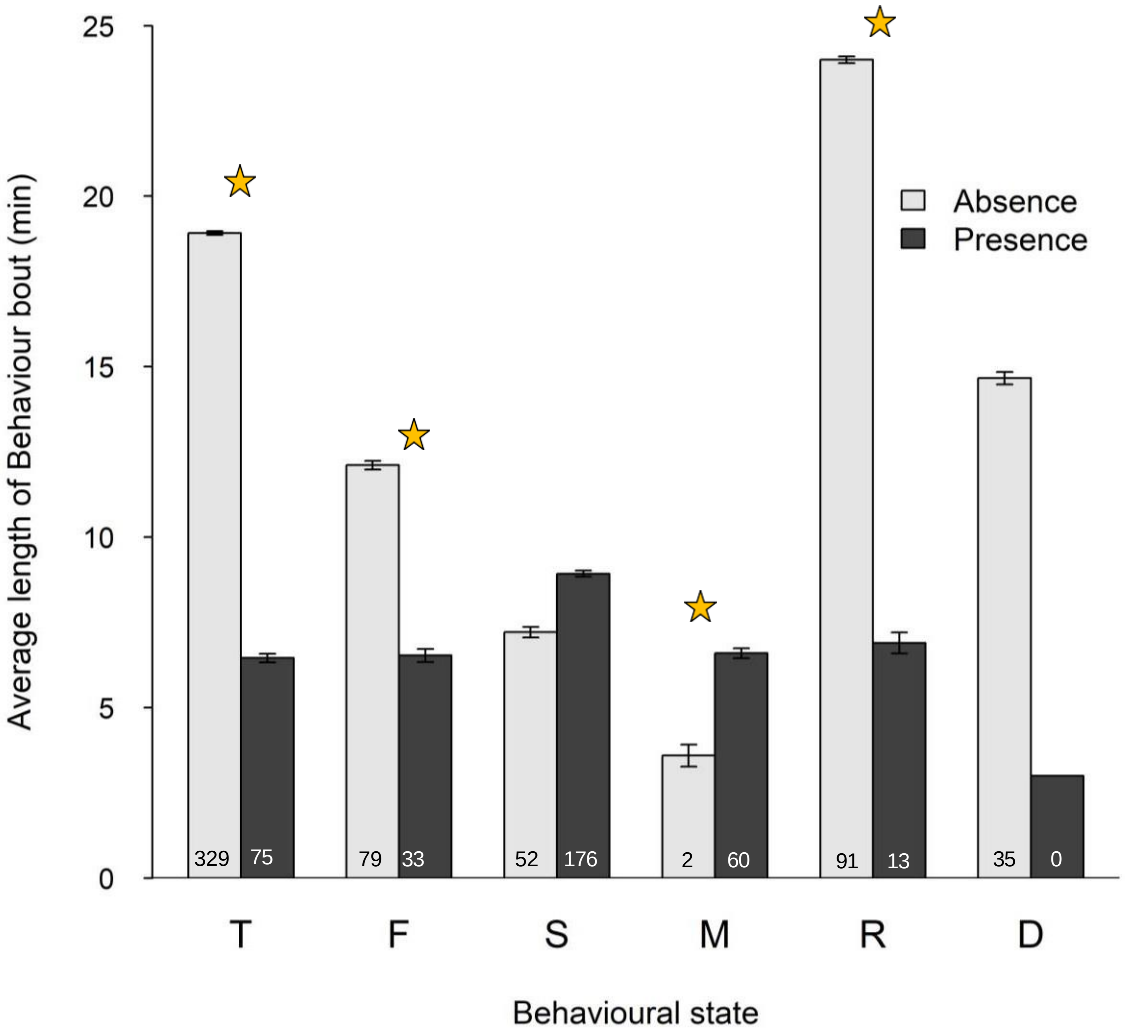


Figure 22: Mean bout length (minutes) of each behavioural state for bottlenose dolphins in absence and presence of vessels between June 2019 and November 2021 in Bay of Islands waters, New Zealand. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant differences between categories (z-test p<0.05) are marked with a yellow star. Error bars represent standard error. N values (same state transitions) for each category are displayed on the bars.

5.7.3.3 Transition probabilities

The summary of probabilities to shift from one state to another in presence and absence of vessels is shown in Figure 20. No transitions to diving were observed in the presence of vessels. Overall, in the presence of vessels, dolphins were less likely to remain in the same state when traveling, foraging, and resting, and more likely when socializing and milling.

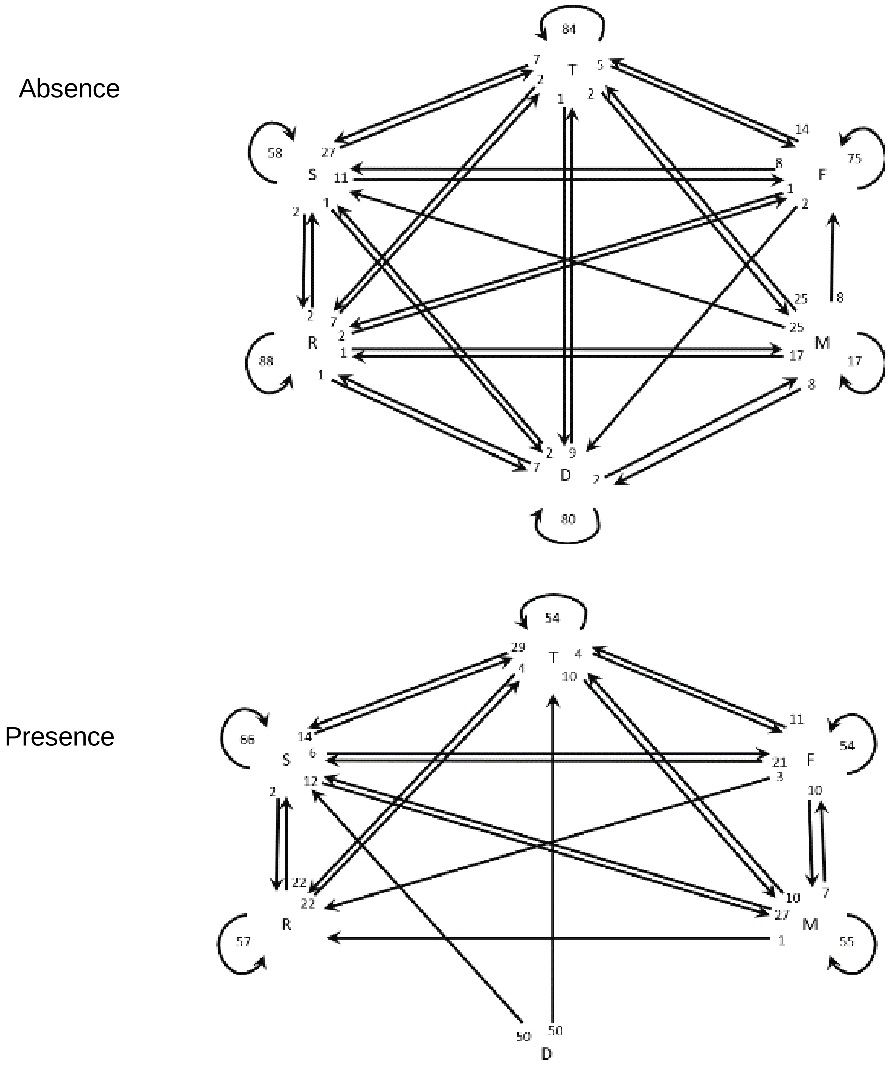


Figure 23: Probabilities in percentage of bottlenose dolphins observed from research vessel to shift from one behavioural state to another between June 2019 and November 2021 in Bay of Islands waters, New Zealand in absence and presence of vessels. Probabilities are placed at the start of each arrow. The absence of arrow between two states means there was no transition recorded between the two states. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving.

Fifty percent (n=18) of transitions were significantly affected by the presence of vessels (Figure 21). In the presence of vessels, the likelihood to stay in a given state significantly decreased for traveling, foraging, resting and diving, while it significantly increased for milling. No diving-diving transition was observed in the presence of vessels. 65% of diving-diving transition observed occurred over one encounter

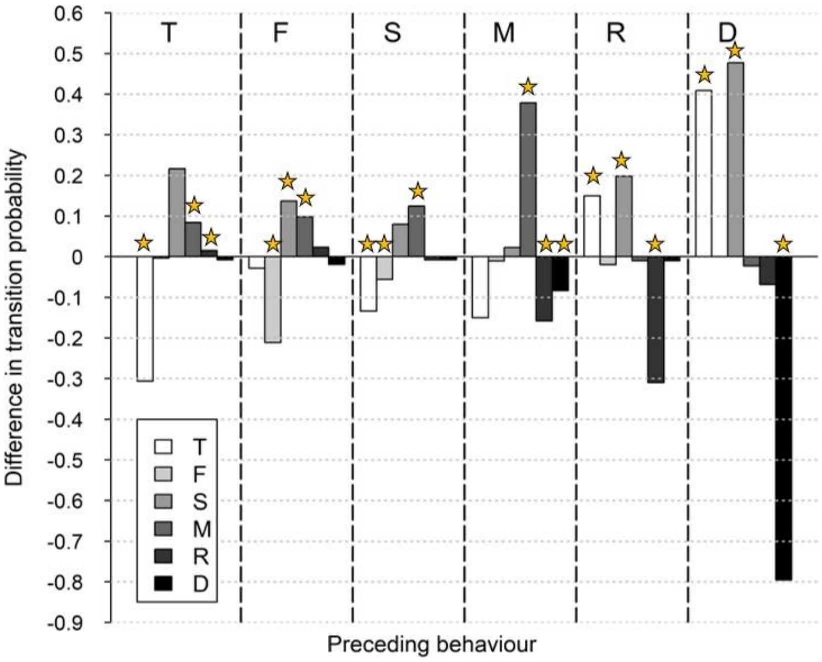


Figure 24: Effect of vessel presence on transitions in behavioural states of bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, based on differences in transition probabilities pij(presence) - pij(absence). A negative value on the Y-axis means that the probability of a behavioural transition in the presence chain is lower than the one in the absence chain. The six sections correspond to the six preceding behavioural states. Each bar represents a succeeding state. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Transitions showing a significant difference (z-test p<0.05) are marked with a yellow star.

5.7.3.4 Time to resume state

Time to return to a given behavioural state prior to being disturbed was significantly affected by the presence of vessels for all behavioural states (z-test, pvalue<0.05) (Table 10). Specifically, time to return to behaviour increased by 117.2%, 41.5%, 245.9% and 1793.7% in the presence of vessels for travelling, foraging, resting and diving, respectively, and decreased by 72.2% and 91.9% for socialising and milling, respectively.

Table 10: Probability of staying in a given state πj, mean number of transitions Tj it took for bottlenose dolphins to return to that state, and time (min) required to return to the state when interrupted in absence of vessels (absence, exception of the research boat), and in presence of vessels between June 2019 and November 2021 in Bay of Islands waters, New Zealand.

Behavioural state	**πj**	**E(Tj)**	**Behavioural state resumed (min)**
Absence			
Travelling	0.52	1.92	5.76
Foraging	0.14	6.97	20.91
Socialising	0.12	8.33	24.99
Milling	0.02	67.34	202.02
Resting	0.14	6.97	20.91
Diving	0.06	17.19	51.57
Presence			
Travelling	0.24	4.17	12.51
Foraging	0.10	9.86	29.58
Socialising	0.43	2.32	6.96
Milling	0.18	5.47	16.41
Resting	0.04	24.11	72.33
Diving	<0.01	325.52	976.56

5.7.4 Seasonal vessel presence effect on behaviour

5.7.4.1 Behavioural budget

When comparing seasonal absence to whole database, behavioural budget did not significantly vary in Winter (Figure 22). In Spring, diving increased in absence of vessels by 56.7% (p=0.02). In Autumn, socialising decreased in absence of vessels by 69.6%(p=0.01). Summer had the most variation, with an increase of traveling and resting (49.0% and 102.2%, p<0.001 and p<0.001, respectively), and decrease in socialising and milling (69.4% 84.1%, p<0.001 and <0.001, respectively) in absence of vessels.

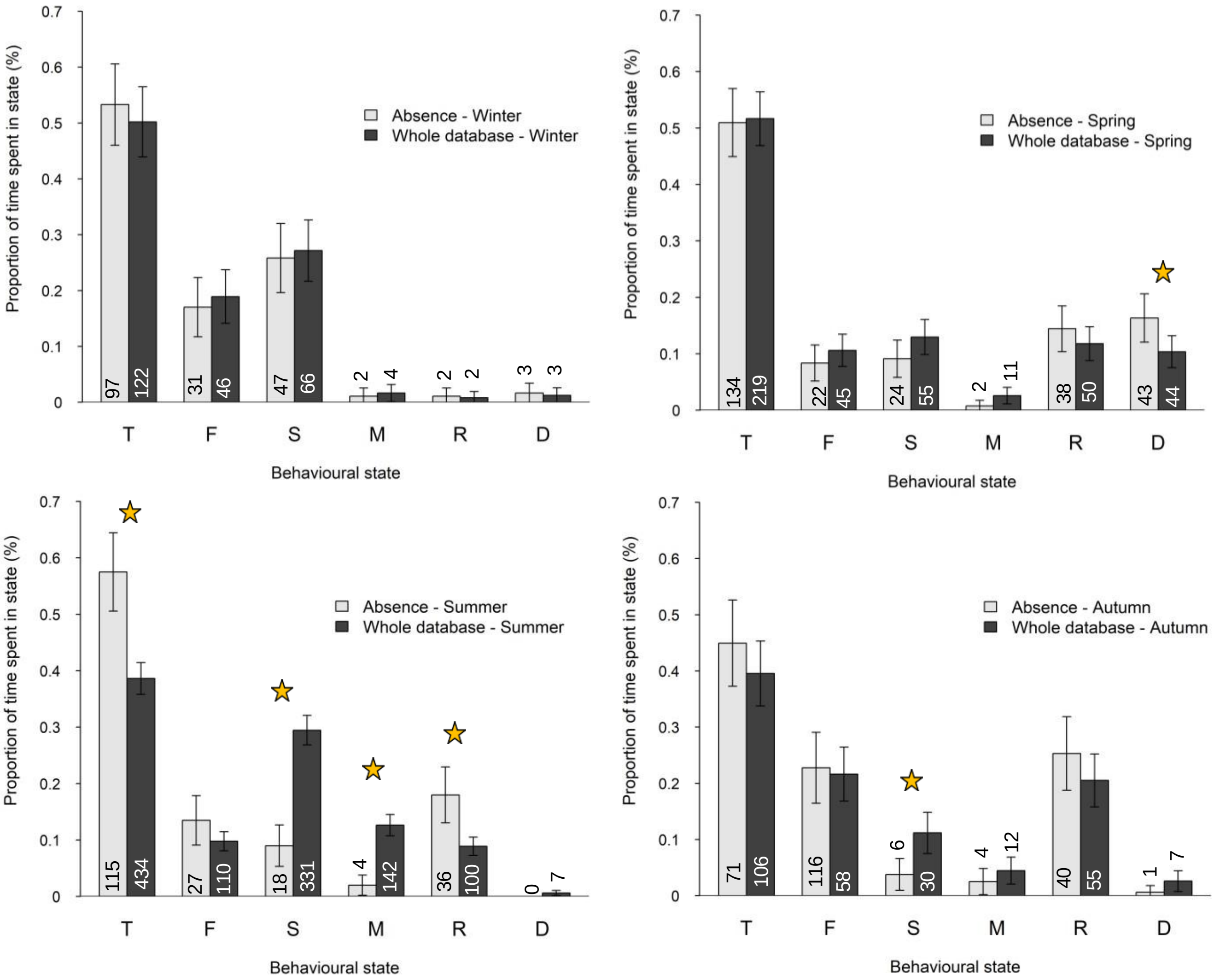


Figure 25: Overall behavioural budget of each behavioural state for bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, by season, comparing control to whole database. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant differences between categories (z-test p<0.05) are marked with a yellow star. Error bars represent standard error. N values (same state transitions) for each category are displayed on the bars.

5.7.4.2 Mean behavioural bout length

No significant differences were observed for behavioural bout length of absence vs whole database for Winter, Spring, and Autmn (Figure 23). In Summer, traveling and resting bout length increased (69.8% and 206.1%, p=0.02 and p=0.03, respectively) and socialising decreased (27.7%, p=0.02) in the absence of vessels.

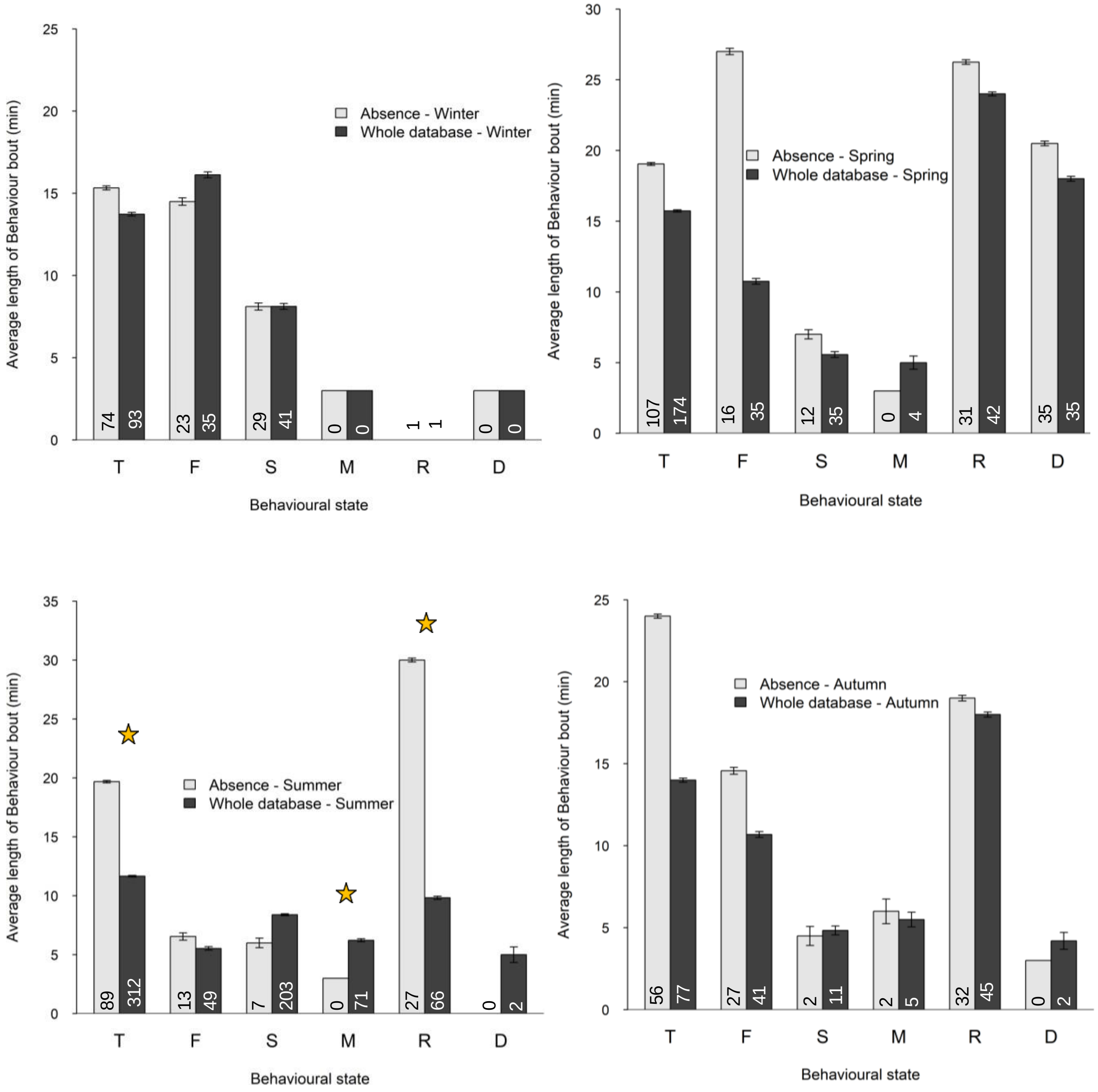


Figure 26: Mean bout length (minutes) of each behavioural state for bottlenose dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand, by season, comparing control to whole database. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant differences between categories (z-test p<0.05) are marked with a yellow star. Error bars represent standard error. N values (same state transitions) for each category are displayed on the bars.

5.8 Vessel effort

In 114h of encounter effort in Bay of Islands waters, a total of 1385 vessels were recorded entering within 300m of bottlenose dolphins. Seasonal vessels per hour of encounter effort are presented in Table 11. The overall season-weighted average resulted in 7.3 boats per hour (one vessel entering to within 300m of marine mammals every eight minutes)

Table 11: Number of vessels recorded entering within 300m of bottlenose dolphins and encounter effort by season, between June 2019 and November 2021 in Bay of Islands waters, New Zealand.

Seasons	**Winter**	**Spring**	**Summer**	**Autumn**	**TOTAL**
Number of vessels recorded entering 300m	20	86	1208	71	**1385**
On encounter hours	11.3	24.1	64.1	14.5	**114**
New vessels/hour	1.8	3.6	18.8	4.9	**7.3** (average)

Bottlenose dolphins spent significantly more time with at least one vessel within 300m during the afternoon (46% in the afternoon, 37% in the morning) (z-test, pvalue<0.01). The effort of all vessels with bottlenose dolphins, between sunrise and sunset, resulted in a mean of 25.5 continuous minutes without the presence of vessels (other than the research vessel (range = 0-126, n= 974, sample size = 1104)). Overall daylight hours spent with vessels varied seasonally, with the highest observed in Summer (62%, n=714), followed by Autumn (23%, n=63), Spring (20%, n=87) and Winter (15%, n=39). This resulted in a season-weighted average of 30% of daylight hours with the presence of vessels.

A large majority of Private vessels were recorded entering within 300m of bottlenose dolphins (85%, n=1180), followed by Permitted (9%, n=124), Commercial (5%, n=73) and DOC/research (1%, n=8) vessels. The highest number of vessels recorded entering within 300m over an hour was 107, recorded in Summer. New vessels within 300m of dolphins were recorded across the Bay of Islands, with higher density around the Russell Peninsula and the Eastern islands (Figure 25). Within the current no-interaction and MMS 5 knots zones, high variability in vessel traffic was observed, ranging from highest densities in both zones to no vessels observed in parts of the southern zone.

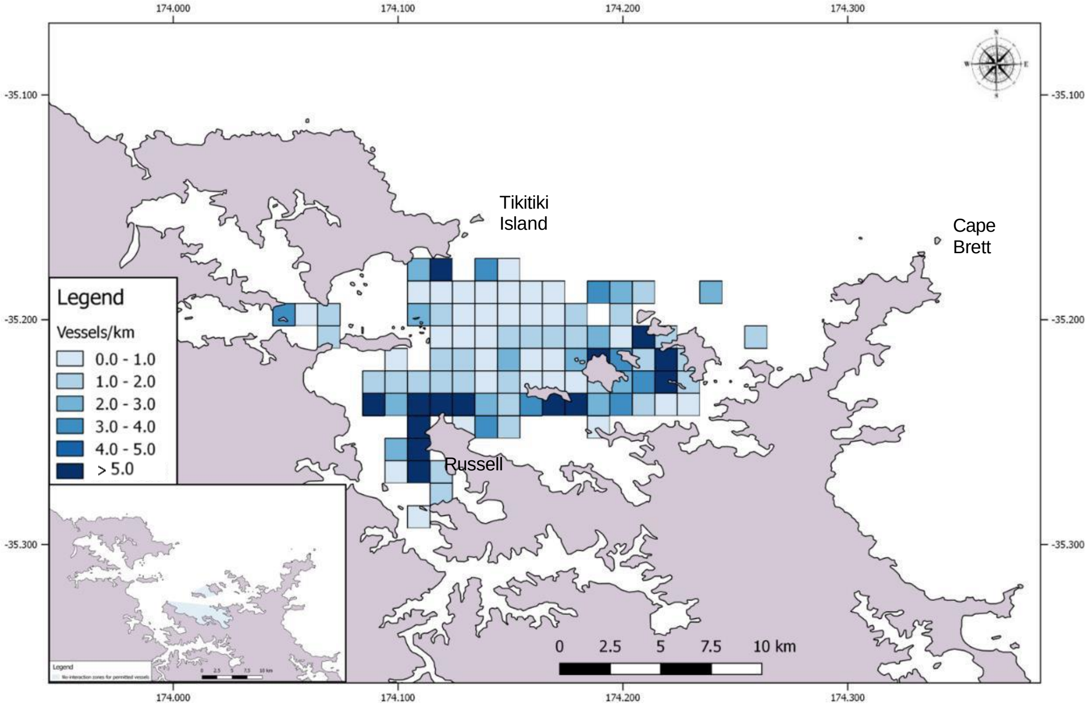


Figure 27: Vessel traffic around bottlenose dolphins in Bay of Islands waters, New Zealand, coloured according to number of vessels recorded entering within 300m of bottlenose dolphins/km of encounter effort between June 2019 and November 2021. Current permitted vessels no interaction zones are represented on the bottom left.

Vessel types recorded entering within 300m of dolphins also varied throughout the day (Figure 24). Commercial vessels reached a peak mid/late morning (percentile 3), then steadily reduced. Permitted vessels reached a peak early afternoon (percentile 5), then reduced at percentile 6 to increase again at percentile 7 (mid-late afternoon). Private vessels increased steadily from early/midmorning to reach a peak early afternoon, then decreased. Overall, Private vessels were the large majority recorded entering within 300m of the dolphins. No encounter data was recorded in percentile 1, and no vessels were recorded in percentiles 8 and 9. DOC/research vessel type were excluded here for clarity due to low n numbers.

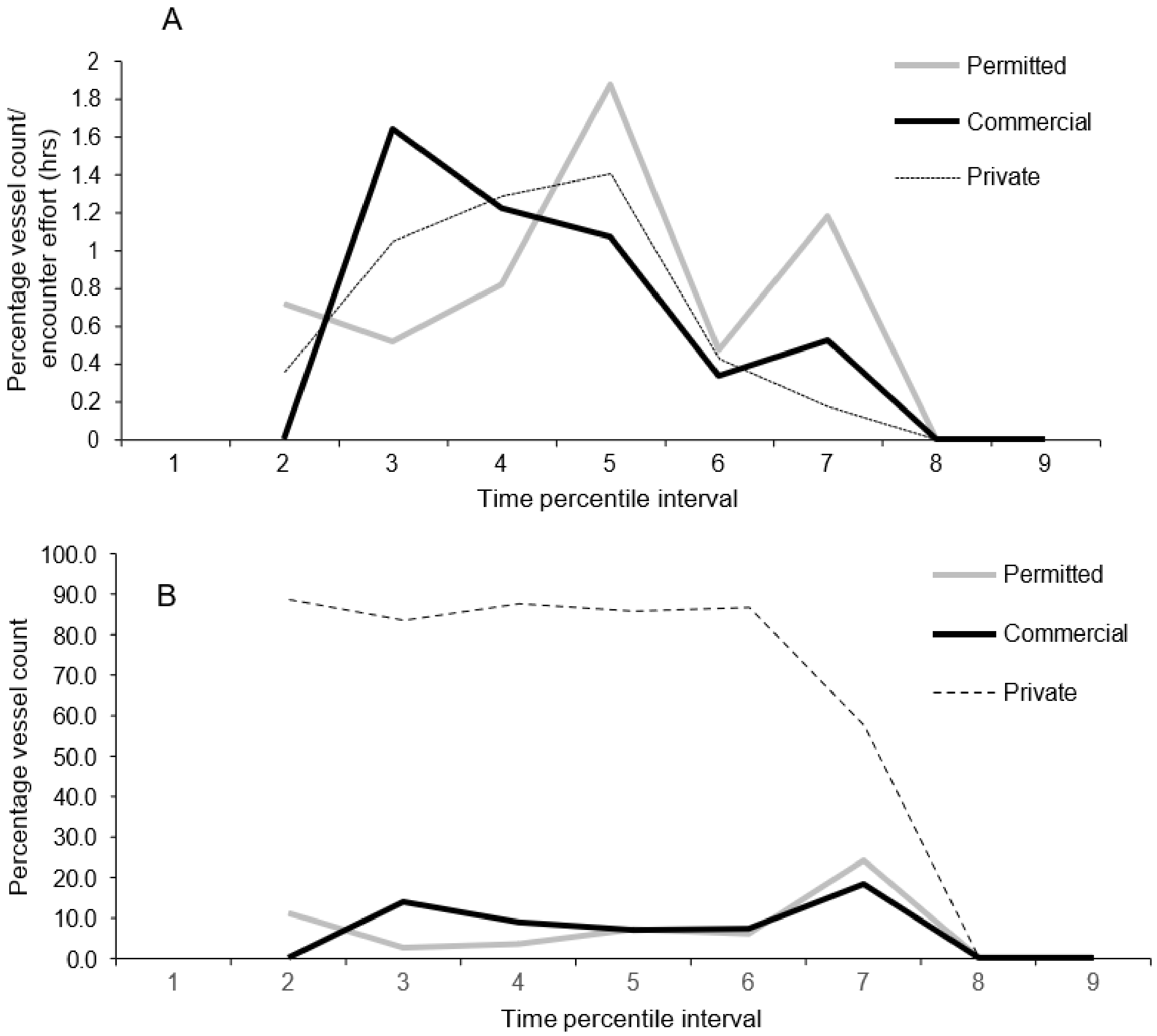


Figure 28: Diurnal variation in vessels recorded entering within 300m of dolphins between June 2019 and November 2021 in Bay of Islands waters, New Zealand. Daylight percentile is presented to account for seasonal variation in sunrise hour. A) Individual vessels type proportions in each time percentile divided by on encounter effort hours and B) Overall diurnal proportion for each individual vessel type

A total of 10 swims with bottlenose dolphins were recorded. All swims occurred with groups containing calves. No swims were recorded from Permitted or Commercial vessels.

5.9 Calf survival

Available data taken from October 2017 onwards were included within this section (Guerin, unpublished data). Data collection and analysis from October 2017 followed the methods of this study.

From October 2017 to November 2021, a total of 13 young of the year calves were observed. Of these 13, five calves were observed only once during the study period, alongside individuals identified only once during the study period. These five individuals were excluded from further analysis as no further information is available. The remaining eight calves were observed on multiple occasions. Of those eight, the fate of five calves could be documented over one year of age, and the fate of four calves could be documented over two years of age.

1st year mortality was observed for two calves of five (40% 1st year mortality, calves 3 and 5).
2nd year mortality was observed for two calves of four (50% 2nd year mortality). The remaining calf (calf 6) survived as of November 2021 (20 months of age).

Table 12: Summary of calves observed between October 2017 and November 2021 in Bay of Islands waters, New Zealand.

Calf ID	Date of birth	Status as of November 2021	Presumed mother user type
1	Dec 2017	Weaning age reached (>24 months of age)	Frequent user
2	Apr 2018	Unknown as of June 2018 (under one year old)	Frequent user (2012-2018)
3	Oct 2018	Presumed dead	Frequent user
4	Dec 2018	Weaning age reached (>24 months of age)	Frequent user
5	Jan 2019	Confirmed dead	Frequent user
6	Mar 2020	Survived as of November 2021 (under two years old)	Frequent user
7	Dec 2020	Survived as of November 2021 (under one year old)	Frequent user
8	Nov 2021	Survived as of November 2021 (under one year old)	Frequent user

The fate of the three remaining calves (calves 2, 7 and 8) could not be documented over one year of age. This includes one mother-calf pair (calf 2) which was not observed in Far North Waters since 2018, when the calf was two to three months old, although the presumed mother was categorized as a frequent user of the Bay of Islands since 2012 (Peters & Stockin, 2016), as well as two calves who were observed regularly but not over one year old (calf 7 and 8, 11 months and one month of age as of November 2021, respectively).

Between December 2018 and November 2021, 76 photos were of sufficient quality for calf laser photogrammetry. Those included Calf 1 (n=18), 3 (n=5), 4 (n=28), 6 (n=10), 7 (n=12) and 8 (n=3). Measured blowhole-to-dorsal-fin lengths ranged from 36.4cm for a one-month-old neonate and 82.0cm for a 41-months old juvenile (Figure 28). Where several measures were taken in one month, results were averaged for that month.

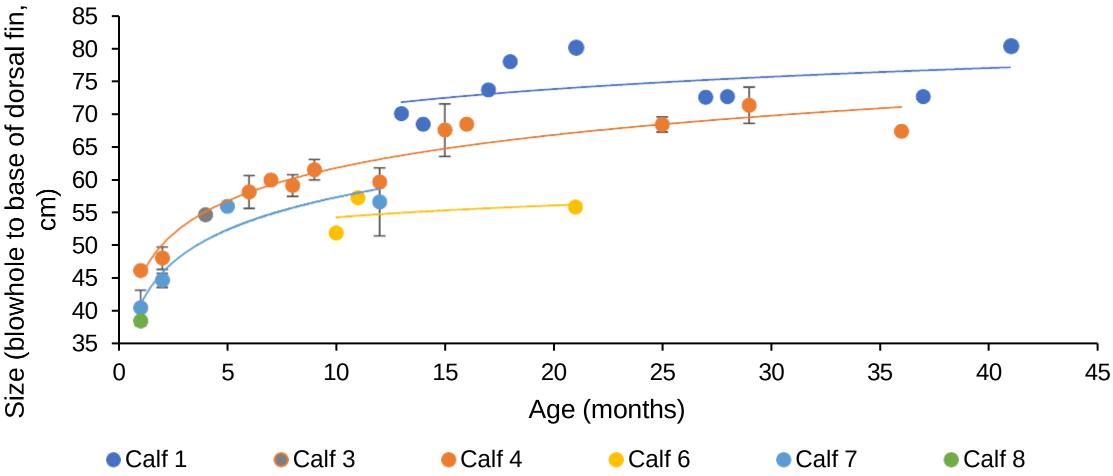


Figure 29: Blowhole to dorsal fin measurements of calves observed between December 2018 and November 2021 in Bay of Islands waters, New Zealand. Error bars represent standard error.

6. Summary of deliverables

6.1 Determine the range extent of bottlenose dolphins in Far North waters and Bay of Islands waters

Continuous presence and high density of bottlenose dolphins were observed only in the Bay of Islands, suggesting the rest of Far North water is used more intermittently. This is consistent with Peters 2018, although comparatively high density of bottlenose dolphins was also reported in Whangaroa Harbour in that study, which was not observed here.

- Between June 2019 and November 2021, 6291.1km of on survey effort tracks were completed (296.2hrs) between Doubtless Bay and Whangarei Harbour, including 4841.1km (76.9%) within Bay of Islands waters. Overall survey effort was lowest in the area between Motuwhararaki and Whangarei Harbour, which was covered on one occasion.
- Bottlenose dolphins were encountered on 62 occasions while *on survey* in Bay of Islands waters, and on one occasion outside Bay of Islands waters (1450km of effort). This suggests the Bay of Islands has remained the area of highest use by bottlenose dolphins, with other Far North waters used as transit areas.
- Consistently with Peters & Stockin 2016, broad scale distribution in the Bay of Islands remained consistent with Hartel et al., 2014, while fine scale habitat use was reduced to a smaller area around the Russell Peninsula and eastern islands.

6.2 Provide an update in the number of identifiable individuals and usage patterns in Far North and Bay of Islands waters

Results indicate a continued decline in bottlenose dolphin identifiable individuals in the Bay of Islands, consistently with Tezanos-Pinto et al., 2013 and Peters & Stockin 2016. A percentage of 72.8% (monthly resights) of bottlenose dolphin presence in the Bay of Islands is accounted for by individuals in one group of 15 identifiable individuals (frequent users), accompanied by approximately five unidentifiable individuals. The steepest decline occurred within occasional visitor individuals, with a 95.6% decline in identifiable individuals since 1999 (Constantine 2002). Results suggest that the local BOI bottlenose dolphin population is changing, with only one group of frequent users seen regularly and fission-fusion examples rarely observed. The near-loss of occasional visitor individuals brings concerns to the status quo of bottlenose dolphin presence in the Bay of Islands, should the one group of frequent users shift its preferred area of use to a different location. Full mark-recapture assessment is underway to allow comparison with Tezanos-Pinto et al., 2013, and will be carried out by combining data from Peters & Stockin 2016 and this study. This will provide analysis over a long-term dataset, rather than producing an abundance estimate for the three years that this contract is based on. This will be provided to the Department in the form of a peer- reviewed publication to use for management purposes.

- A total of 85 individuals were identified over the study period. This resulted in a 36.7% decrease in identifiable individuals since Peters & Stockin 2016 and a 69.4% decrease in identifiable individuals since Constantine 2002. The differences in survey effort type (tour vessels may not allow for thorough photo-identification effort for each group encountered, and opportunistic only surveys may result in missing groups across the study area) and quantity between the major studies in the Bay of Islands should be considered when reviewing these numbers (Table 13).

Table 13: Summary of photo-identification effort conducted in the Bay of Islands using similar methodologies during 1997-1999 (Constantine 2002), 2003-2006 (Tezanos-Pinto et al., 2013), 2012-2016 (Peters & Stockin 2016) and 2019-2022 (this study), including surveys from independent research vessel (IRV) and tour boats (TB).

	1997-1999	**2003-2006**	**2012-2016**	**2019-2022**
Photo-ID Surveys	246 (TB and IRV)	205 (TB and IRV)	1,472 (TB and IRV)	130 (IRV only)
Type of survey	Opportunistic	Opportunistic	Systematic & Opportunistic	Systematic & Opportunistic
Survey span	Year round	Year round	Year round	Year round
Groups encountered	198	265	222	71
Individual dolphins identified	278	159	134	85

- The last 12 months of survey effort in this study resulted in the identification of only one additional individual.
- The number of 85 identifiable individuals presented here does not constitute a full population estimate. A full mark-recapture assessment, following Tezanos-Pinto et al., 2013 for direct comparisons, will be prepared by TriOceans. For best results, this will include mark- recapture data from Peters & Stockin 2016.
- The resight rate of those 85 individuals varied considerably during the study period. Frequent users (n=15), occasional visitors (n=6) and infrequent users (n=64) were identified, consistently with Constantine 2002, Tezanos-Pinto 2009 and Peters & Stockin 2016.
- To allow for direct comparison of user groups since Constantine 2002, categories were arbitrarily assigned for Constantine 2002 and this study as follows: frequent users (more than 7 monthly resights), occasional visitors (2 to 7 monthly resights) and frequent users (one monthly resight) (Table 14).

Table 14: Number of individuals identified in each user group (frequent users, occasional visitors and infrequent users) between 1997 and 1999 (Constantine 2002) and 2019-2022 (this study).

	1997-1999	2019-2022	Percentage decrease
Frequent users (>7 monthly resights)	59	15	74.6%
Occasional visitors (2 to 7 monthly resights)	135	6	95.6%
Infrequent users (one monthly resight)	84	64	23.8%

- All major Bay of Islands studies compared here (Constantine 2002, Tezanos-Pinto et al., 2013, Peters & Stockin 2016 and this study) included data collected over two to three years. Frequent users and occasional visitors are likely to have been fully identified over such a timeframe, allowing for direct comparison. In this study, all frequent users were identified within 2 months of effort, and all occasional visitors within 12 months of effort.
- 37 frequent users were also reported in 2002-2005 (Tezanos-Pinto 2009) and 19 frequent users in 2012-2015 (Peters & Stockin 2016), showing a consistent decline trend.
- The 15 frequent users represented 81.4% of resights (n=491) (71.2% of monthly resights, n=225), and were consistently recorded in the same group (containing juveniles and calves) over the study period.
- No calves or neo-nates were recorded alongside occasional visitors. Infrequent users were observed with calves on three encounters out of seven.
- Seasons had little effect on the number of individuals identified.
- Outside of Bay of Islands waters, only two individuals were identified during one encounter, including a BOI frequent user and a BOI occasional visitor, accompanied by one juvenile (unidentifiable).

6.3 Quantify variation in vessel effort around bottlenose dolphins in the Bay of Islands post changes in management.

Vessel traffic within 300m of bottlenose dolphins was noticeably lower than Peters & Stockin 2016, most likely due to a combination of COVID-19 and the July 2019 changes to Permitted vessels effort. High vessel traffic areas coincide with areas of high bottlenose dolphin density. Swim-with activities with bottlenose dolphins were rarely observed (n=10). Vessel traffic around bottlenose dolphins is however still significant, with 30% of daylight hours spent with vessels year-round. This varied seasonally, with highest presence in daylight hours in Summer (62%) and lowest in Winter (15%).

- Over the study period, season-weighted vessel effort within 300m of bottlenose dolphins during daylight hours resulted in the following:
  - Average daylight hours spent by bottlenose dolphins with vessels within 300m was 30%, a 56% decrease from Peters & Stockin 2016 (86%).
  - Vessel traffic varied seasonally, with highest effort in Summer (62% of daylight hours) and lowest in Winter (15% of daylight hours).

  - Absence of vessels lasted an average of 25.5 continuous minutes, a 125.7% increase from Peters & Stockin 2016 (11.3min)
  - Average number of vessels entering within 300m of dolphins per hour was 7.3.

- This decrease in vessel effort takes place around three contexts:
  1. COVID-19 lockdowns and travel restrictions (national and international) over most of the study period (March 2020 onwards)
  2. Management changes reducing permitted vessel dolphin-watching activities implemented in July 2019
  3. Increase of general public awareness to dolphin-vessel interactions due to several education campaigns (2018 onwards) and public consultation on a proposal for a Marine Mammal Sanctuary (April/May 2021).

While context 3 is acknowledged, contexts 1 and 2 are likely to have had the most effect on number of vessels recorded within 300m of bottlenose dolphins during the study period.

- The ratio of vessel types entering within 300m of dolphins varied from equally spread (Peters & Stockin 2016) between Permitted, Commercial and Private to a large majority of Private vessels (85%), followed by Permitted (9%) and Commercial (5%) during this study.
- The highest number of vessels recorded entering within 300m of dolphins over one hour was 107, recorded in Summer.
- Vessel types entering within 300m of dolphins varied throughout the day. Commercial vessels reached a peak mid/late morning (percentile 3), then steadily reduced. Permitted vessels reached a peak early afternoon (percentile 5), then reduced at percentile 6 to increase again at percentile 7 (mid-late afternoon). Private vessels increased steadily from early/midmorning to reach a peak early afternoon, then decreased.
- High vessel traffic areas were recorded around the Russell Peninsula and in the Easter Islands, consistently with Peters & Stockin 2016 and coinciding with bottlenose dolphin high density areas.
- The number of swims with dolphins decreased substantially in this study, with an average of 0.5 (this study, n=10 swims within 20 months with encounters) versus 37.2 (Peters & Stockin 2016) swims/months from Private vessels or land (99% decrease). No swims were recorded from Permitted or Commercial vessels.

6.4 Determine the potential effects of interacting with bottlenose dolphins as currently permitted for both commercial operations and private vessels in the Bay of islands.

Overall, vessel presence effects were consistent with Peters & Stockin 2016, indicating a reduction in energy acquisition behaviours (foraging and resting) and increase in energy expenditure behaviours (socialising and milling) in the presence of vessels, as well as a reduction in group mobility (traveling). This varied seasonally, with no significant difference in Winter, one behavioural state affected in Spring and Autumn, and 4 behavioural states affected in Summer behavioural budgets. Bout length was only significantly affected in Summer (3 behavioural states). The small amount of behavioural variation in 3 out of 4 seasons is an encouraging result; however, the more important variation observed in Summer is concerning as this is the peak calving period for bottlenose dolphins.

- Consistently with Peters & Stockin 2016: traveling, foraging and resting were observed to significantly decrease in the presence of vessels. Socialising and milling were observed to significantly increase in the presence of vessels.
- In contrast with Peters & Stockin 2016: diving was observed to decrease significantly in the presence of vessels. Conclusions on this variation should however be made with caution as 1. Diving n numbers were the lowest overall (n=47 in absence and n=2 in presence), and 2. more than one-half of diving observations were made during one single encounter.
- Time to resume state was significantly affected by the presence of vessels for all behavioural states, with increases for traveling, foraging, resting and diving, and decreases for socialising and resting.
- When broken down by seasons, Winter showed no significant difference between overall budget and absence only budget. Spring and Autumn only showed significant difference in one behavioural state (diving and socialising, respectively), whereas

Summer showed significant differences in 4 behavioural states (traveling, socialising, milling and resting).

- Similar results were observed for overall bout length compared to absence only bout length, with no significant differences observed in Winter, Spring or Autumn, but significant increase in socialising and milling and significant decrease in resting in Summer.
- All behaviours were observed across Bay of Islands waters, suggesting there are no particular preferred areas for specific behaviours.
- Dolphin presence was recorded in medium to high density in both the current Permitted vessel no-interaction and MMS 5 knots safe zones. Within these zones, high variability in vessel traffic was observed, ranging from highest densities in both zones to no vessels observed within 300m of dolphins in parts of the southern zone.
- Scat sampling data collection efforts were undertaken, with two samples collected over the study period. The method has been used successfully on various species in New Zealand and internationally, and has potential to bring important insight into bottlenose dolphin diet and physiology. We note, however, that the methodology is labour intensive and requires close approach to the dolphins.

6.5 Provide an update in bottlenose dolphin calf survival in the Bay of Islands

Overall calf mortality during the first two years was observed as 50%. Peters & Stockin 2016 reported a 75% calf mortality (12 calves monitored over three years), and Tezanos-Pinto (2009) reported a 52% calf mortality (41 calves monitored over 11 years), however the low sample size in this study (2 calves out of 4) should be considered when interpreting this data. Only calves from frequent user individuals could be monitored, as all other calves were sighted only once. While the low n numbers should be kept in mind before making conclusions (no statistical significant difference observed between studies with a Z-test for proportions), it is worth considering that those low numbers are a concern in themselves.

- From October 2017 to November 2021, a total of 13 young of the year calves were observed. This includes five calves who could be monitored over one or two years of age, three calves who could be monitored but not over one year of age, and a further five calves observed on one occasion only.
- The fate of five calves could be documented over one year, and the fate of four calves could be documented over two years. 1st year mortality was observed for two calves of five (40% 1st year mortality, calves 3 and 5). 2nd year mortality was observed for two calves of four (50% 2nd year mortality). The remaining calf survived as of November 2021 but was not over 24 months of age (20 months of age).
- The total number of calves whose survival rates could be determined over one year was reduced by 70.6% from Constantine 2002 (n=5 (this study) and n=17 (Constantine 2002)).
- Photogrammetry measurements were carried out on 6 calves. Results are promising as a monitoring method but will require more data before conclusions can be drawn. Growth rate profiles are however consistent with van Aswegen et al., 2019 and show high early growth rates, slowing down as the individual ages.

6.6 Provide an update in other marine mammal species occurrence in Far North waters and in the Bay of Islands

- Marine mammals were recorded throughout the study area
- A total of 9 marine mammal species were recorded in Far North waters. 8 of those species were recorded both inside and outside of Bay of Islands waters, with pilot whales recorded only inside Bay of Islands waters.
- Fur seals (n=40) were the most commonly recorded species after bottlenose dolphins, followed by common dolphins (n=9).

6.7 Integrate present and historical research results to produce statements and recommendations regarding existing and future anthropogenic activities around bottlenose dolphins in the Bay of Islands and Far North waters.

Peters & Stockin 2016 identified 5 critical issues for the local BOI population:

1. Significant decline in nationally endangered bottlenose dolphin Bay of Islands population and potential risk of localised extinction
2. High and unsustainable calf mortality
3. Vessels and swim-with activities disturb/disrupt behaviours critical to bottlenose dolphin survival
4. Higher than sustainable vessel effort exerted on local population
5. Poor compliance across all vessel types utilising BOI waters

The present study took place between June 2019 and November 2021, within two major contexts for dolphin-vessel interactions in the Bay of Islands:

- Implementation in July 2019 of changes in permitted vessels activities around marine mammals in the BOI, including bottlenose dolphin encounter times reduced from 50 minutes to 20 minutes removal of static "no-go" zones to implement new no-interaction zones, and a ban on morning encounters and swim-with activities with bottlenose dolphins.
- COVID-19 lockdowns and travel restrictions (national and international) over most of the study period (March 2020 onwards).

The present study shows significant behavioural changes due to vessel presence, although vessel effort (30% of daylight hours) was reduced from Peters & Stockin 2016 (86% of daylight hours). The summer season showed the highest number of behavioural states affected, which coincides with the peak calving season of bottlenose dolphins. Calf mortality during the first two years, although reduced from Peters & Stockin 2016, was still high (50%, n=4). Identifiable individuals have declined from Peters & Stockin 2016 by 7.1%, with 81.4% of resights accounted for by one single group of 15 identifiable individuals, resulting in an annual decline in identifiable individuals since first published results (Constantine 2002, n=278, database 1997-1999) of 5.2 %. The Bay of Islands remains at risk of abandonment by bottlenose dolphins (previously referred to as "localised extinction"), which would result in local marine mammal tourism industry losing its viability and local Hapū losing a taonga species.

To mitigate effects of vessel presence on bottlenose dolphin behaviour, it is recommended:

- For the current moratorium to remain in place until results indicate no significant changes in behavioural budget or bout length for a control and impact database compared to a control only database, for all seasons.
- For the DOC to ensure Bay of Islands Marine Mammal Sanctuary rules and regulations and national MMPR are enforced, particularly in Summer. The high ratio of Private vessels presence within 300 of bottlenose dolphins shows the importance of regulations applicable over recreational boaties. Regular marine patrols with a dedicated, easily recognisable vessel, would allow for both rule enforcement and benefits of long-term presence and clear identity of the program within the community.
- For Permitted vessels effort around bottlenose dolphins to maintain current status quo or align Permitted vessels regulations with MMS rules. An increase in Permitted vessel effort is not recommended until an assessment of how the new management in place is affecting the population is completed.
- For education initiatives in the Bay of Islands around marine mammal protection to be encouraged. A central Marine Conservation/Education Hub in the Bay of Islands would have multiple education and conservation benefits, for the local area, nationally and internationally. Positive messaging similar to "enjoy the dolphins, in their own space/at their own pace" or "let us all use the Bay of Islands safely" is particularly encouraged
- For such education initiatives to be broadcasted on a wide range of platforms, including radio, television, and social media to increase public awareness. This would have benefits for marine mammals both in the Bay of Islands and nationally.
- For the DOC to encourage establishment of land-based viewing platforms to advocate no disturbance viewing. Areas such as Tapeka Point, Roberton Island or Moturoa all offer high vantage points close to dolphin high-density areas.

To benefit marine mammal fitness over multiple parameters, it is recommended:

- For the DOC to investigate the creation of marine reserves (no-take zones) within the Bay of Islands. Such reserves will be most efficient if they are all species inclusive, both for enforceability and ecosystem health reasons.
- A long-term management plan for the Bay of Islands be implemented, as per Higham et al, 2008, including regular intervals for scientific research and reviews of rules and regulations in place. Such a plan will need to include multiple stakeholders' perspectives (such as the conservation and education benefits of permitted operations), make research-based management decisions, and integrate the Bay of Islands' marine ecosystem as a whole. Keeping rules and regulations clear-cut and simple should remain a primary objective.

To allow for all-inclusive well-informed management decisions, it is recommended:

- For the DOC to investigate potential parameters behind the decline in bottlenose dolphin numbers. Parameters such as food source availability and environment changes should particularly be investigated, and efforts into ecosystem considerations made.
- For the DOC to keep monitoring vessel effects on the local BOI population, as a way to assess the effectiveness of the new Bay of Islands Marine Mammal Sanctuary. The Sanctuary will have reached its full effectiveness when results indicate no significant changes in behavioural budget or bout length for a control and impact database compared to a control only database, for all seasons. A more modern approach to data analysis could also be taken with the inclusion of generalized additive models.
- For the DOC to keep monitoring bottlenose dolphin numbers and other marine mammal species occurrence within Bay of Islands and Far North waters.
- For the DOC to keep monitoring bottlenose and other species' distribution within the Bay of Islands to ensure current Marine Mammal Sanctuary safe zones remain appropriate. Both zones currently experience very high vessel traffic near their edges as well as medium to high use by bottlenose dolphins. The southern zone also covered an area where no vessels were recorded within 300m of bottlenose dolphins. The rationale of providing a safer zone within and close to high vessel traffic areas is consistent with the results presented here. The use of fixed hydrophones, ideally with paired whistle and click detection systems, both within and outside of safe zones is also recommended to assess the soundscape benefits of those regulations.
- For non-invasive research methods to be prioritized, such as land-based research stations for theodolites, as much as feasible.

On a national scale, it is recommended:

- For the DOC to instigate a review of national MMPR. The Bay of islands is a known high-vessel traffic area nationally and as such is a good indicator of what other areas may experience in the future. The unenforceability of current MMPR leaves all species of marine mammals at risk of vessel strike and behavioural changes on a national scale. Clear-cut, black-and-white rules, applicable over all marine mammal species to remove misidentification issues, and including approach distances, are recommended.

7. Conclusions and perspectives

Bottlenose dolphins remain the most encountered cetacean species in the Bay of Islands, the economic core of dolphin-watch operations and a taonga species for local Hapū. Findings presented here indicate a further continuation of the local BOI population decline, since first reported (Tezanos-Pinto 2009) and confirmed (Peters & Stockin 2016), with a near-loss (95.6% decline since Constantine 2002) of occasional visitor individuals. Results indicate significant changes in behavioural budget and bout length due to the presence of vessels, with increase of energy expenditure behaviours and decrease of energy acquisition behaviours. These changes are still occurring in a context of reduced boat traffic from Peters & Stockin 2016 (through increased management and COVID19 restrictions), however a strong seasonality in the behavioural change is now observed, ranging from no significant differences in Winter to most behavioural states affected in Summer (peak calving season). In a context of high calf mortality (Peters & Stockin 2016), this brings concerns as to the bottlenose dolphin local population's ability to produce viable offspring, and to the status quo of bottlenose dolphin presence in Bay of Islands waters, should the one group of frequent users shift its preferred area of use to a different location.

The Bay of Islands represents only part of the range of bottlenose dolphins along the North-East coast of New Zealand. Bay of Islands waters are however one of only two areas (Great Barrier Island, Dwyer et al, 2014) where year-round presence and high resight rates of bottlenose dolphins have been reported.

The reduced numbers of dolphins within Bay of Islands waters also raise questions about the status quo of the bottlenose dolphin population across its North-East coast range.

Management decisions aiming at improving population fitness, including reducing behavioural changes, are recommended. The decline in numbers observed here is likely to be due to several parameters. As such, a management plan including a cumulative impact assessment, with a combination of focusing on the identified issue of vessel traffic related behavioural changes in the Bay of Islands, while investigating other parameters which may take part in the observed decline, is recommended. To monitor the effectiveness of the Bay of Islands Marine Mammal Sanctuary, the continuation of seasonal control vs whole database investigations is recommended, with a goal of attaining no significant changes observed in any seasons.
As top-predators, easily detected and highly mobiles cetacean species are considered reliable environment sentinels (Fossi et al., 2018) giving early indications of changes in marine ecosystems. Other species have been the topic studies in the Bay of Islands, including identification of changes in subtidal seagrass beds (Booth 2019) or of rodolith beds harbouring high diversity of invertebrate taxa (Nelson et al, 2012, Meill et al, 2015). In some cases, protection measures have been taken, including closure of Kūtai /Mussels in the Te Puna Mātaitai since March 2020 and Temporary Fishing Closure (except Kina) in Maunganui Bay since December 2010. A reduction in cetacean populations such as the one reported here represents a potential warning sign for the Bay of Islands' rich ecosystem, and offers an opportunity to investigate other elements in time to promote conservation efforts.

8. Acknowledgments

We thank the Department of Conservation Bay of Islands office for funding this study, with particular thanks to R. Elliot, B. Bauerhunt and A. Walker for their support and availability throughout the study. This report would not have been possible without the interns who participated in data collection and processing, T. Sundermann, C. Peters (Coline), A. Boucher and C. Remy from the ENVT school of Toulouse, G. Foucher and A. Guerin from the IUT of Tours, E. Greenwood and M. McCurdy from the University of Otago. We also thank B. Thrippleton and M. Byrne for their work as Research Assistants on data collection and processing, as well as A. Ramsay and K. Keyes. Thanks go to Bay of Islands coastal Hapū as valued partners. A special thanks goes to Highfield for helping provide an excellent research vessel. We are grateful to Dr C. Peters, Dr J. Weir and K. Keyes for their time spent reviewing and commenting on the report before submission, and to the DOC team for providing peer review post-submission. Our thanks go to the Bay of Islands and Far North community for their encouragements and support throughout the study.

9. Literature cited

Arico, S.; Barbiere, J.; Bedard-Vallee, A.; Belov, S.; Belbeoch, M.; Bermiasa, J.; Clausen, A.; de Pinho, R.; Gonzalez, D.; Enevoldsen, H. & Heslop, E. (2020). Global Ocean Science Report 2020-Charting Capacity for Ocean Sustainability. *UNESCO*.

Bas, A.; Christiansen, F.; Öztürk, B.; Öztürk, A.; Erdoğan, M.; & Watson, L. (2017). Marine vessels alter the behaviour of bottlenose dolphins *Tursiops truncatus* in the Istanbul Strait, Turkey. *Endangered Species Research*, 34, 1-14.

Baker, C.; Chilvers, B.; Childerhouse, S.; Constantine, R.; Currey, R.; Mattlin, R.; Van Helden, R. & Rolfe, J. (2016). Conservation status of New Zealand marine mammals, 2013. *Publishing Team, Department of Conservation.*

Bejder, L.; Dawson, S. & Harraway, J. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science*, 15(3): 738-750.

Bejder, L.; Higham, J. & Lusseau, D. (2022). Tourism and research impacts on marine mammals: A bold future informed by research and technology. In *Marine Mammals: the Evolving Human Factor* (pp. 255-275). Cham: Springer International Publishing.

Booth, J. (2019). Recent (post-1930) changes in the extent of subtidal seagrass (Zostera muelleri) beds of the eastern Bay of Islands, *New Zealand, New Zealand Journal of Marine and Freshwater Research*, 53:1, 113-127.

Buckstaff, K. (2004). Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine mammal science*, *20*(4), 709-725.

Brough, T.; Guerra, M. & Dawson, S. (2015). Photo-identification of bottlenose dolphins in the far south of New Zealand indicates a ‘new’, previously unstudied population. *New Zealand Journal of Marine and Freshwater Research*, *49*(1), pp.150-158.

Cañadas, A. & Hammond, P. (2008). Abundance and habitat preferences of the short-beaked common dolphin *Delphinus delphis* in the Southwestern Mediterranean: implications for conservation. *Endangered Species Research*, 4(3): 309-331.

Cockcroft, V. & Ross, G. (1990). Observations on the early development of a captive bottlenose dolphin calf. *In: The Bottlenose Dolphin (Eds: Leatherwood, S. & Reeves, R.R.), Academic Press, San Diego, CA, USA*, 461-478 pp.

Constantine, R. (2002). The behavioural ecology of bottlenose dolphins (*Tursiops truncatus*) of Northeastern New Zealand: A Population exposed to tourism. *Unpublished PhD thesis, University of Auckland, Auckland, New Zealand,* 160 pp.

Constantine, R.; Brunton, D. & Baker, S. (2003). Effects of tourism on behavioural ecology of bottlenose dolphins of northeastern New Zealand*. DOC Science Internal Series 153. Department of Conservation, Wellington, New Zealand.*

Constantine, R.; Brunton, D. & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation*, 117(3): 299-307.

Dwyer, S.; Tezanos-Pinto, G.; Visser, I.; Pawley, M.; Meissner, A.; Berghan, J. & Stockin, K. (2014) Overlooking a potential hotspot at Great Barrier Island for the nationally endangered bottlenose dolphin of New Zealand. *Endangered Species Research*, 25(2): 97-114.

Fleiss, J. (1981). Statistical methods for rates and proportions. Wiley, New York. 1981

Fossi, M.; Panti, C.; Baini, M. & Lavers, J. (2018). A review of plastic-associated pressures: cetaceans of the Mediterranean Sea and eastern Australian shearwaters as case studies. *Frontiers in marine science*, *5*, 173.

Guerra, M.; Dawson, S.; Brough, T. & Rayment, W. (2014). Effects of boats on the surface and acoustic behaviour of an endangered population of bottlenose dolphins. *Endangered Species Research*, *24*(3), pp.221-236.

Hartel, E.; Constantine, R.; & Torres, L. (2014). Changes in habitat use patterns by bottlenose dolphins over a 10-year period render static management boundaries ineffective. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *25*(5), 701-711.

Higham, J.; Bejder, L.; & Lusseau, D. (2008). An integrated and adaptive management model to address the long-term sustainability of tourist interactions with cetaceans. *Environmental Conservation*, *35*(4), 294-302.

Kastelein, R.; Dokter, T. & Zwart, P. (1990). The suckling of a bottlenose dolphin calf (*Tursiops truncatus*) by a foster mother, and information on transverse birth bands. *Aquatic Mammals*, 16(3): 134-138

Lundquist, D. (2012). Behaviour and movement patterns of dusky dolphins (*Lagenorhynchus obscurus*) off Kaikoura, New Zealand: Effects of tourism. *Unpublished PhD thesis, University of Otago, Dunedin, New Zealand*, 142 pp.

Lundquist, D.; Gemmell, N. & Würsig, B. (2012). Behavioural responses of dusky dolphin groups (*Lagenorhynchus obscurus*) to tour vessels off Kaikoura, New Zealand. *PloS One,* 7(7): e41969: 9.

Lusseau, D. (2003). Effects of tour boats on the behaviour of bottlenose dolphins: Using Markov chains to model anthropogenic impacts. *Conservation Biology*, 17(6): 1785-1793.

Lusseau, D. (2004). The hidden cost of tourism: Detecting long-term effects of tourism using behavioural information. *Ecology and Society*, 9(1): 2.

Lusseau, D. (2005). Residency pattern of bottlenose dolphins *Tursiops* species in Milford Sound, New Zealand, is related to boat traffic. *Marine Ecology Progress Series*, 295: 265-272.

Lusseau, D. (2006). The short-term behavioural reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Marine Mammal Science*, 22(4): 802-818.

Mann, J. (1999). Behavioural sampling methods for cetaceans: a review and critique*. Marine Mammal Science*, 15(1): 102-122.

Mann, J.; Connor, R.; Tyack, P. & Whitehead, H. (2000). Cetacean societies: field studies of dolphins and whales. *University of Chicago Press, Chicago, Il, USA*, 448 pp.

Mann, J. & Smuts, B. (1999). Behavioural development in wild bottlenose dolphin newborns (*Tursiops sp*.). *Behaviour*, 136(5):529-566.

Mack, D.; Raphael, M. & Laake, J. (2002). Probability of detecting Marbled Murrelets at sea: effects of single versus paired observers. *The Journal of wildlife management*, 865-873.

Markov, A. (1906). Extension of the law of large numbers to dependent quantities. *Bulletin of the Society for Physical Mathematics*, 2: 135-156.

Markowitz, T.; DuFresne, S. & Würsig, B. (2009). Tourism effects on dusky dolphins at Kaikoura. *DOC Science Internal Series, Department of Conservation, Nelson, New Zealand*, 12 pp

Martinez, E. & Stockin, K. (2013). Blunt trauma observed in a common dolphin delphinus sp. Likely caused by a vessel collision in the Hauraki Gulf, New Zealand. *Pacific Conservation Biology*, *19*(1), 19-27.

Meissner, A.; Christiansen, F.; Martinez, E.; Pawley, M.; Orams, M. & Stockin, K. (2015). Behavioural effects of tourism on oceanic common dolphins, Delphinus sp., in New Zealand: the effects of Markov analysis variations and current tour operator compliance with regulations. *PloS one*, *10*(1).

Neill, K., Nelson, W., D'Archino, R., Leduc, D. & Farr, T. (2015). Northern New Zealand rhodoliths: assessing faunal and floral diversity in physically contrasting beds. *Marine Biodiversity*, *45*, pp.63-75.

Nelson, W.; Neill, K.; Farr, T.; Barr, N.; D'Archino, R.; Miller, S. & Stewart, R. (2012). Rhodolith Beds in Northern New Zealand: Characterisation of Associated Biodiversity and Vulnerability to Environmental Stressors. *New Zealand Aquatic Environment and Biodiversity Report* No. 99. 102 p.

Neumann, D. (2001). Activity budget of free-ranging common dolphins (*Delphinus delphis*) in the northwestern Bay of Plenty, New Zealand. *Aquatic Mammals* 27(2): 121-136.

Neumann, D. & Orams, M. (2005). Behaviour and ecology of common dolphins (*Delphinus delphis*) and impact of tourism in Mercury Bay, North Island, New Zealand. Science and Technical Publishing. *DOC Science for conservation 254, Department of Conservation, Wellington, New Zealand*, 40 pp.

Neumann, D. & Orams, M. (2006). Impacts of ecotourism on short-beaked common dolphins (*Delphinus delphis*) in Mercury Bay, New Zealand. *Aquatic Mammals*, 32(1): 1-9.

Nishiwaki, M. & Sasao, A. (1977). Human activities disturbing natural migration routes of whales. *The Scientific Reports of the Whales Research Institute*, *29*, 113-120.

O'Connor, S.; Campbell, R.; Cortez, H. & Knowles, T. (2009). Whale Watching Worldwide: tourism numbers, expenditures and expanding economic benefits, a special report from the International Fund for Animal Welfare. *Yarmouth MA, USA, prepared by Economists at Large*, *228*.

Parsons, E.; Warburton, C.; Woods-Ballard, A.; Hughes, A. & Johnston, P. (2003). The value of conserving whales: the impacts of cetacean-related tourism on the economy of rural West

Scotland. *Aquatic conservation: marine and freshwater ecosystems*, *13*(5), pp.397-415.

Peters, C. (2018). Context-specific signal plasticity of two common bottlenose dolphin ecotypes (*Tursiops truncatus*) in Far North waters, New Zealand. *Unpublished PhD thesis, Massey University, Auckland, New Zealand,* 295 pp.

Peters, C. & Stockin, K. (2016). Responses of bottlenose dolphins to vessel activity in northland, New Zealand. *Progress report, Department of Conservation, Northland, New Zealand*

Pirotta, E.; Merchant, N.; Thompson, P.; Barton, T. & Lusseau, D. (2015). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. *Biological Conservation*, *181*, pp.82-89.

Rako, N.; Fortuna, C.; Holcer, D.; Mackelworth, P.; Nimak-Wood, M.; Pleslić, G.; Sebastianutto, L.; Vilibić, I.; Wiemann, A. & Picciulin, M. (2013). Leisure boating noise as a trigger for the displacement of the bottlenose dolphins of the Cres–Lošinj archipelago (northern Adriatic Sea, Croatia). *Marine pollution bulletin*, *68*(1-2), 77-84.

Smolker, A.; Richards, E.; Connor, C. & Pepper, W. (1992). Sex differences in patterns of associations among Indian Ocean bottlenose dolphins. *Behaviour*, 123: 38-69.

Steiner, A. & Bossley, M. (2008). Some Reproductive Parameters of an Estuarine Population of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*). *Aquatic Mammals*, 34: 84-92.

Stockin, K.; Lusseau, D.; Binedell, V.; Wiseman, N. & Orams, M. (2008a). Tourism affects the behavioural budget of the common dolphin *Delphinus sp.* in the Hauraki Gulf, New Zealand. *Marine Ecology Progress Series*, 355: 287-295.

Stockin, K; Pierce, G.; Binedell, V.; Wiseman, N. & Orams, M. (2008b). Factors affecting the occurrence and demographics of common dolphins (*Delphinus sp*.) in the Hauraki Gulf, New Zealand. *Aquatic Mammals*, 34(2): 200-211.

Stockin, K.; Binedell, V.; Wiseman, N.; Brunton, D. & Orams, M. (2009). Behaviour of free-ranging common dolphins (*Delphinus sp.*) in the Hauraki Gulf, New Zealand. *Marine Mammal Science*, 25(2): 283-301.

Tezanos-Pinto, G (2009). Population structure, abundance and reproductive parameters of bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands (Northland, New Zealand*). Unpublished PhD thesis, University of Auckland, Auckland, New Zealand,* 243 pp.

Tezanos-Pinto, G.; Baker, C.; Russell, K.; Martien, K.; Baird, R.; Hutt, A.; Stone, G.; Mignucci-Giannoni, A.; Caballero, S.; Endo, T. & Lavery, S. (2009). A worldwide perspective on the population structure and genetic diversity of bottlenose dolphins (*Tursiops truncatus*) in New Zealand. *Journal of Heredity*, *100*(1), 11-24.

Tezanos-Pinto, G. (2013). Population viability analysis of the Bay of Islands dolphin: understanding the demographic consequences for current population parameters. *DOC Science Internal report, Department of Conservation, Northland, New Zealand*, 38 pp.

Tezanos-Pinto, G.; Constantine, R.; Brooks, L.; Jackson, J.; Mourão, F.; Wells, S. & Baker, S. (2013b). Decline in local abundance of bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands, New Zealand. *Marine Mammal Science*, 29(4): 390-410.

Tezanos-Pinto, G.; Constantine, R.; Mourao, F.; Berghan, J. & Scott Baker, C. (2015). High calf mortality in bottlenose dolphins in the Bay of Islands, New Zealand–a local unit in decline. *Marine Mammal Science*, *31*(2), 540-559.

Visser, I.; Zaeschmar, J.; Haliday, J.; Abraham, A.; Ball, P.; Bradley, R.; Daly, S.; Hatwell, T.; Johnson, T.; Johnson, W.; Kay, L.; Maessen, T.; McKay, V.; Turner, N.; Umuroa, B. & Pace, D. (2010). First Record of Predation on False Killer Whales (*Pseudorca crassidens*) by Killer Whales (*Orcinus orca*). *Aquatic Mammals*, 36: 195-204.

van Aswegen, M.; Christiansen, F.; Symons, J.; Mann, J.; Nicholson, K.; Sprogis, K., & Bejder, L.

(2019). Morphological differences between coastal bottlenose dolphin (*Tursiops aduncus*) populations identified using non-invasive stereo-laser photogrammetry. *Scientific reports*, *9*(1), 1-14.

Wells S. & Scott D. (1999). The Bottlenose Dolphin. *In: Ridgway SH, Harrison S. Handbook of Marine Mammals: Small Cetaceans. London: Academic Press*, 1-55.

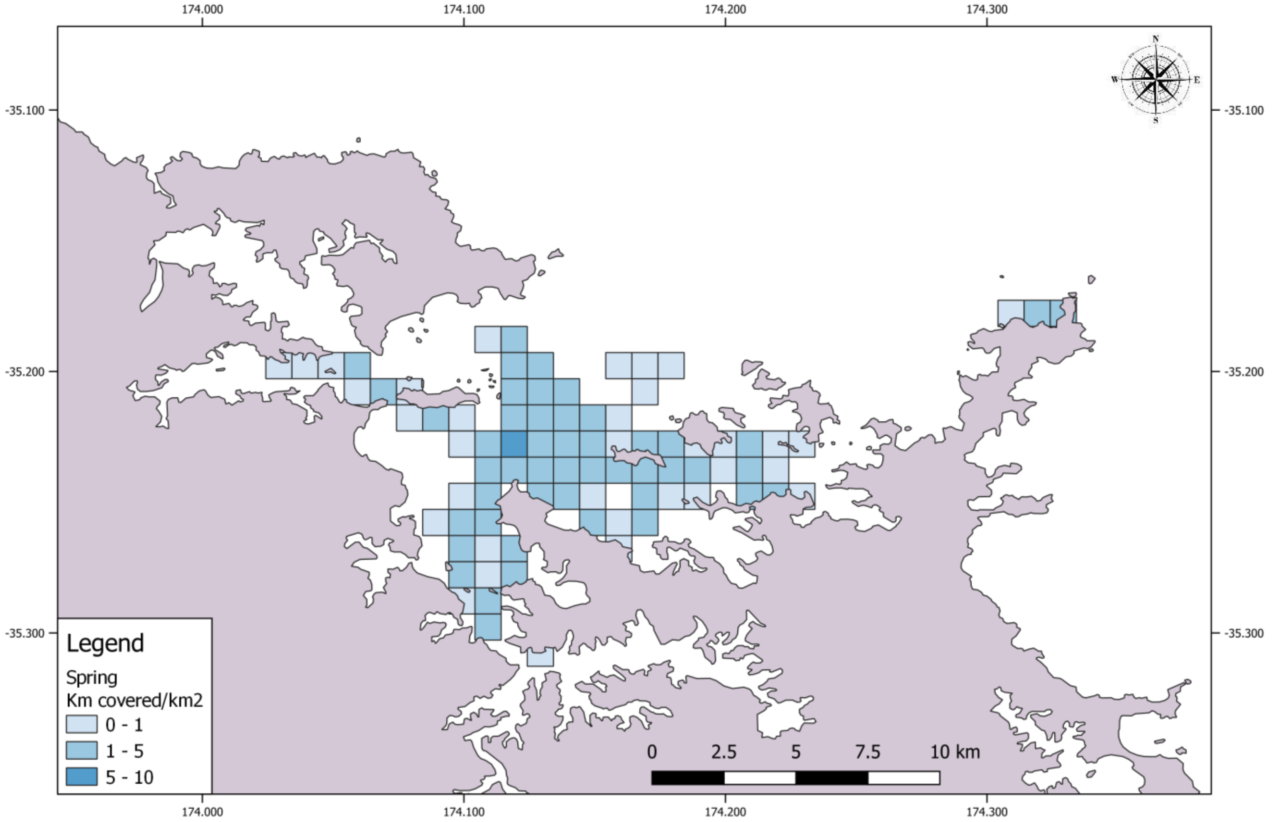
WSAS (2020) Washington state academy of sciences. Summary of key research findings about underwater noise and vessel disturbance. WSAS, Seattle, WA, pp 1–25

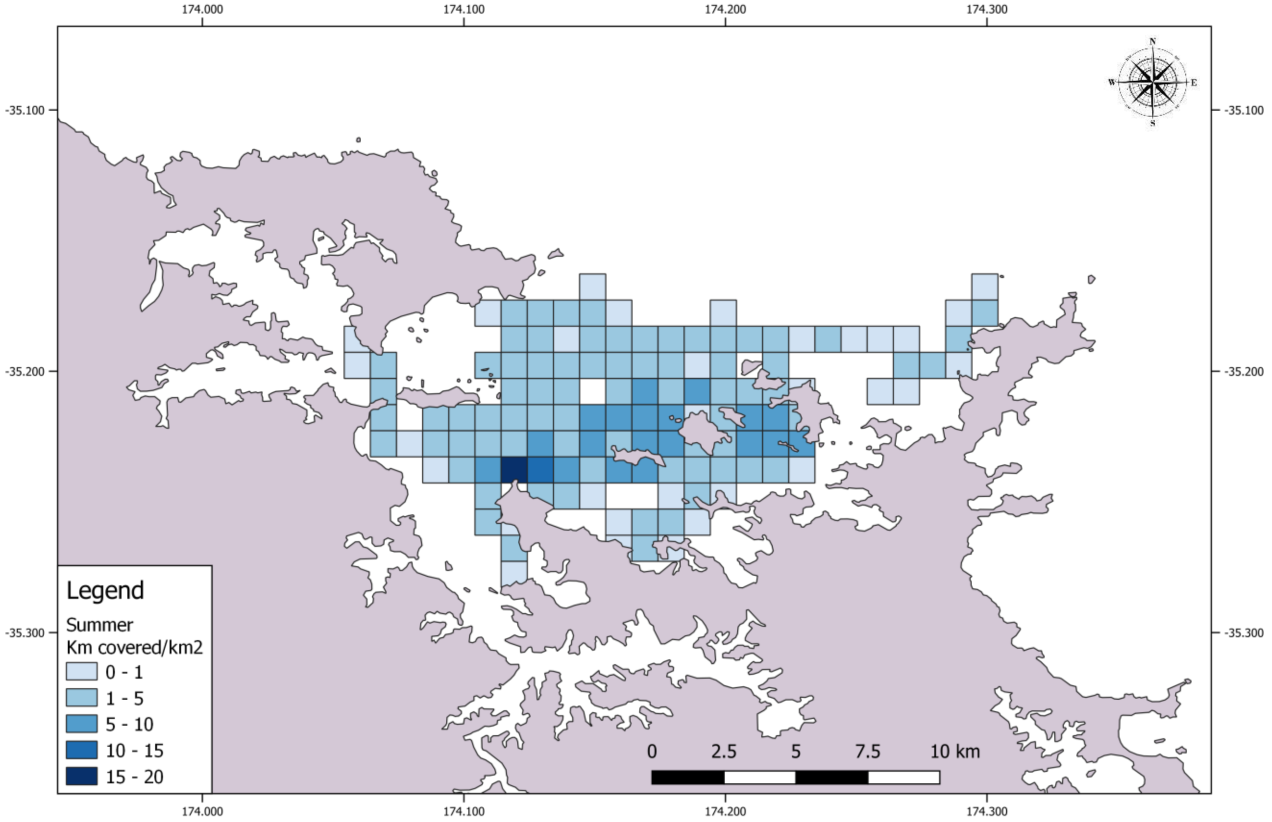
Würsig, B. & Jefferson, T. (1990). Methods of photo-identification for small cetaceans*. Reports of the International Whaling Commission, Special* 12: 443-55.

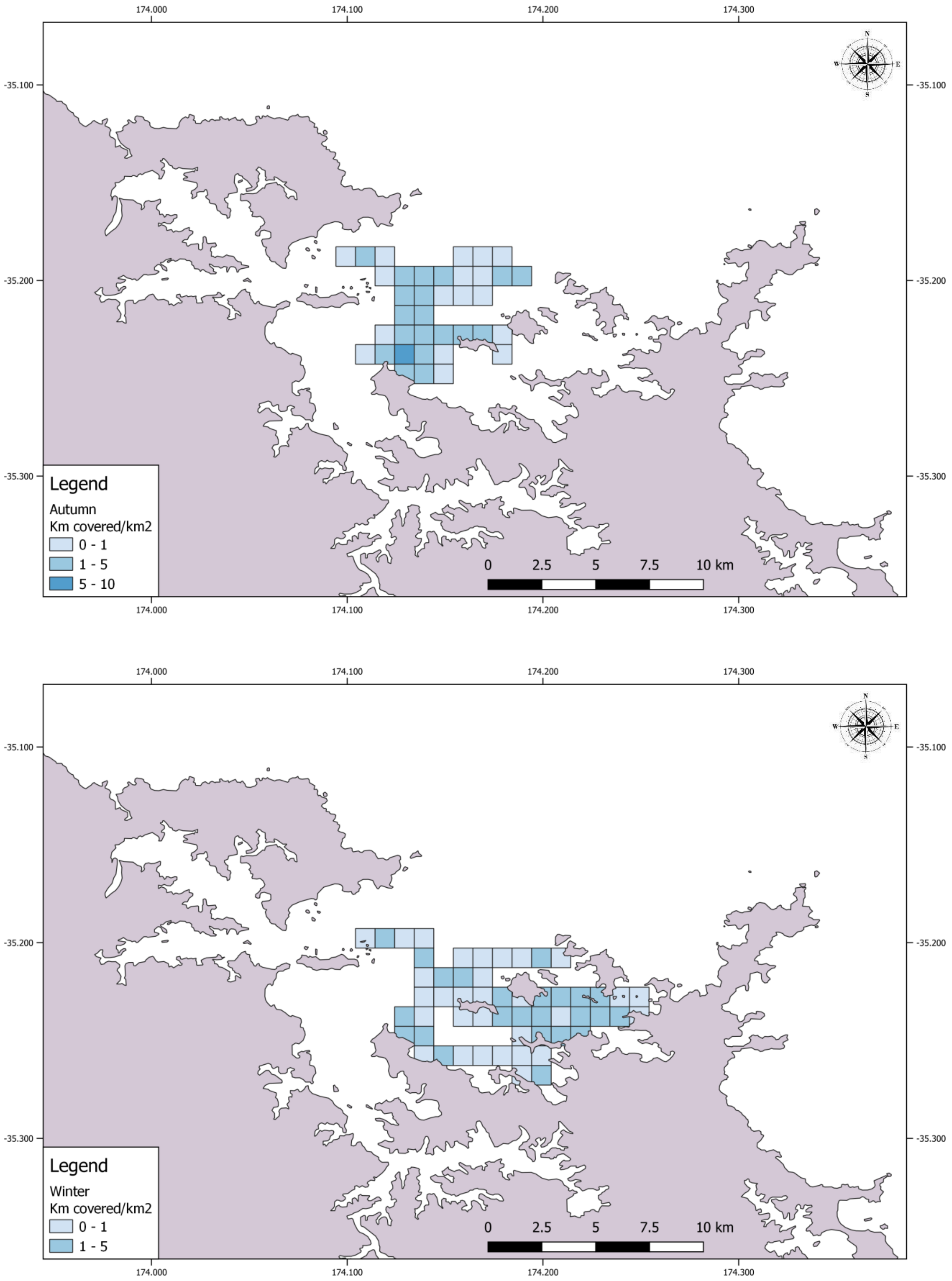
Zaeschmar, J. (2015) False Killer Whales (*Pseudorca Crassidens*) in New Zealand waters. *Unpublished Masters thesis, Massey University, Auckland, New Zealand*, 135pp.

Zaeschmar, J.; Tezanos-Pinto, G.; Dwyer, S.; Peters, C.; Berghan, J.; Donnelly, D.; Meissner, A.; Visser, I.; Weir, J.; Judkins, A. & Brough, T. (2020). Occurrence, site fidelity, and associations of oceanic common bottlenose dolphins (*Tursiops truncatus*) off northeastern New Zealand. *Marine Mammal Science*, *36*(4), pp.1180-1195.

Appendix 1

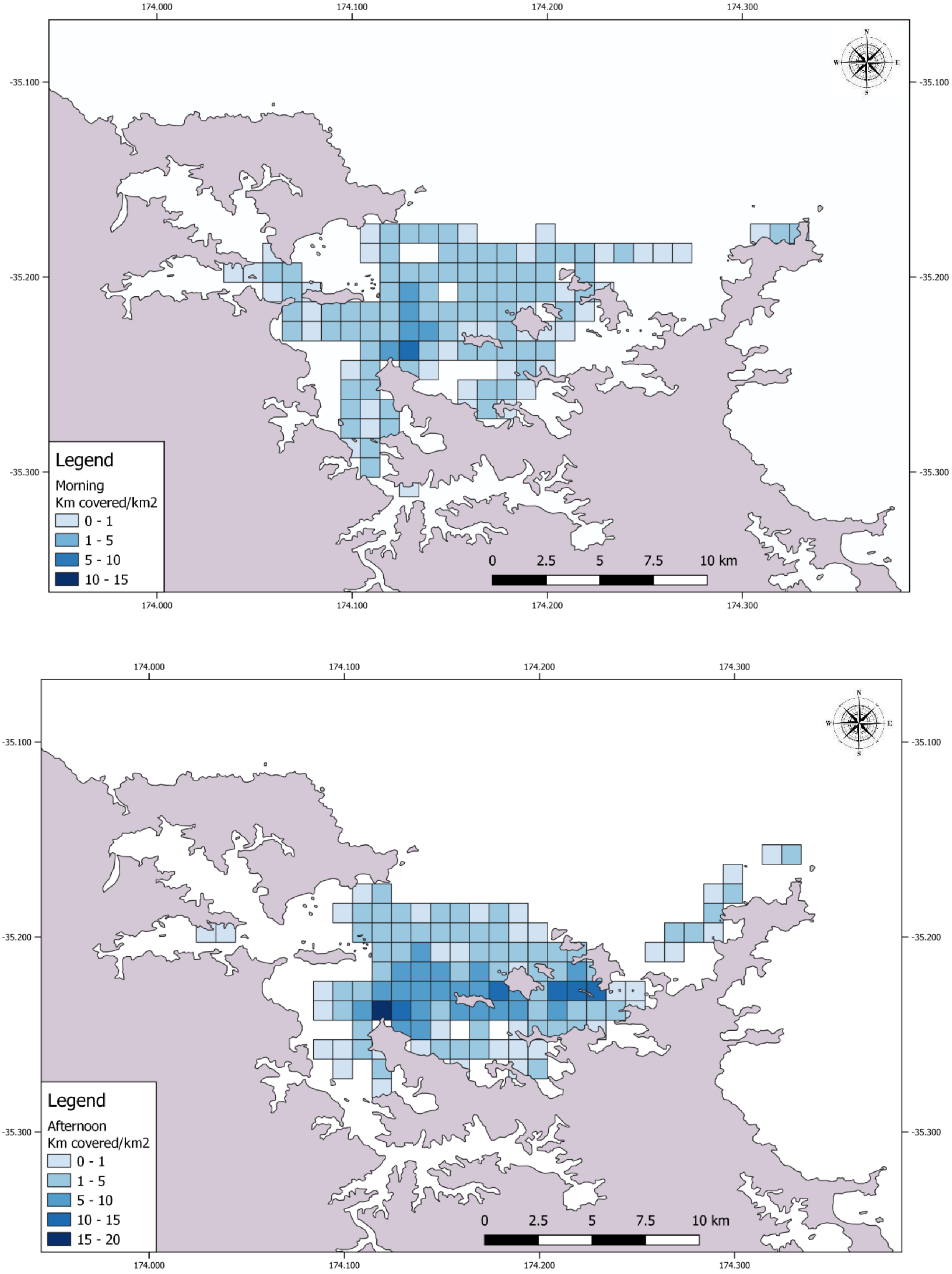

174.000
174.100
174.200
174.300
-35.100
-35.200
-35.300
N
W
E
S
Legend
Spring
Km covered/km2
0 - 1
1 - 5
5 - 10
0
2.5
5
7.5
10 km


174.000
174.100
174.200
174.300
-35.100
-35.200
-35.300
N
W
E
S
Legend
Summer
Km covered/km2
0 - 1
1 - 5
5 - 10
10 - 15
15 - 20
0
2.5
5
7.5
10 km



Research vessel coastal bottlenose dolphin encounter effort between June 2019 and November 2021 in Bay of Islands waters, New Zealand, coloured according to the proportion of kilometres (km) travelled while on encounter within each grid cell (1km x 1km), stratified by seasons.

Appendix 2



Research vessel coastal bottlenose dolphin encounter effort between June 2019 and November 2021 in Bay of Islands waters, New Zealand, coloured according to the proportion of kilometres (km) travelled while on encounter within each grid cell (1km x 1km), stratified by time of day.