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

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1. Executive summary

In the Bay of Islands (BOI), high vessel traffic has been shown to disrupt critical bottlenose dolphin behaviours (Peters & Stockin 2016, Peters 2018). In the context of continued local population decline and high calf mortality (Tezanos-Pinto 2013; Tezanos-Pinto et al., 2013; Peters & Stockin 2016), the risk of localised extinction of this *nationally endangered* species (Baker et al., 2016) has been highlighted (Peters & Stockin 2016). In July 2019, The Department of Conservation of New Zealand implemented changes in permitted vessels activities around marine mammals in the BOI, including encounter times reduced to 20 minutes, re-localisation of exclusion zones, and a ban on morning encounters and swim-with activities with bottlenose dolphins. This resulted in the need for a comparative study to 1) quantify the effects of the management changes and 2) re-evaluate the status quo of the bottlenose dolphin population.

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 March 2020, which resulted in a total of 3054 km of track surveyed whilst on effort (143hrs). Coastal bottlenose dolphins were the most encountered species in the area (n=36), with 81hrs of encounter effort. No bottlenose dolphins were encountered outside of Bay of Islands waters.

A total of 26 individuals were identified, representing a 91% decline from Constantine 2002 (n=278) and current annual decline rate of 23%. Resight rates were variable, with 16 individuals identified as frequent users and the other 10 as infrequent users. The frequent users were all part of one group, representing 95% (n=278) of resights and 94% (n=76hrs) of encounter effort.

Vessel effort was high compared to both national and international literature. Most vessels recorded entering within 300m of dolphins were private vessels (82%, n=381). Significant effects on bottlenose dolphin behavioural budget, bout length, transitions, and time to return to behaviour were detected in the presence of vessels. Overall, in the presence of vessels dolphins spent more time in energy expenditure behaviours (socialising), and less time in energy acquisition behaviour (resting, trends visible for foraging). Traveling was also reduced, as well as distribution when compared to previous studies, suggesting a reduced mobility over the dolphins' natural range.

A total of 5 calves were observed from October 2017 to March 2020 (27 months), compared to 12 calves over 29 months in Peters & Stockin 2016. The fate of 4 calves could be determined, resulting in a 50% calf mortality. All calves were observed in the frequent user group. No new calves were observed in the peak calving season (November to April, Peters & Stockin 2016) of 2019-2020.

The Bay of Islands bottlenose population is at higher risk than ever of localised extinction. The number of individuals is at the lowest recorded for this population in comparable assessments and with a greater decline than any other in New Zealand. The usage patterns and lack of sightings in areas outside of the Bay of Islands shows the current bottlenose dolphin tourism industry is 94% (n=76hrs) dependent on one group of 16 identifiable individuals, which if displaced could bring local extinction in a short timeframe. Combined with the high calf mortality continuously reported in the area, and the lack of new calves altogether in the last season, those results raise concerns for the viability of the overall North-East coast population.

Strong management action including enforceable regulations over all vessel types and an associated conservation education program is recommended. A Marine Mammal Sanctuary is considered an appropriate tool to establish locally specific rules and regulations.

2. Introduction

Worldwide, the use of marine mammals as a resource has shifted from hunting to viewing. While whale and dolphin watching is presumably a more sustainable exploitation strategy, it comes with its caveats, particularly for behaviour disturbances and displacement from habitat for targeted species (New et al., 2020). Those effects can occur from both commercial and private activities (Peters & Stockin 2016, Peters 2018)

In New Zealand, the *nationally endangered* bottlenose dolphin (*Tursiops truncatus,* referred to hereafter as TT) (Baker et al., 2016) inhabits three discontinuous coastal regions, forming genetically distinct populations (Tezanos-Pinto et al., 2009). Bottlenose dolphin research in Fiordland has 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). For the North-East coast population, the local Bay of Islands dolphins have shown similar changes, with reductions in resting in the presence of permitted vessels (Constantine 2002). Further concerns were raised by Tezanos-Pinto (2009; et al., 2015) with the detection of a population decline and high calf mortality. Those concerns were by Peters & Stockin 2016, with a further decline in identifiable individuals, disruption in critical behaviours by all vessel types and increased sensitisation to vessel interactions.

Following recommendations from Peters & Stockin 2016, population management changes (July 2019) in permitted activities around bottlenose dolphins were put in place. These included a reduction in vessel effort around bottlenose dolphins to one 20 minutes encounter in the afternoon only, the ban of commercial swim-with activities and shifting of no-interaction zones to more relevant areas.

The Department of Conservation of New Zealand (DOC) contracted this research to obtain sound scientific evidence on the effectiveness of such management decisions and an update on the status of the bottlenose dolphin population.

3. Objectives

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

1. Provide an update in the number of identifiable individuals and usage patterns in far North waters. Provide the range extent of bottlenose dolphins in Far North waters.
2. Quantify post management changes variation in vessel effort around bottlenose dolphins in far North waters.
3. Determine the potential effects of interacting with bottlenose dolphins as currently permitted in far North waters. This includes describing behavioural responses of dolphin groups to allow comparison with Peters & Stockin 2016.
4. Provide an update in bottlenose dolphin calf survival in far North waters.
5. Integrate present and historical research results to produce statements and recommendations regarding existing and future anthropogenic activities around bottlenose dolphins in far North waters.

More explicitly:

1. What is the current level of vessel effort (permitted, commercial (un-permitted) and private) around bottlenose dolphins? Does the current level of effort correlate with any significant effects on dolphin behaviour? How does the current level of effort differ from levels identified in Peters & Stockin 2016?
2. What are the short-term behavioural responses of dolphins in relation to viewing? Are these activities significant for the population of the BOI? Should these activities be reduced, remain at current levels, or could the level of activity be increased? Do behavioural responses vary between what is currently and what was previously reported?
3. How many calves were observed in Far North waters? What is the current calf mortality rate? How does this rate differ from previous studies? Are there any correlations between calf growth and calf mortality in Far North waters?
4. What further conditions (if any) could be considered to minimise any identified effects? These conditions should address the following questions:
    a) What is the occupancy patterns of bottlenose dolphins? Are the location of no-interaction zones put in place in July 2019 still relevant? Are there other areas that should be considered?
    b) Are there any conditions that need review since previous studies? Is the limit on the length of time each permitted operator spends with the dolphins for viewing and swimming, once an interaction is established, still appropriate?
5. What is the potential long-term significance of the current level of tourism activities on bottlenose dolphins in the BOI?
6. Once questions 1, 2, 3 and 4 have been answered: what are the implications of current vessel effort for the bottlenose dolphin population in the Bay of Islands, 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 35.86° S, Longitude 173.45° to 174.70° E), on the North East coast of the North Island, New Zealand (Figure 1), within inshore limits, between June 2019 and March 2020. 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 1) and random survey. The systematic zigzag transects were designed using the software Distance 7 to cover the complex zones of the study area evenly.

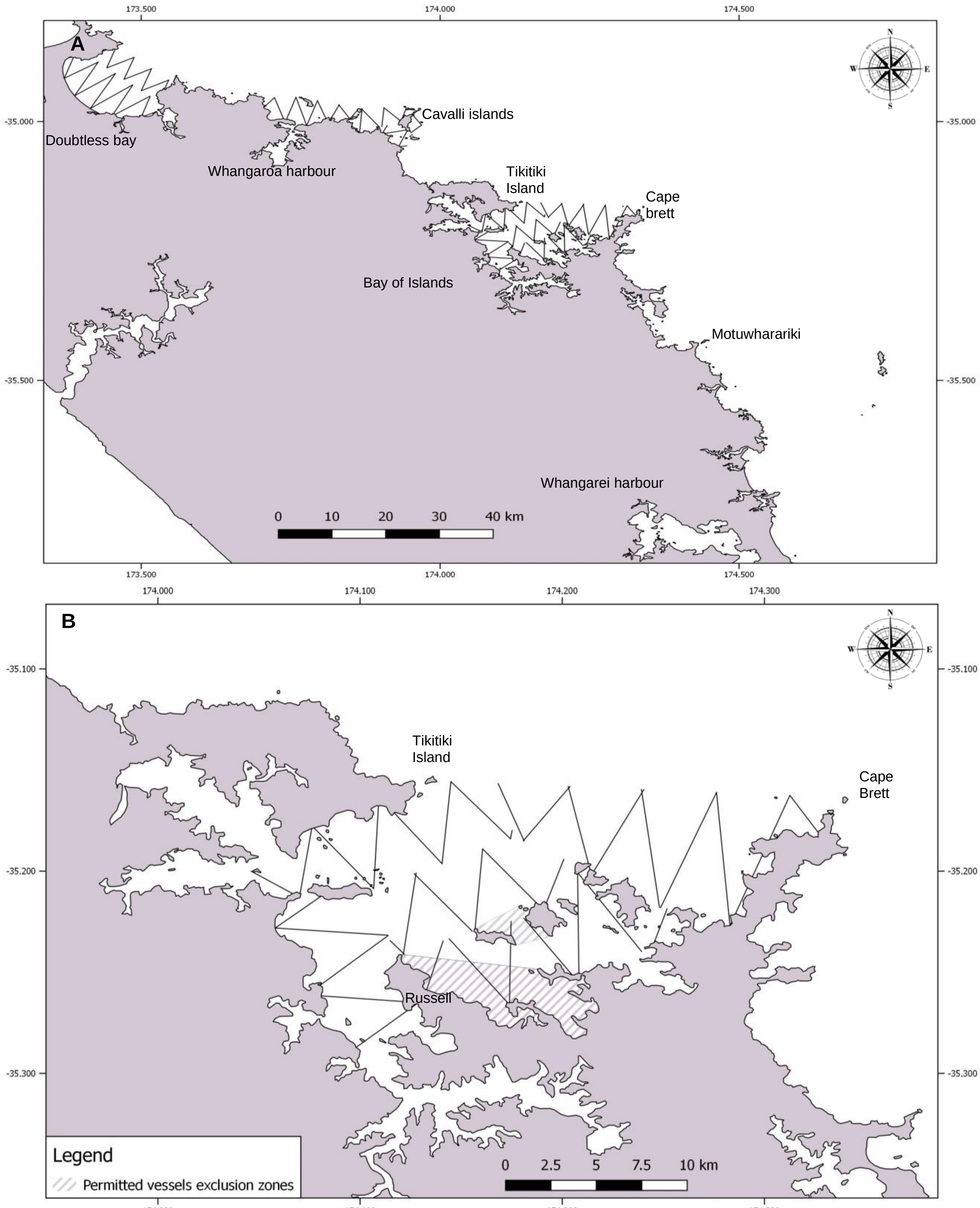


Figure 1: Entire study area (A) and Bay of Islands only (B) and transect lines, New Zealand. The arrows indicate operational limits for permitted vessels. The dashed zones represent the current exclusion zones for permitted vessels.

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 2). 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 cover all areas evenly (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 2: TriOceans research vessels RV Wavelength and RV Kekeno (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 approximately 10-15 knots (average 13 knots, Constantine 2002, 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, vessel behaviour 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; b). 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 Mammal Protection Regulations (MMPR) 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 (Zaeschmar 2015; Visser et al. 2010; Peters 2018, Zaeschmar et al., *in press*).

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 (Peters & Stockin 2016; Stockin et al 2009a). Group sizes were recorded using the absolute minimum, absolute maximum and best estimate for the number of individuals in the group (Peters & Stockin 2016, Dwyer et al 2014)
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 1990b, 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 behavior 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 photograph randomly all individuals present 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 half the group was involved in. If an equal percentage of the group were 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 when there is an intention to view a marine mammal (Regulation 18(1)).

The distance was estimated by eye by trained observers, with daily checks of estimation using laser range finders on fixed objects/slow moving vessels or chart plotter data.

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

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 appear 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

Vessel traffic type	Definition
Absence	Research vessel present with all other vessel types absent 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)
Presence - Permitted	At least one Permitted vessel present within 300m. Other vessels also potentially present
Presence - Unpermitted	No permitted vessels present, but other vessels present (commercial not permitted or private) within 300m

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

Behavioural events were defined as recognisable instantaneous behaviours (see Appendix 1 for full definitions), and were additionally recorded every three minutes, if occurring in that instant.

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

4.1.4 Calf survival

Calf presence in a group was recorded as per section 2.1.2. Observations and photographs of the identified mother (individual in close association) were taken for each calf observed. The calf survival dataset encompasses data collected from October 2017 to March 2020 during 3 previous TriOceans DOC contracts (Bay of Islands Photo-identification 2017, Bay of Islands advocacy 2018, and Bay of Islands photogrammetry 2019-2020 (NNI-O-109)). Photogrammetry data was collected from December 2018 onwards.

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 3). An on-off switch allowed to disable the system to improve both human and animal safety (van Auswegen et al., 2019).

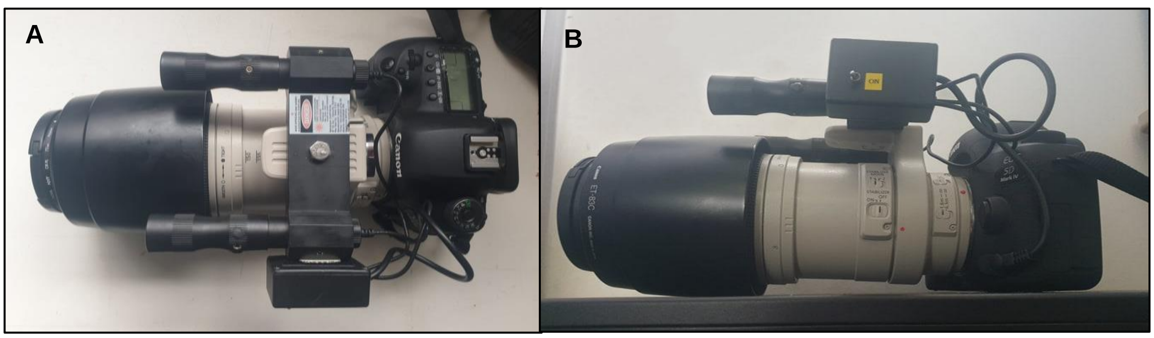


Figure 3: Laser stereo-photogrammetry rig with A) Top view and B) Side view

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 dolphin were within 5-25m of the vessel, and 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 2019).

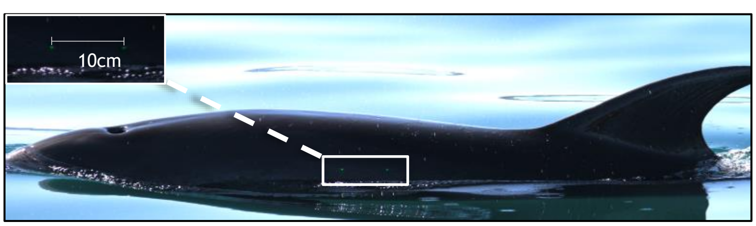


Figure 4: Example of a bottlenose dolphin photograph with calibrated laser dots visible on the flank (Photograph: T. Guerin)

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 was gridded as km effort covered / km2 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 dorsal fin, with secondary features such as scarring (including rake marks due to the short length of study relative to mark loss rate) and additionally fin shape (Dwyer et al., 2014; 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 the BoI catalogue. Before adding a new individual or resighting of a previously identified individual in the 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 was 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 discarded. To allow for full mark-recapture analysis and allow comparison with previous studies, individuals resighted <3 times would normally be removed from analysis. However, this study does not include any population estimate. As such, analysis was also ran including individuals with <3 resights to provide a full record of BND encountered during the study period.

User type was based on sighting frequency and grouped into two categories: frequent users 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., frequency of sightings). The point at which the frequency of observed sightings 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.

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 half 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 at 3 different levels:

- Diurnal (morning vs afternoon). To match permitted vessels regulations (no bottlenose encounter before 12:00PM), morning was defined as before 12:00PM and afternoon as after 12:00PM.
- Absence vs Presence (as described in Table 3)
- Permitted vs Unpermitted (as described in Table 3)

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 (Meissner et al., 2015, Stockin *et al*., 2008). No assumption is made that the research vessel had no effect on dolphin behaviour. To minimize 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.

4.2.4 Probability matrices

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 absence P_{ij} to its presence counterpart) 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 (Lundquist et al., 2012; Lusseau 2003):

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

where P_{ii} is the probability of transitioning from state *i* to state *i*, i.e. remaining in the same state.

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

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

Where n_i is the number of times the behavioural state *i* was counted as the preceding behaviour. Pairs (each absence $\bar{t}_{ii}$ 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:

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

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 daylights variations across the year, using a time of day index (Lundquist 2011). Both datasets of vessel traffic recorded every 3min and individual vessel type entering within 300m of the dolphins were investigated.

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. 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). Calf mortality was calculated as the proportion of calves assumed to not have survived, excluding calves of unknown status.

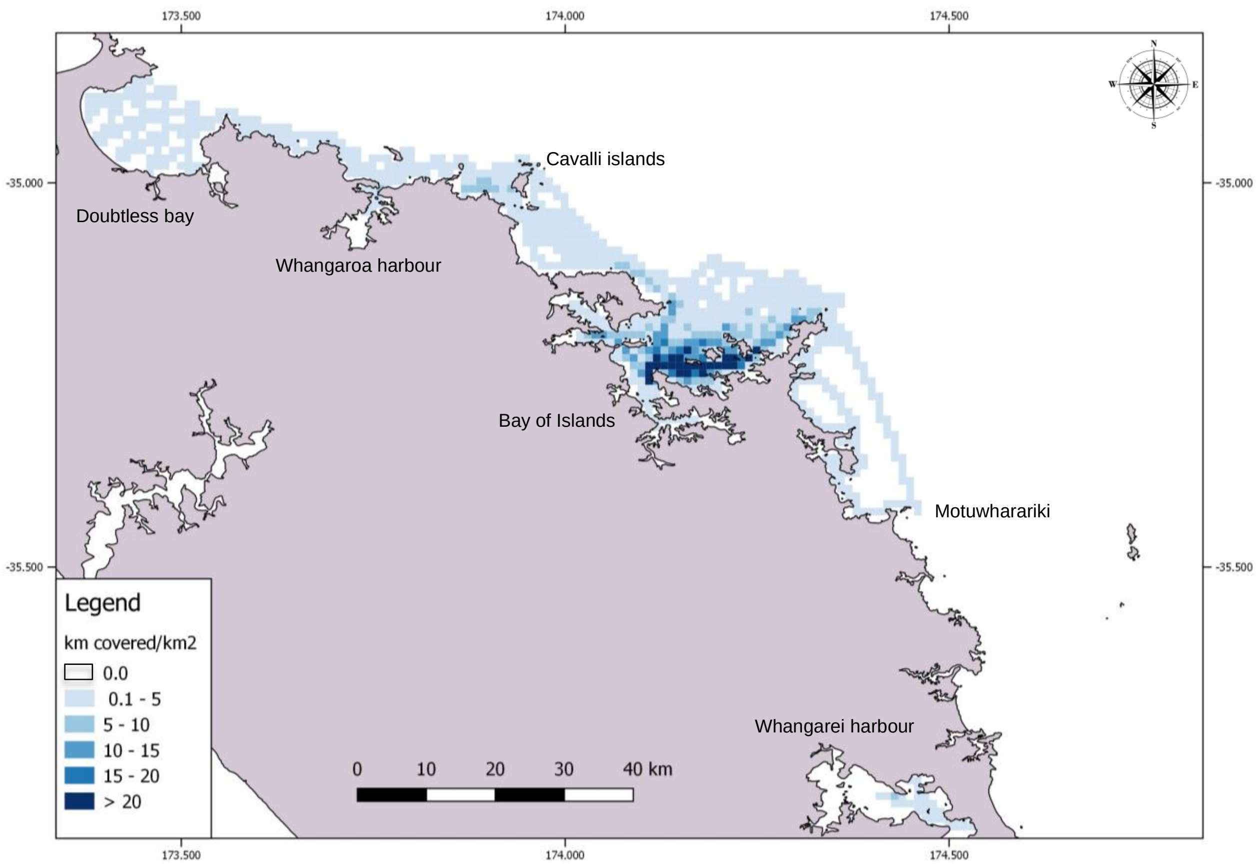
All photogrammetry-based measurements were made using the free image processing software ImageJ. To reduce horizontal angle error, only photos of very high quality, considering focus, clear display of laser dots, parallel positioning of the dolphin and visibility of the dorsal fin and blowhole were selected (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 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 March 2020 comprised 61 vessel-based surveys. A total of 3054km of track were surveyed whilst on effort (143hrs) (Figure 5). 70% (n=100hrs) of survey effort occurred within Bay of Islands waters. One area was not covered (Motuwharariki to Whangarei harbour) due to the interruption of data collection (New Zealand Covid-19 quarantine,



25th March 2020).

Figure 5: Research vessels survey effort between June 2019 and March 2020 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 Autumn due to interruption of data collection (New Zealand Covid-19 quarantine, 25th March 2020).

Table 4: Surveys per season between June 2019 and March 2020, in Far North waters, New Zealand.

Seasons	**Winter**	**Spring**	**Summer**	**Autumn**
No of surveys	8	19	32	2

5.2 Sightings

Out of a total of 66 marine mammal encounters, bottlenose dolphins were the most recorded marine mammal species within the study area (60.6%, n=40), with almost all sightings being of the coastal ecotype (90%, n=36) and the remaining 10% (n= 4) being of the oceanic ecotype (Table 5).
The remaining sightings were of New Zealand fur seals (*Arctocephalus forsteri*) (16.7%, n=11), common dolphins (*Delphinus sp.*) (7.6%, n=5), killer whales (*Orcinus orca*) (4.5%, n=3), false killer whales (*Pseudorca crassidens*, referred to hereafter as Pseudorca) (3.0%, n=2), Bryde's whales (*Balaneoptera edeni*) (3.0%, n=2), humpback whales (*Megaptera novangliae*) (3.0%, n=2) and pilot whales (*Glopbicephalia melas*) (1.5%, 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 March 2020, in Far North waters, New Zealand. (SE=Standard Error).

Species	N	Group size		
		Mean	SE	Range
Coastal TT	36	17.9	0.9	1-20
Fur seals	11	3.8	1.0	1-12
Common dolphin	5	26	2.5	20-30
Oceanic TT	4	21.3	13.6	2-60
Orca	3	10	2.0	6-12
Pseudorca	2	55	15.0	40-70
Brydes whale	2	1.5	0.5	1-2
Humpback	2	1	0.0	1
Pilot whale	1	30	NA	NA

Depth and sea surface temperature mean, standard error and range for each species are presented in Table 6.

Table 6: Mean sea surface temperature (SST) and water Depth (m) of marine mammal encounters, between June 2019 and March 2020, in Far North waters, New Zealand. (SE=Standard Error).

Species	N	Depth (m)			SST (°C)		
		Mean	SE	Range	Mean	SE	Range
Coastal TT	36	22.8	1.7	5-45	19.9	0.4	15.2-23.7
Fur seals	11	30.2	NA	NA	16.4	0.4	14.5-17.6
Common dolphin	5	45.8	5.4	29.7-62.4	18.2	0.9	15.1 - 20.7
Oceanic TT	4	53.1	9.5	34.1-78	19.8	1.2	17.4-22
Orca	3	24.1	14.1	2.8-50.7	18.4	0.9	17.4-20.2
Pseudorca	2	50.1	6.9	43.2-57	21.8	0.2	21.6-22
Brydes whale	2	24.7	4.4	20.3-29	17.9	0.1	17.8-18
Humpback	2	22.5	1.1	21.4-23.5	17.75	0.05	17.7-17.8
Pilot whale	1	34.1	NA	NA	18.1	NA	NA

Marine mammals were observed across the whole study area, in all seasons (Figure 6A). Most sightings occurred in the Bay of Islands (Figure 6B).

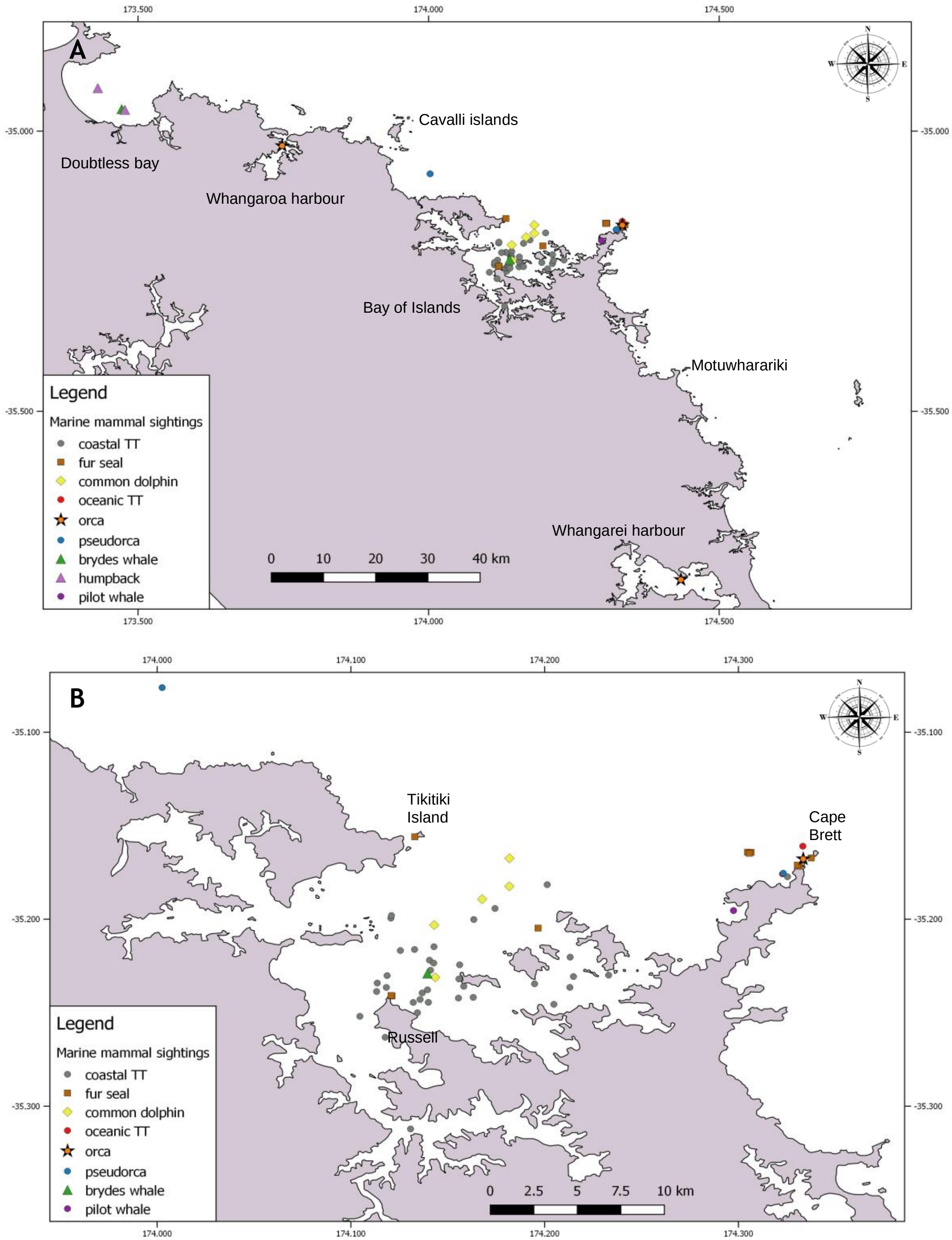


Figure 6: Marine mammal sightings while on survey between June 2019 and March 2020 in A) Far North waters and B) zoomed in on Bay of Islands waters, New Zealand.

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 81hrs (306 km) (Figure 7). No coastal bottlenose dolphins were observed outside of Bay of Islands waters.

Bottlenose dolphins were mostly observed in the inner Bay of Islands, with high densities areas around Russell and the Eastern islands (Figure 7). Dolphins were observed in high density in the current permitted vessels exclusion zones (represented in Figure 1).

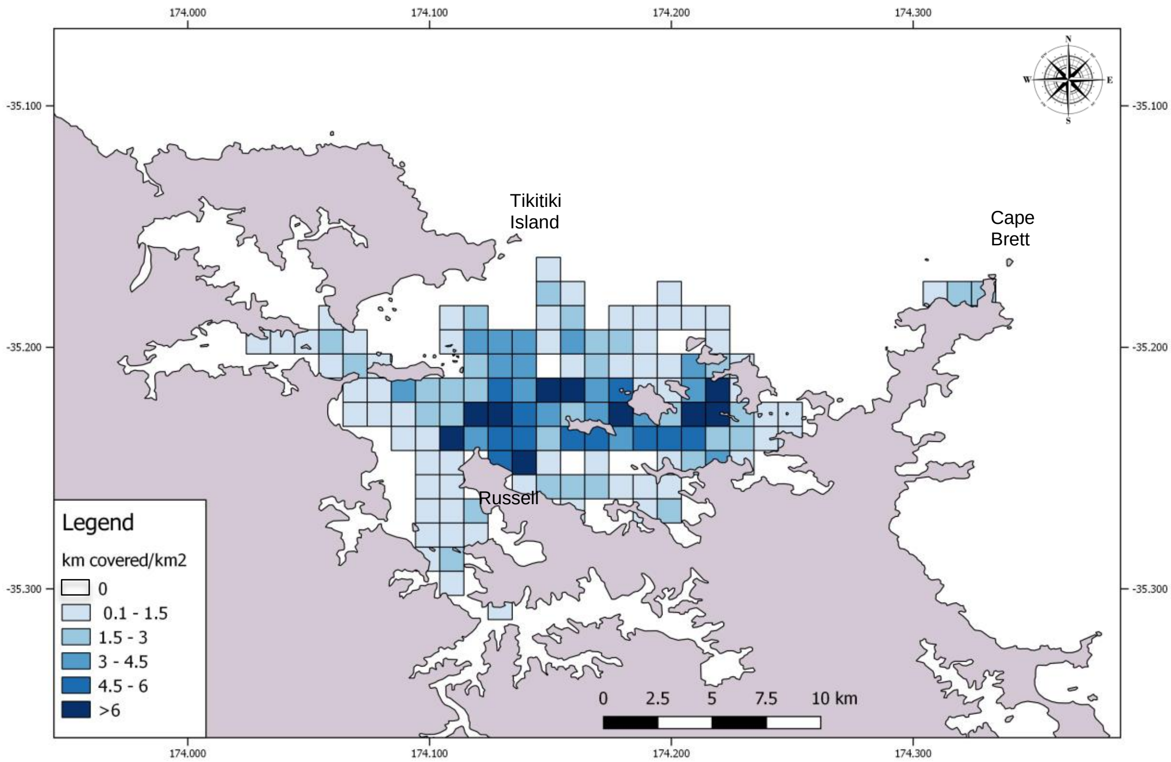


Figure 7: Research vessels coastal bottlenose dolphin encounter effort between June 2019 and March 2020 in Far North waters (zoomed in to range extent), New Zealand, coloured according to the proportion of kilometres (km) travelled while on survey within each grid cell (1km x 1km).

5.4 Group composition

Out of the 36 sightings of coastal TT groups, 2 group categories were recorded (Figure 8). The predominant category recorded was Adult-Juvenile-Calf (89%, n=32), and the remaining 11% (n=4) were composed of Adult only. Mean group size overall was 17.9 (SE=0.9, n=36).

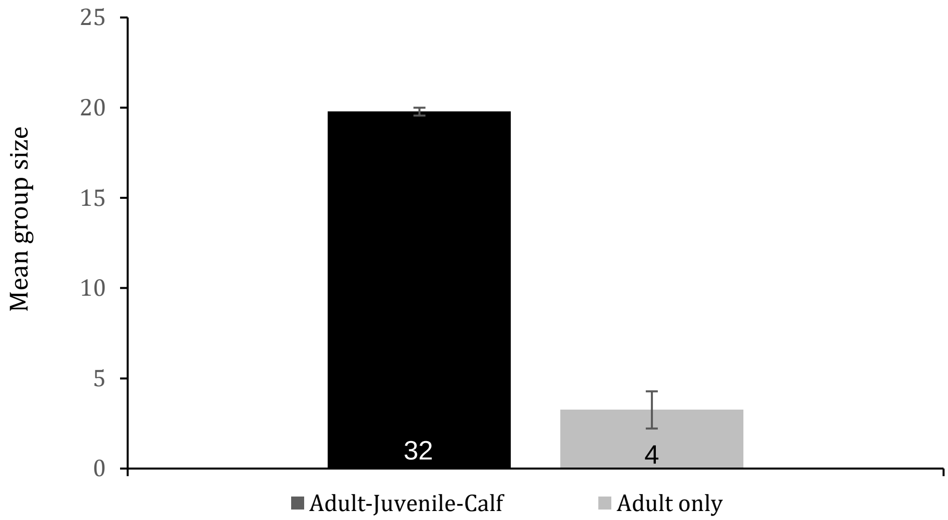


Figure 8: Mean group size vs Group composition between June 2020 and March 2020, in Far North waters, New Zealand. N numbers are displayed on the bars. Error bars represent standard error.

Data were further categorised to represent the number of sightings for each group size and composition recorded (Figure 9), showing a large majority of Adult-Juvenile-Calf group of 20 individuals (86%). The sighting of a group of 13 relates to 100% of the encounter effort visible around the Cape Brett area (Figure 7).

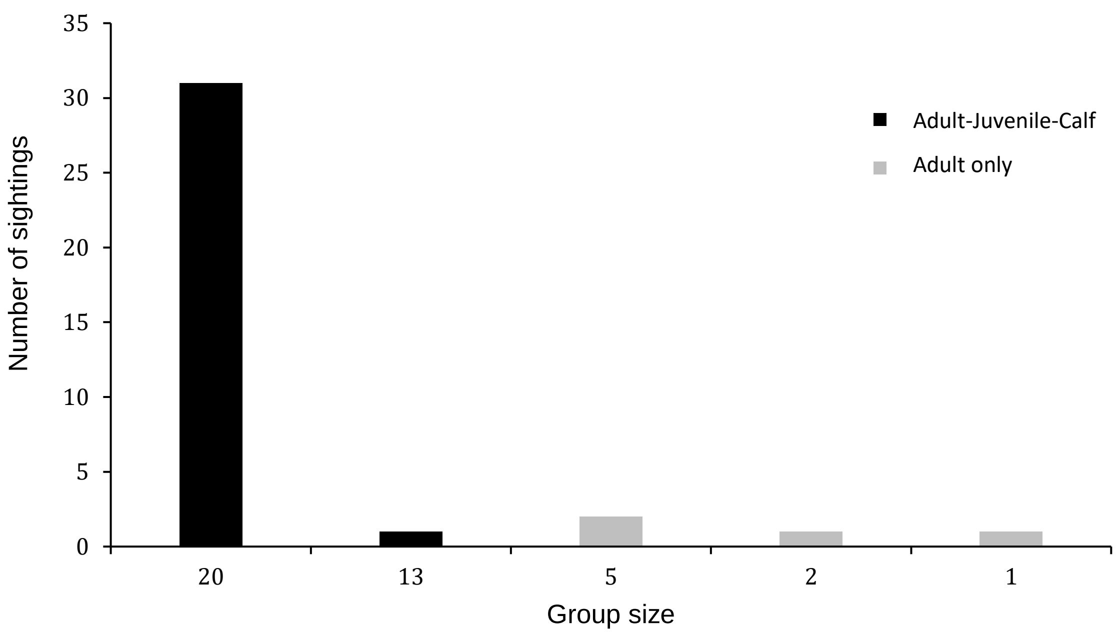


Figure 9: Number of sightings vs group size for both group classes recorded between June 2019 and March 2020, in Far North waters, New Zealand.

5.5 Unique individuals and site fidelity

Coastal bottlenose dolphins were encountered in 80% of survey months (n=8) over 36 encounters. Whole group Photo-ID was taken for each encounter, resulting in 15,571 digital photographs taken. 523 fin photos were selected after initial processing. 15% (n=77) photos were removed off that number after final quality check, resulting in 85% (n=446) photos being used in final analysis.

A total of 26 bottlenose dolphins were identified. This included 17 individuals matched to the Bay of Islands bottlenose dolphin catalogue, and 9 new additions to the catalogue. Of the 26 dolphins identified, 59% (n=16) were sighted more than seven times. The remaining 11 dolphins (41% of total) were less than three times. Please note, those individuals would not meet confidence criteria for mark-recapture assessment (this assessment is not presented here, and individuals with less than three sightings have been included). In this study's timeframe, 6 surveys out of 61 brought new individual identifications. A minimum of 14 dolphins was identified on any month with encounter effort. Survey and encounter effort had little influence on the number of dolphins identified (Table 7).

Table 7: Summary of survey/encounter effort and number of identifiable dolphins sighted per month between June 2019 and March 2020 in Far North waters, New Zealand.

	Jun -19	**Jul -19**	**Aug -19**	**Sep -19**	**Oct -19**	**Nov -19**	**Dec -19**	**Jan -20**	**Feb -20**	**Mar -20**
Number of surveys	2	4	2	2	4	13	7	13	12	2
Survey effort (km)	57	135	88	88	94	490	237	1024	782	61
Encounter effort (hr)	3	3	2	0	0	41	5	11	14	2
No of encounters	1	4	1	0	0	10	2	6	9	3
Dolphins sighted	15	16	14	0	0	25	14	16	16	15

The discovery curve (Figure 10) showed a plateau in the cumulative numbers of individuals from the first month of the study. An increase in November led to a second plateau until the end of the study.

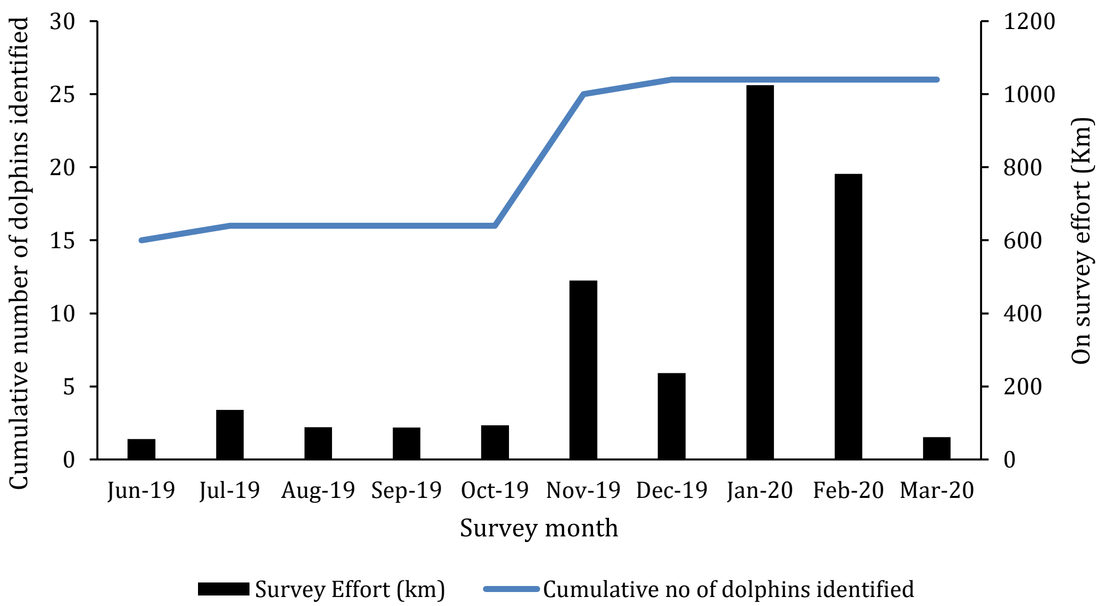


Figure 10: Discovery curve of bottlenose dolphins between June 2019 and March 2020 within Far North waters, New Zealand, with cumulative number of individuals photo-identified per survey day. Bars represent the number of kilometers (km) spent on effort.

5.6 Resight rates

Between June 2019 and March 2020, the 26 individuals categorised as unique were matched or added to the Far North waters bottlenose dolphin catalogue. The highest number of individually identified dolphins per encounter was 16 dolphins (range=0-16; mean=10.8; SE=1.8). From June 2019 to March 2020, a total of 292 resights were made.

The resight rate of those 26 individuals varied during the study period (range 1 – 8, mean= 3.25). Patterns of use significantly differed from the Poisson distribution (Figure 11) (chi-square goodness-of-fit test, pvalue <0.001, df=7). The point at which the monthly frequency of observed sightings exceeded expectation (i.e., ≥ 7) was considered to indicate frequent users of the BOI. Infrequent users were arbitrarily defined as the individuals with ≤ 1 for the study period (all dolphins were observed either ≤ 1 or ≥ 7 months during the study period).

Frequent users formed the majority group (62%, n=16), while infrequent users represented another 38% (n=10). No occasional visitors were recorded. Individuals categorised as Frequent users represented 95% (n=278) of all resights.

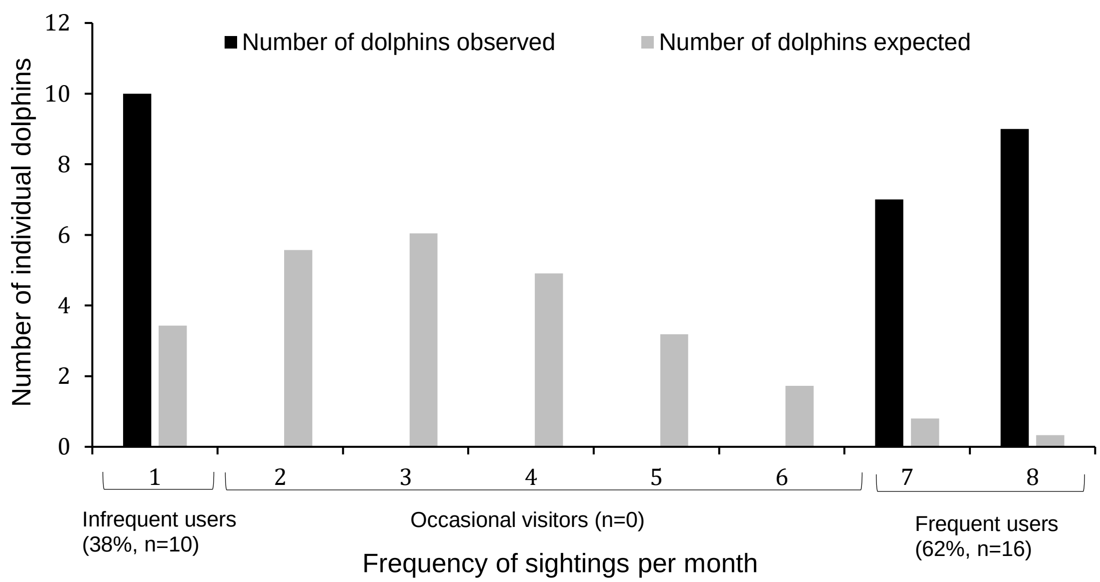


Figure 11: Observed (black) vs. expected (grey) Poisson distribution of number of times individual bottlenose dolphins were identified between June 2019 and March 2020, in Far North waters, New Zealand. The proportion of different user types (infrequent users, occasional visitors and frequent users) are also indicated.

Fusion-fission population structure was not observed with the 16 frequent users consistently identified in the same group (86% of sightings, section 5.4) with calves and juveniles, accounting for 94% (n=76hrs) of encounter effort. Of the 10 infrequent users, 50% (n=5) were seen in a group containing calves and juveniles (one sighting), and 50% (n=5) were seen in an adult only group (2 sightings, in the same month).

5.7 Behavioural observations

A total of 1086 behavioural observations of coastal bottlenose dolphins were recorded within Far North waters between June 2019 and March 2020. Number of observations and transitions after data processing into 1st order Markov chains (section 2.2.4) is presented in Table 8. All observations occurred within Bay of Islands waters.

Table 8: Count of observed behavioural observations and transitions by time of day and vessel traffic types between June 2019 and March 2020 in Far North waters, New Zealand.

	Behavioural observations	Total	Behavioural transitions	Total
Morning	336	1045	321	1004
Afternoon	709		683	
Absence	437	748	401	684
Presence	311		283	
Permitted	108	277	95	251
Unpermitted	169		156	

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 March 2020 in Far North waters, New Zealand.

Behavioural state	Time of day			Absence vs Presence			Vessel traffic type		
	Morning	Afternoon	Total	Absence	Presence	Total	Permitted	Unpermitted	Total
Behavioural observations									
Travelling	186	315	501	245	78	323	30	34	64
Foraging	46	83	129	68	39	107	15	24	39
Socialising	55	235	290	74	150	224	50	84	134
Milling	12	27	39	2	29	31	5	23	28
Resting	33	42	75	41	14	55	8	3	11
Diving	4	7	11	7	1	8	0	1	1
Total	336	709	1045	437	311	748	108	169	277

5.7.1 Spatial distribution of behaviours

All 6 behaviours were recorded across Bay of Islands waters (Figures 12, 13 and 14), with no clear spatial distribution pattern detected.

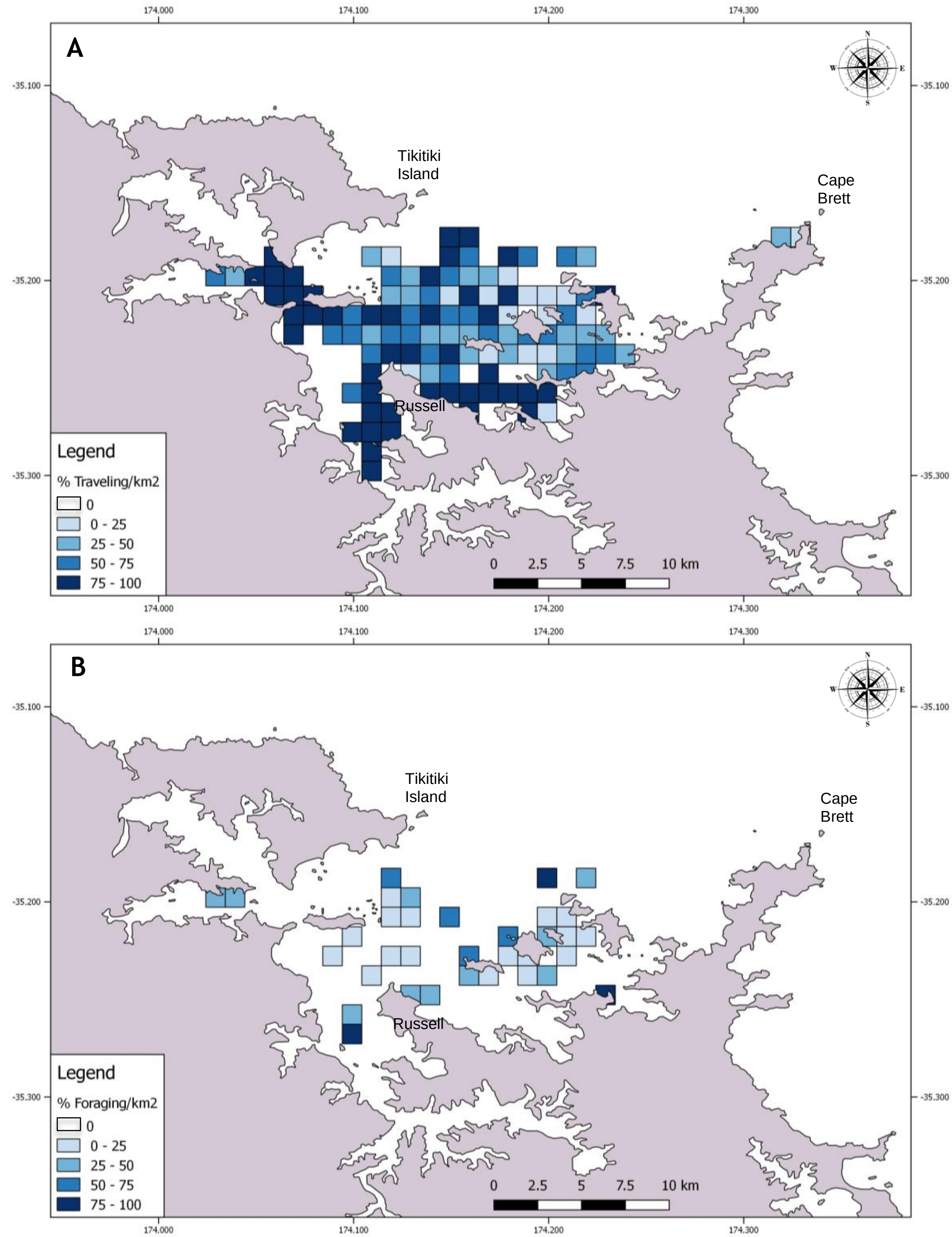


Figure 12: Bottlenose dolphin on encounter effort categorised by behaviour between June 2019 and March 2020, in Far North waters (zoomed in to range extent), New Zealand, with A) Traveling and B) Foraging behaviour gridded as proportion of all behaviours, coloured according to the proportion per kilometer (km) within each grid cell (1km x 1km)

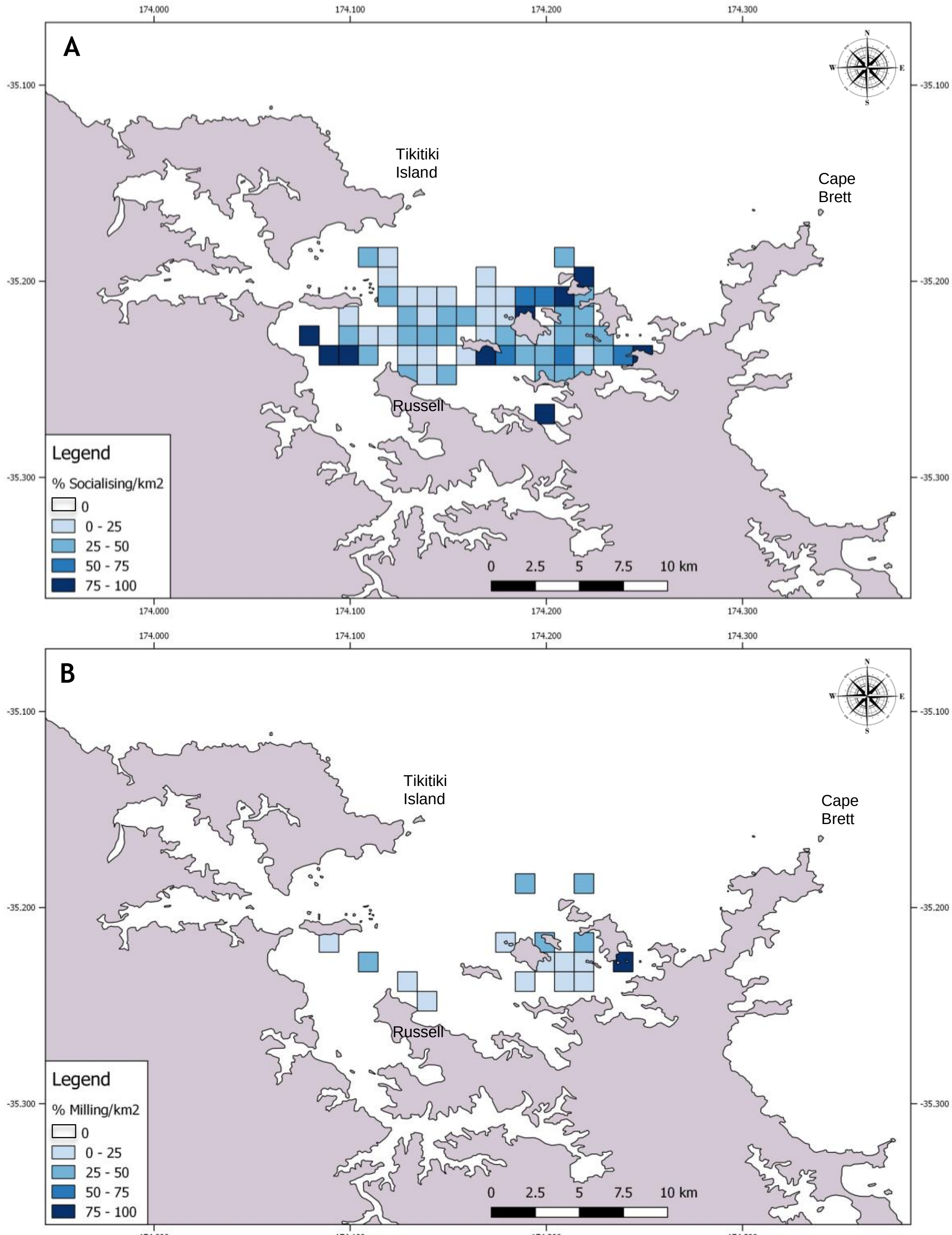


Figure 13: Bottlenose dolphin on encounter effort categorised by behaviour between June 2019 and March 2020, in Far North waters (zoomed in to range extent), New Zealand, with A) Socialising and B) Milling behaviour gridded as proportion of all behaviours, coloured according to the proportion per kilometer (km) within each grid cell (1km x 1km)

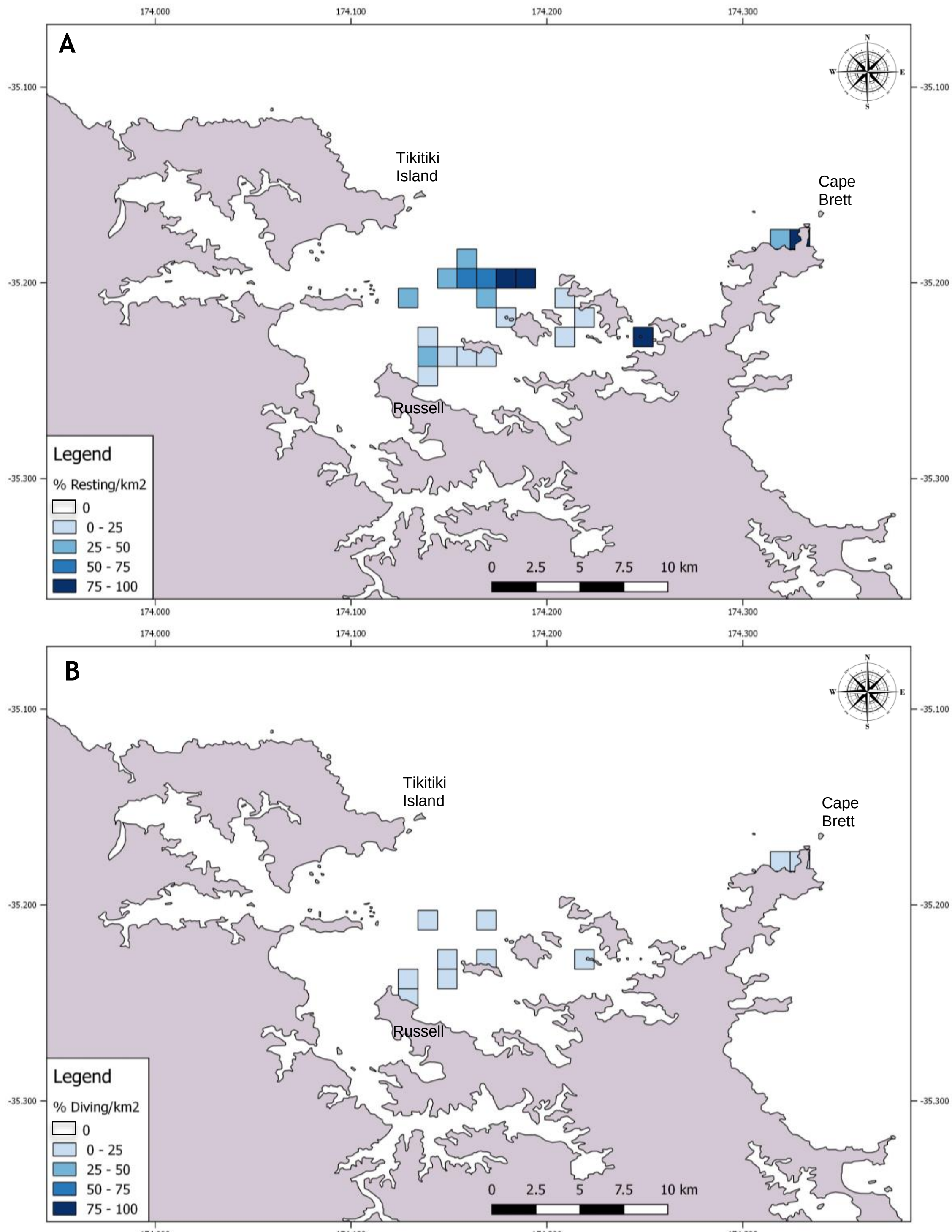


Figure 14: Bottlenose dolphin on encounter effort categorised by behaviour between June 2019 and March 2020, in Far North waters (zoomed in to range extent), New Zealand, with A) Resting and B) Diving behaviour gridded as proportion of all behaviours, coloured according to the proportion per kilometer (km) within each grid cell (1km x 1km)

5.7.2 Diurnal variation in behaviour
5.7.2.1 Behavioural budget

Time of day (Figure 15) had a significant effect (z-test $p<0.05$) on the behavioural budget of bottlenose dolphins. Resting ($p=0.02$) and traveling ($p<0.001$) budgets showed a significant decrease in the afternoon of 40% and 20%, respectively. Socialising showed a significant ($p=<0.001$) increase in the afternoon of 102%. Other behavioural states did not show clear trends.

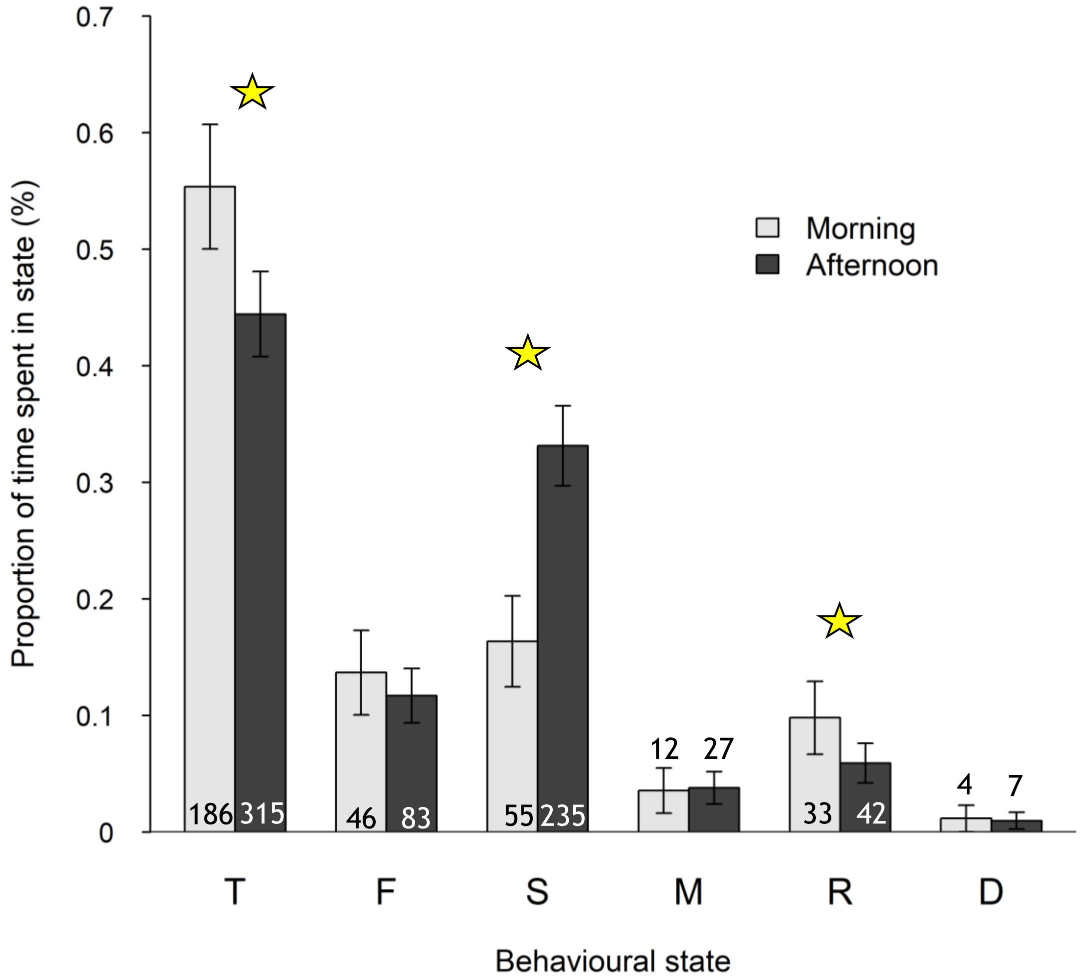


Figure 15: Overall behavioural budget of each behavioural state for bottlenose dolphins observed from research vessel between June 2019 and March 2020 in Far North waters, New Zealand, by time of day (before and after 12:00PM). Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant behaviour budget 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.

5.7.2.1 Mean behavioural bout length

Time of day had a significant effect on the behavioural bout length of socialising (p=0.01), with an increase of 55% in the afternoon (Figure 16). While other behavioural states did not show significant differences, strong trends were present.

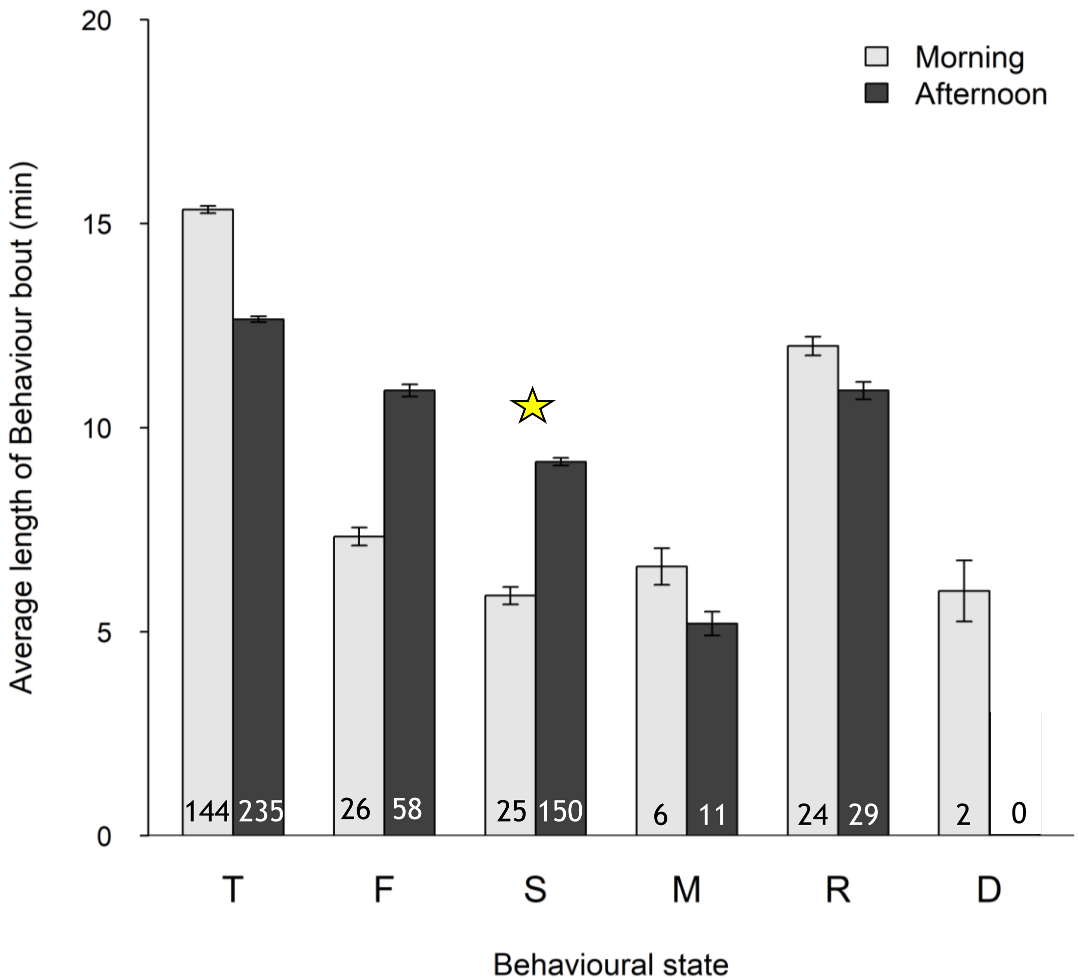


Figure 16: Mean bout length of each behavioural state for bottlenose dolphins observed from research vessel between June 2019 and March 2020 in Far North waters, New Zealand, by time of day (before and after 12:00PM). Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. No statistical difference was detected (z-test, a=0.05) between morning and afternoon. 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

Overall, dolphins spent significantly less time travelling ($p<0.001$) and resting ($p=0.011$) in the presence of vessels within 300 m of the dolphin group, which decreased by 57% and 53%, respectively (Figure 17). However, dolphins spent more time milling ($p<0.001$) and socialising ($p<0.001$) in the presence of vessels, which increased by 1856% and 181%, respectively (note: n numbers for milling are low). Other behaviours did not show clear trends.

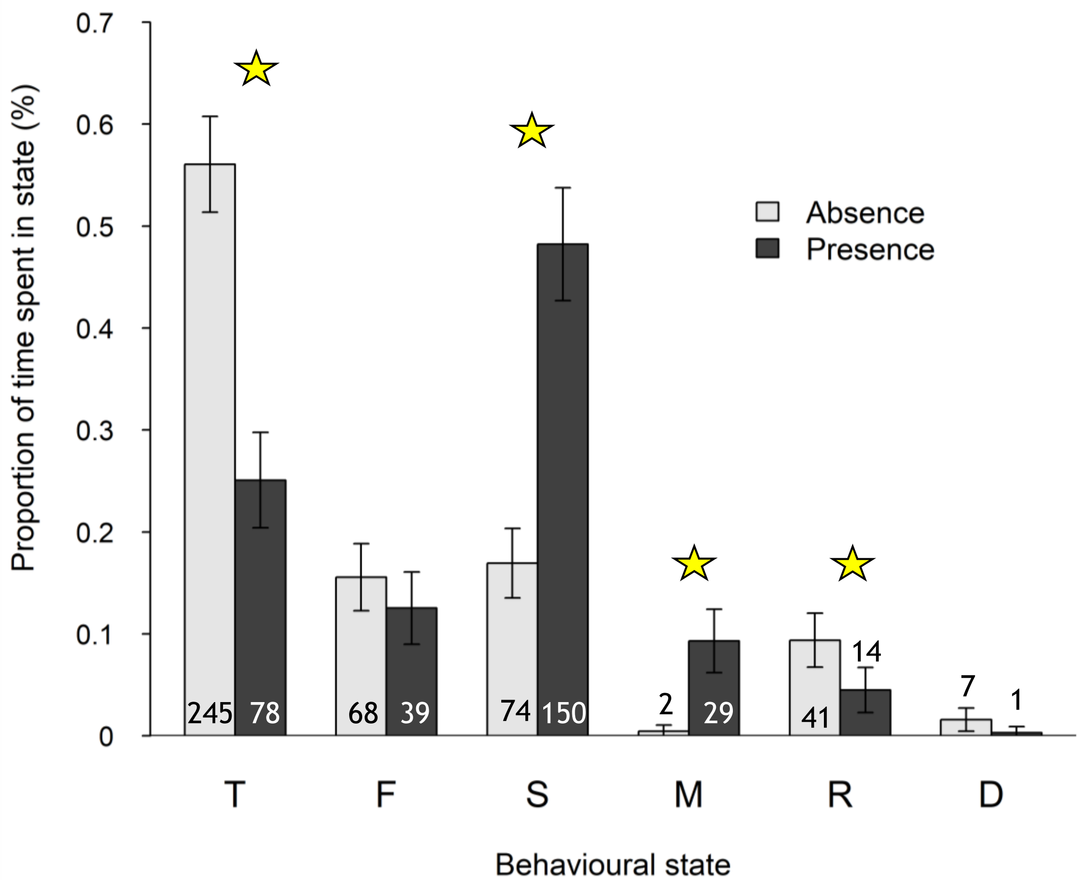


Figure 17: Overall behavioural budget of each behavioural state for bottlenose dolphins observed from research vessel between June 2019 and March 2020 in Far North waters, New Zealand, in absence and presence of vessels. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant behaviour budget 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 3 states (Figure 18). In the absence of vessels, resting (p=0.018) and travelling (p<0.001) bouts were longer (68% and 63% increase, respectively), while socialising (p=0.025) bouts were longer in the presence of vessels (58% increase). Foraging, milling and diving did not significantly vary in the presence of vessels, although a trend is noticeable for foraging with shorter bouts in the presence of vessels (43% decrease).

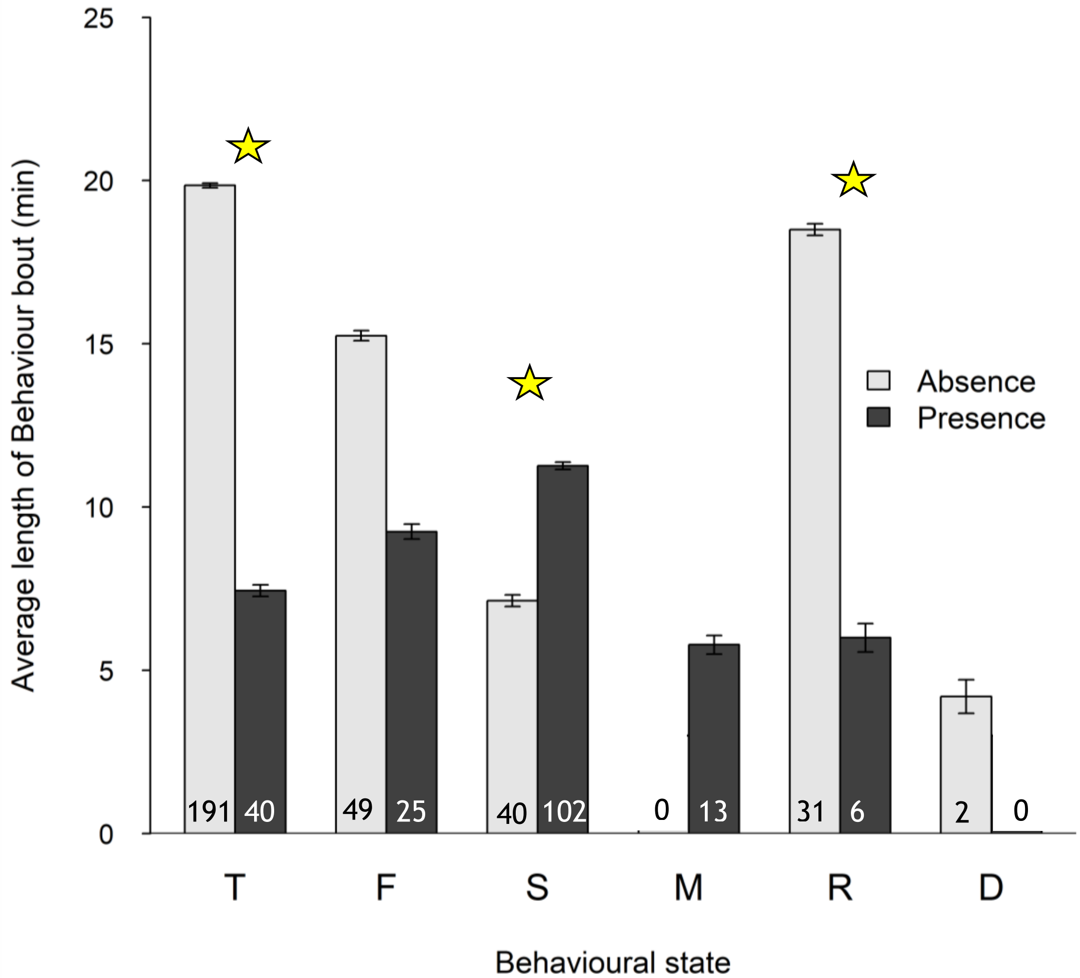


Figure 18: Mean bout length (min) of each behavioural state for bottlenose dolphins observed from research vessel in absence and presence of vessels between June 2019 and March 2020 in Far North waters, New Zealand. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant bout length difference between the presence and absence of vessels (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 Effect of vessel traffic type on behaviour
5.7.4.1 Behavioural budget

The behavioural budget of milling (p=0.015) and resting (p=0.019) were significantly affected by vessel traffic type, with a 75% increase and a 57% decrease, respectively, from Permitted vessel traffic to Unpermitted vessel traffic (Figure 19) (note: n numbers for milling, resting and diving are limited). Other behavioural states did not show clear trends between Permitted and Unpermitted vessel traffic types.

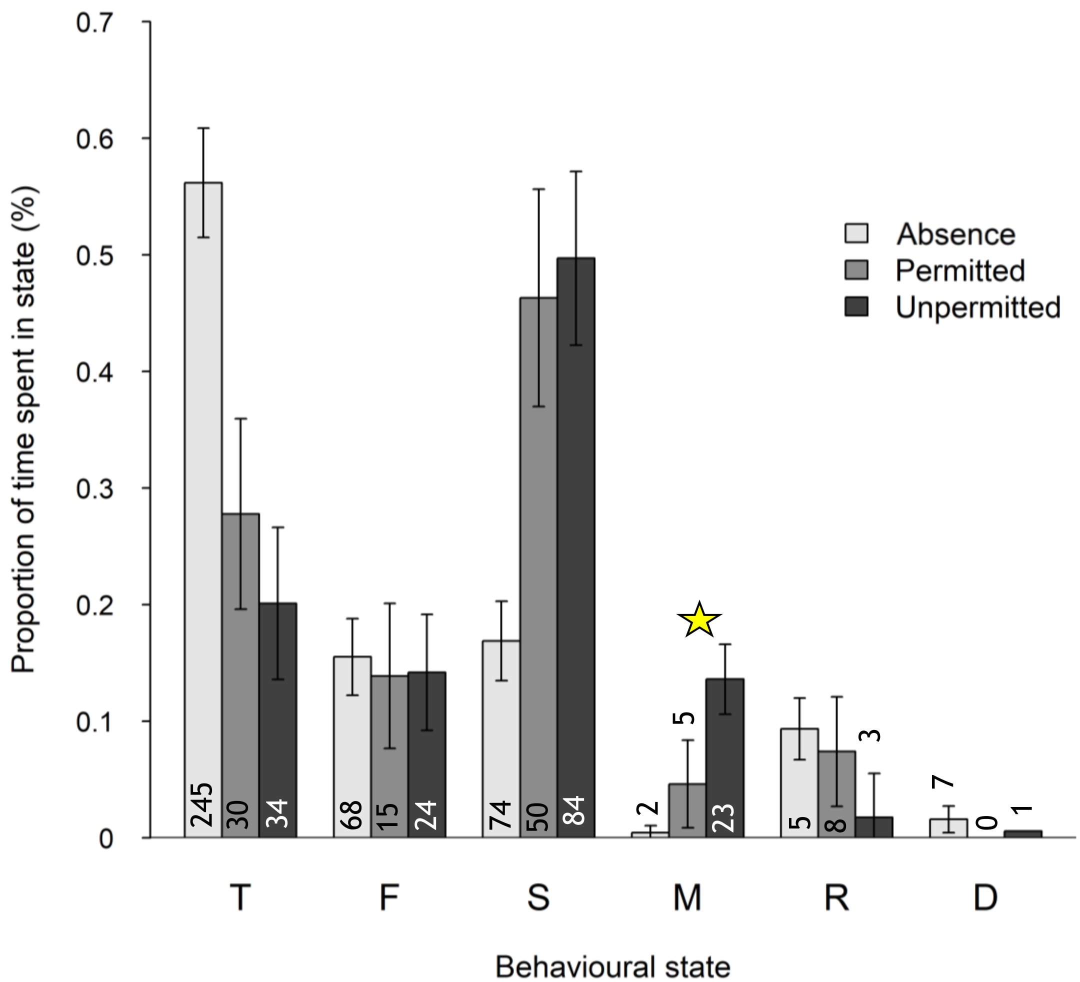


Figure 19: Overall behavioural budget of each behavioural state for bottlenose dolphins observed from research vessel between June 2019 and March 2020 in Far North waters, New Zealand, in Absence, Permitted and Unpermitted vessel traffics. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. Significant behaviour budget 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.

5.7.4.2 Mean behavioural bout length

Bout length did not vary significantly depending on vessel traffic type (Figure 20). A strong trend was visible for socialising, with a 58% increase with unpermitted vessels. No diving was observed when Permitted vessel traffic were present. No resting was observed with Unpermitted vessel traffic.

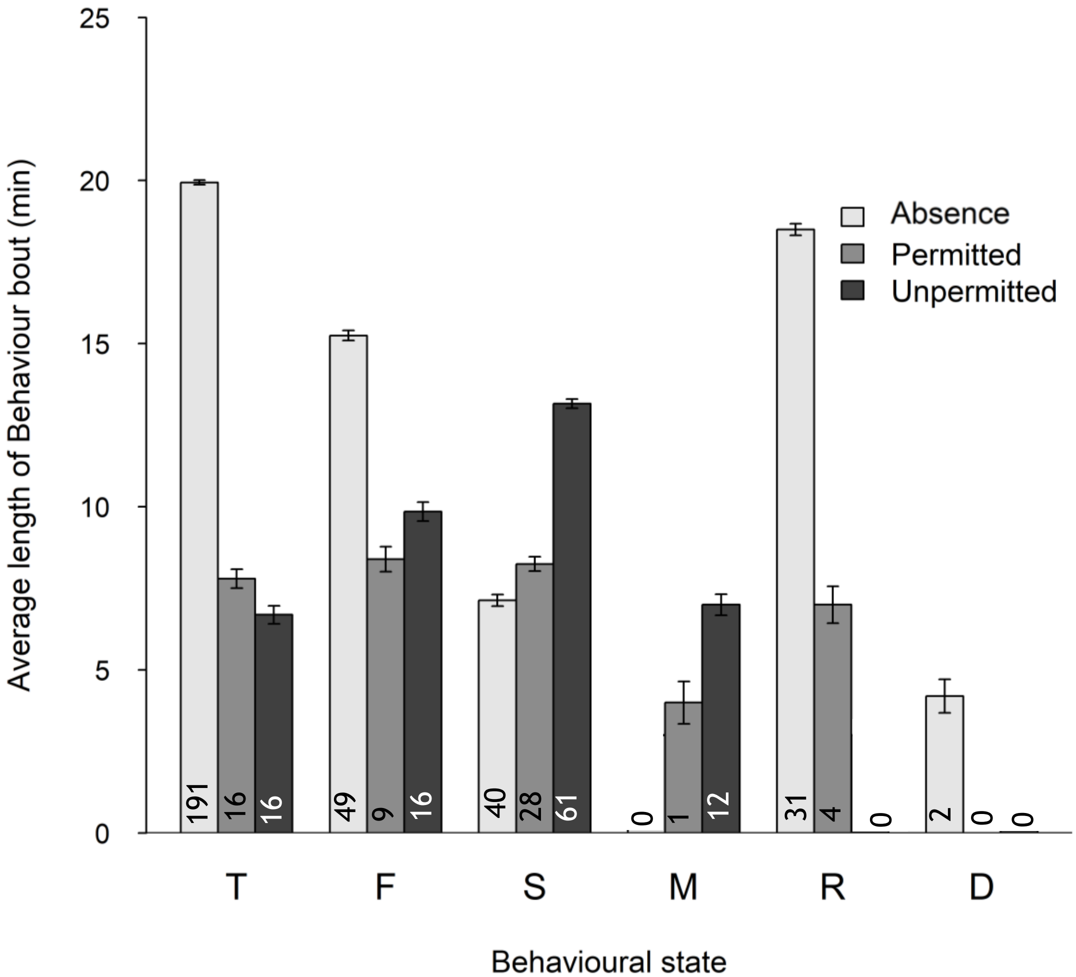


Figure 20: Mean bout length of each behavioural state for bottlenose dolphins observed from research vessel between June 2019 and March 2020 in Far North waters, New Zealand, in Absence, Permitted and Unpermitted vessel traffics. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving. No statistical difference was detected between permitted and unpermitted (z-test, a=0.05). Error bars represent standard error. N values (same state transitions) for each category are displayed on the bars.

5.7.5 Transition probabilities

The summary of probabilities to shift from one state to another in presence and absence of vessels is shown in Figure 21. No resting-foraging or resting-diving transitions were observed in the presence of vessels. No foraging-milling transitions were observed in the absence of vessels.

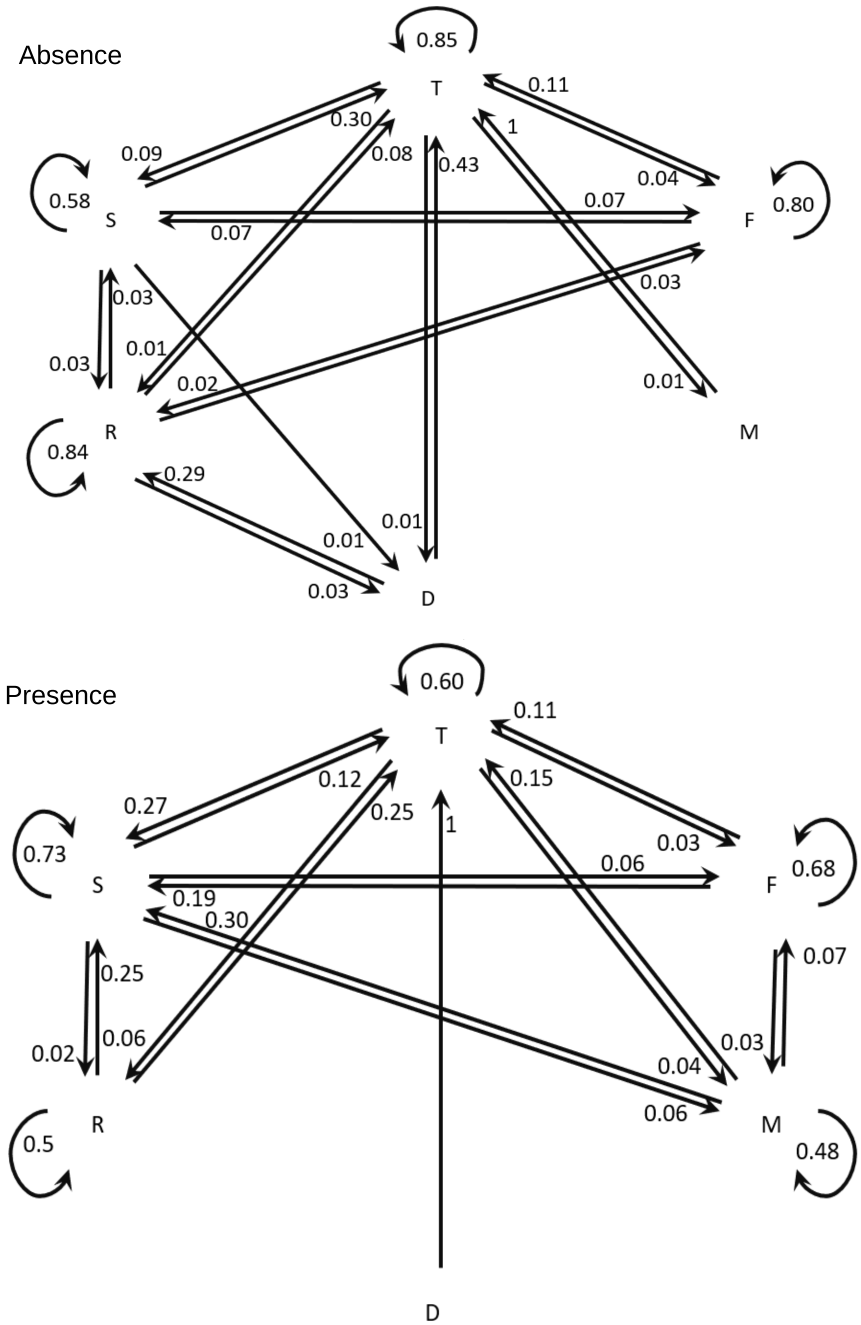


Figure 21: Probabilities of bottlenose dolphins observed from research vessel to shift from one behavioural state to another between December 2012 and April 2015 in Far North waters, New Zealand in A) absence, and B) presence of vessels. The absence of arrow between two states means there was no transition recorded between the two states. Note: T=travelling, F=foraging, S=socialising, M=milling, R=resting and D=diving.

Twenty-seven percent of transitions were significantly affected by the presence of vessels (Figure 22). Vessel presence significantly increased the probability to shift from resting and traveling to socialising by 733% and 200%, respectively, and the probability to shift from traveling to resting and milling by 500% and 300%, respectively. Vessel presence also significantly increased the probability to remain socialising by 26%, and significantly decreased the probably to remain resting and remain traveling by 40% and 29%, respectively. The probability to remain foraging decrease by 15% in the presence of vessels. (Note: sample size for diving and milling are limited).

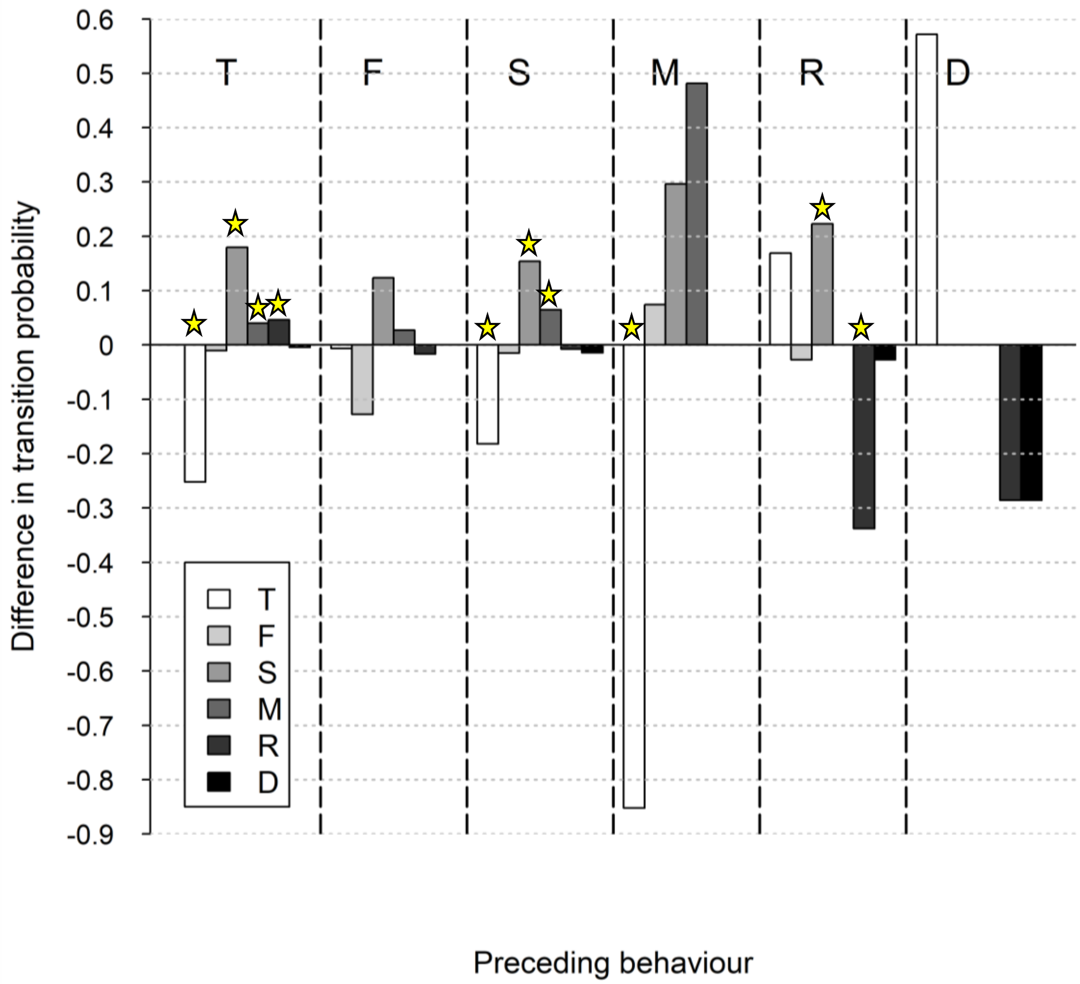


Figure 22: Effect of vessel presence on transitions in behavioural states of bottlenose dolphins between June 2018 and March 2020 in Far North waters, New Zealand, based on differences in transition probabilities pij(Presence) - pij(Absence). A negative value on the Y-axis means that the probability 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.

5.7.6 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 travelling, socialising, milling and resting (z-test, pvalue<0.05) (Table 10). Specifically, time to return to behaviour increased by 124% and 108% in the presence of vessels for travelling and resting, respectively, and decreased by 95% and 65% for milling and socialising, respectively. Time to return to behaviour also increased for foraging and diving in the presence of vessels, though no significance was detected.

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 March 2020 in Far North waters, New Zealand.

Behavioural state	**πj**	**E(Tj)**	**Behavioural state resumed (min)**
Absence			
Travelling	0.56	1.78	5.34
Foraging	0.16	6.43	19.29
Socialising	0.17	5.91	17.73
Milling	<0.1	218.48	655.44
Resting	<0.1	10.66	31.98
Diving	<0.1	62.43	187.29
Presence			
Travelling	0.25	3.99	11.97
Foraging	0.13	7.97	23.91
Socialising	0.48	2.07	6.21
Milling	0.09	10.72	32.16
Resting	0.05	22.21	66.63
Diving	<0.1	311.04	933.12

5.7.7 Behavioural events

Specific behavioural events were also documented, if occurring, alongside 3min behavioural observations (n=103). As not all events can be recorded due to most of them being subsurface, the following data is not exhaustive of all events and only represents occurrence sampling.

The predominant behavioural event recorded was bow riding (85%, n=87), which consisted of 47 observations with permitted vessels present (54%) and 40 observations (46%) with unpermitted vessels only present.

3 group splits were also recorded. All occurred concurrently with bow riding events, 2 with unpermitted vessels only present and 1 with permitted vessels present.

29 occurrences of vessels driving over dolphins were also recorded. 93% (n=27) driving over dolphins occurred from unpermitted vessels.

5 swims with bottlenose dolphins were observed. 1 swim occurred from a private vessel and the 4 others from land. All swims occurred with groups containing calves and juveniles.

5.8 Vessel effort

In 81h of encounter effort, a total of 464 vessels were recorded entering within 300m of bottlenose dolphins, resulting in an average of 1 vessel every 10 minutes.

A mean number of 1.2 vessels were recorded interacting and actively positioned to view within 300m of dolphins (range=0-14, n=1,086). Bottlenose dolphins spent significantly more time with at least one vessel within 300m during the afternoon (49.4% in the afternoon, 30.3% in the morning) (z-test, pvalue=0.001).

The effort of all vessels with bottlenose dolphins, between sunrise and sunset, resulted in a mean of 20.2 continuous minutes without the presence of vessels (other than the research vessel (range = 0-126, n= 1086)). This was not significantly different in the morning and afternoon (t-test, pvalue=0.69). The longest time recorded with at least 1 vessel (excluding the research vessel) within 300m was 2.5h.

A large majority of Private vessels were recorded entering within 300m of bottlenose dolphins (82%, n=381), followed by Commercial (8%, n=39), Permitted (8%, n=37) and DOC/research (2%, n=7) vessels. This equates to a mean number of vessels per hour of 4.7, 0.5, 0.5 and 0.1 for Private, Commercial, Permitted and DOC/research, respectively. The highest number of vessels recorded entering within 300m over an hour was 52.

New vessels within 300m of dolphins were recorded across the Bay of Islands, with higher density near Russell and the Eastern islands (Figure 23).

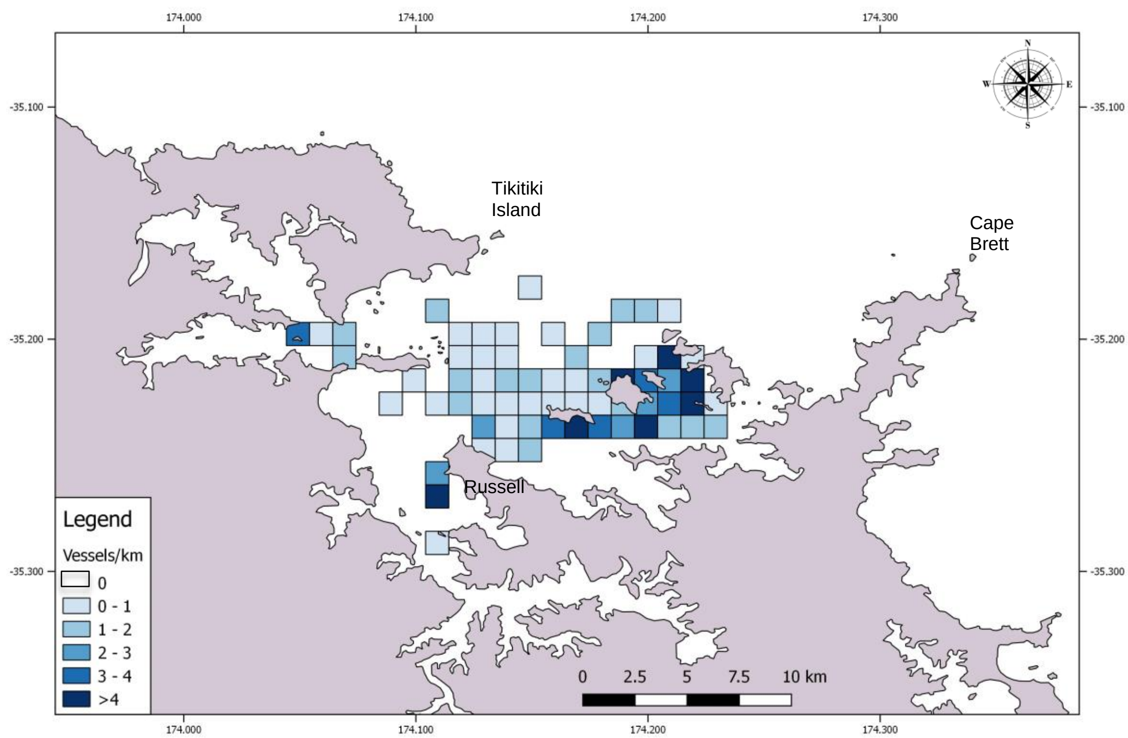


Figure 23: Vessels recorded entering within 300m of bottlenose dolphins/km of encounter effort between June 2019 and March 2020 in Far North waters (zoomed in to range extent), New Zealand, coloured according to the proportion of kilometres (km) travelled while on survey within each grid cell (1km x 1km).

Vessel types recorded entering within 300m of dolphins also varied throughout the day (Figure 24). All vessel types presented a peak at around midday (percentiles 3-6), though Private vessels reached their peak slightly earlier (percentile 4) than Permitted and Commercial (Percentile 5). Overall, Private vessels were the large majority recorded entering within 300m of the dolphins. DOC/research vessel type were excluded here for clarity due to low n numbers.

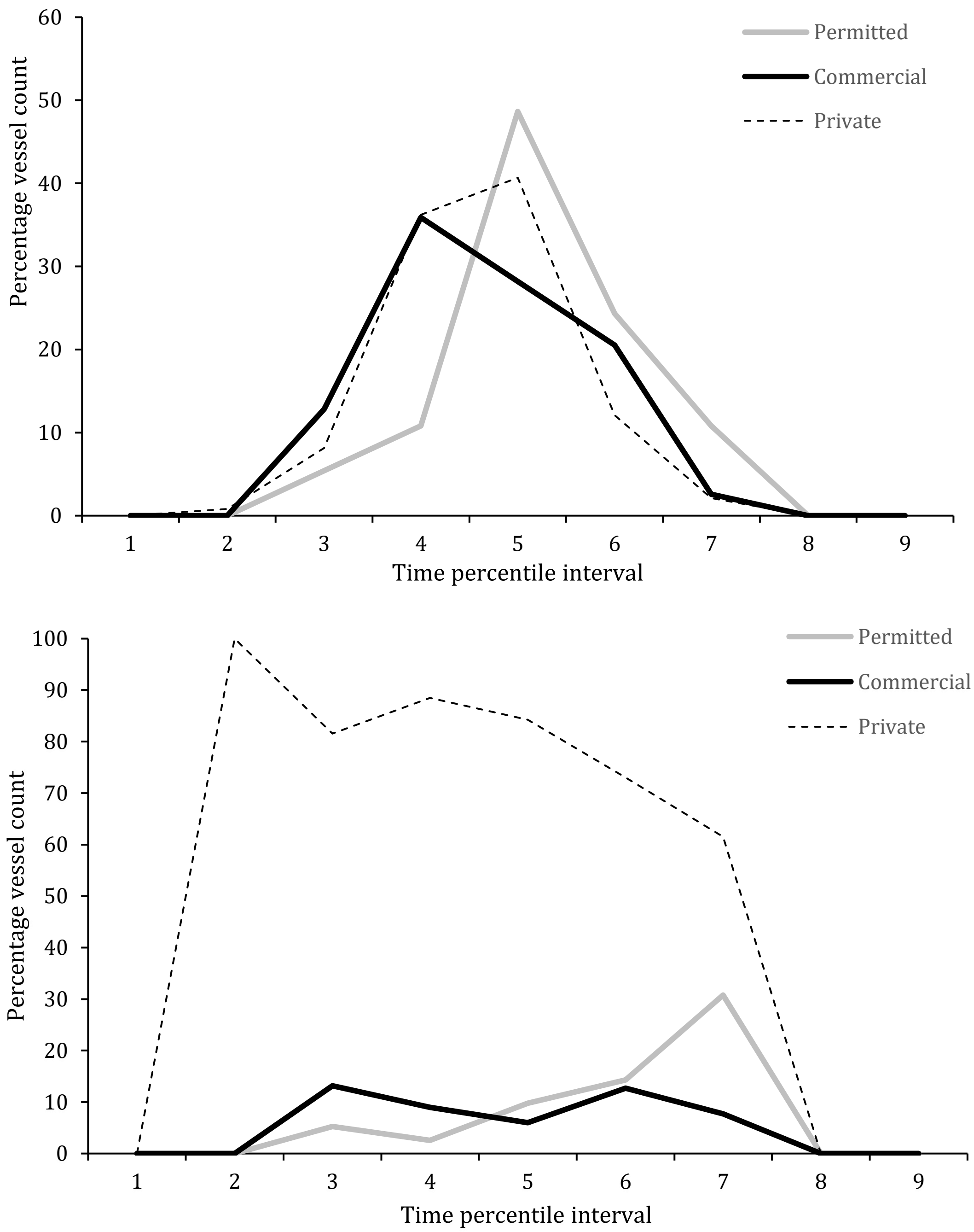


Figure 24: Diurnal variation in vessels recorded entering within 300m of dolphins between June 2019 and March 2020 in Far North waters, New Zealand. Daylight percentile is presented to account for seasonal variation in sunrise hour. A) Individual vessels type proportions in each time percentile and B) Overall diurnal proportion for each individual vessel type

5.9 Calf survival

On survey effort from October 2017 to June 2019 (183hrs) covered Bay of Islands waters and followed the methods of this study.

From October 2017 to March 2020, a total of 5 identifiable adult females were observed with 5 young of the year calves. One additional calf was observed on a single occasion, alongside individuals identified only on that one occasion. This calf did not match the criteria of neonate/young calf of the year and was therefore not included to avoid potential error regarding date of birth.

Out of the 5 calves observed, the fate of 4 calves could be documented (Table 11). The remaining calf and its presumed mother have not been observed in Far North waters since June 2018, when the calf was 2-3 months old. Two calves had survived as of March 2020, including one reaching perceived independence (28 months old as of March 2020). Of the remaining two, one was presumed still-born (observed dead and carried by presumed mother in January 2019) and one was assumed to have not survived the first year of life (presumed mother resighted without calf in more than two consecutive encounters while the calf was <18 months of age). This results in a 50% calf mortality (excluding the calf of unknown fate). No new calves were observed in the summer season of 2019-2020, with the last observation of a new neonate in December 2018.

Table 11: Summary of calves observed between October 2017 and March 2020 in Far North waters, New Zealand.

Calf	Date of birth	Status as of March 2020	Presumed mother user type
Calf 1	Dec - 2017	Weaning age reached (28 months)	Frequent user
Calf 2	Apr - 2018	Unknown	Frequent user
Calf 3	Oct - 2018	Assumed dead	Frequent user
Calf 4	Dec - 2018	Survived (16 months as of March 2020)	Frequent user
Calf 5	Jan - 2019	Confirmed dead	Frequent user

Of 32,934 photographs taken between December 2018 and March 2020, 36 were deemed of sufficient quality for calf laser photogrammetry. Those included Calf 1 (n=13), Calf 3 (n=5) and Calf 4 (n=18). Measured blowhole-to-dorsal-fin lengths ranged from 48.2cm for a one-month old calf and 80.0cm for a 28-months old calf (Figure 25).

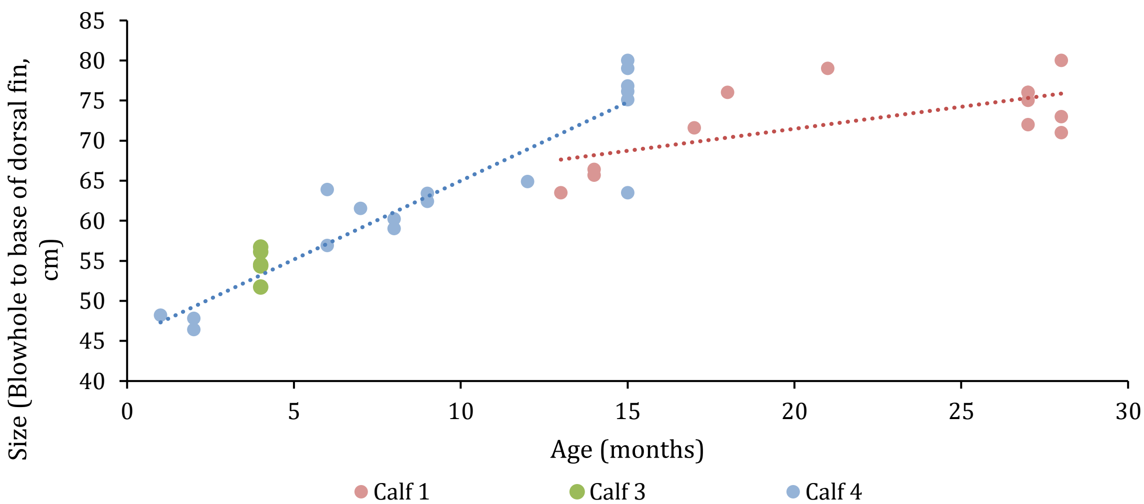


Figure 25: Blowhole to dorsal fin measurements of calves observed between December 2018 and March 2020 in Far North waters, New Zealand.

6. Summary of deliverables

6.1 Determine the range of bottlenose dolphins in Far North waters

- In 143 hours of on survey effort from Doubtless Bay to Whangarei harbour, coastal bottlenose dolphins were only observed within Bay of Islands waters. Previous records have identified occurrence along the coastline (Peters 2018), with highest densities in the Bay of Islands and Whangaroa harbour. Though the higher survey effort in the Bay of Islands (70%) and an un-surveyed area (Motuwharariki island to Whangarei harbour) should be kept in mind, this study's results suggest the Bay of Islands as the primary high-density area.
- Consistently with Peters & Stockin 2016, bottlenose dolphins were primarily seen around Russell and the Eastern islands of the Bay, which represents a reduced distribution from Hartel et al., 2014. Those areas also correlate with high vessel traffic areas.
- A group sighted on one occasion was recorded only on the outlimits of the Bay of Islands. The potential thus exists for individuals traveling along the coastline but avoiding Bay of Islands inner islands and harbor waters altogether. The lack of sightings in areas out of the Bay of Islands suggests the number of those individuals would be limited, and that there is no frequent population in those areas.

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

- Over the 10-months study, a total of 26 individuals were identified. This indicates a continued localised decline, with a 73% decrease since Peters & Stockin 2016 and a 91% decrease since Constantine 2002.
- Identifiable individuals from 1997 (Constantine 2002, 1997-1999, n=278) to 2005 (Tezanos-Pinto et al., 2013, 2003-2005, n=159) resulted in a 6.7% annual decline in this period (Tezanos-Pinto et al., 2013 also reported a conservative estimate of n=256 individuals for the 1997-1999 database, resulting in a 5.8% annual decline). Peters & Stockin (2016) reported 96 identifiable individuals in 2015 (2012-2015), resulting in a 4.9% annual decline from 2005 to 2015. This study reports 26 identifiable individuals between June 2019 and March 2020, resulting in a 23.0% annual decline from 2015 to 2020.
- 16 individuals were categorised as frequent users. Those individuals represented 95% (n=278) of resights, 94% (n=76hrs) of encounter effort and were consistently recorded as one group (containing juveniles and calves) over the study period. If this group of frequent users were to change their usage pattern of the Bay of Islands, the local population could be considered locally extinct in a short timeframe.
- The other 10 individuals were sighted two times or less.

6.3 Quantify post-management changes variation in vessel effort (comparison with Peters & Stockin 2016)

- The mean number of vessels present and actively positioned to view reduced from 11 (2016) to 1.2 (this study). The mean continuous minutes spent without vessels within 300m increased from 11.3 (2016) to 20.2 (this study).
- The ratio of vessel types entering within 300m of dolphins varied from equally spread in 2016 (1/3rd Permitted, Commercial and Private) to a large majority of Private vessels (82%) in this study. While no management changes (apart from an increase number of DOC patrols) were made on Private vessels effort, the mean

number of Private vessels entering within 300m per hour varied form 13.2 in 2016 to 4.7 in this study.

- For all vessel types, the number of vessels entering within 300m was highest at around midday/early afternoon in this study (percentiles 4 and 5), compared to mid/late morning in 2016 (percentiles 3 and 4).
- High vessel traffic areas were similar in both studies, with highest densities recorded around Russell the Eastern islands of the bay.
- The number of swims with dolphins decreased substantially in this study, with an average of 0.5 (this study) versus 37.2 (2016) swims/months from Private vessels or land (99% decrease). No swims from Permitted or Commercial vessels were recorded. Apart from an increase in on the waters DOC patrols, no action was taken to mitigate private vessels interactions with dolphins, suggesting that actions on permitted vessels have the potential to affect private vessels.
- While the reduction in effort reported above is encouraging, it should be considered that no bottlenose dolphin encounter occurred from the research vessel for 3 weeks over the busiest time of the year (Christmas/New year), due to a lack of dolphin sightings in that period. This potentially resulted in a negative bias when compared to previous studies.
- Average daylight hours with vessels requires further data to be comparable with Peters & Stockin 2016.

6.4 Determine the potential effect of current vessel effort on bottlenose dolphin behaviour

- Overall, results indicate a reduction in energy acquisition behaviours and an increase in energy expenditure behaviours in the presence of vessels.
- Dolphins spent significantly less time travelling and resting (57% and 53% decrease, respectively) and more time milling and socialising (1856% and 181%, respectively) in the presence of any vessels within 300m.
- In the absence of vessels, resting and travelling bouts were significantly longer (68% and 63% increase, respectively), while socialising bouts were significantly longer in the presence of vessels (58% increase).
- The reduction of travelling budget and bout length in the presence of vessels suggest an overall reduced mobility, consistent with the reduction in distribution observed since 1996 (Hartel et al., 2014).
- Foraging was not detected as significantly affected by the presence of vessels, as opposed to Peters & Stockin 2016. Some trends were however visible, with shorter bouts (43% decrease) in the presence of vessels.
- Dolphins also spent significantly less time travelling and resting (40% and 20% decrease, respectively) and more time socialising (102% increase) in the afternoon. Bout length was significantly longer for socialising (55% increase) in the afternoon.
- Dolphins spent significantly more time milling and less time resting (75% increase and 57% decrease, respectively) in the presence of Unpermitted vessels traffic, compared to Permitted vessels traffic. Bout lengths showed no significant differences due to vessel type.
- All transitions to socialising increased in the presence of vessels. This was significant for resting, traveling and socialising (733%, 200% and 26% increase, respectively). Resting to resting and traveling to traveling transitions significantly decreased in the presence of vessels (40% and 29% decrease, respectively). A trend was detected for foraging to foraging transitions with a decrease of 15% in the presence of vessels
- In the presence of vessels, time to return to behaviour significantly increased for travelling and resting (124% and 108% increase, respectively), and significantly decreased for milling and socialising (95% and 65% decrease, respectively).

- Vessel effort and therefore the effects described above can be considered to involve the nursery group of frequent users 94% (n=76hrs) of the time.

6.5 Provide an update in calf survival

- 5 calves were observed over 27 months in this study, compared to 12 calves over 29 months for Peters & Stockin 2016.
- Calf mortality was 50% in this study, compared to 75% in Peters & Stockin 2016.
- No new calves were observed in the summer 2019-2020 season.
- All calves were observed from the frequent user group.
- While the preliminary photogrammetry results were promising, the low number of calves available for sampling did not allow for conclusions to be drawn in this study.

A summary of comparative results between this study and Peters & Stockin 2016 is given in Appendix 2.

6.6 Provide statements and management recommendations based on the above

Peters & Stockin (2016) identified 5 critical issues to the Bay of Islands bottlenose population. Those issues and the update on their status quo provided by this report are summarised below. Management recommendations are additionally offered.

"Critical issue 1: Significant decline in *nationally endangered* bottlenose dolphin Bay of Islands population and potential risk of localised extinction"

A continued decline from Constantine 2002, Tezanos-Pinto et al., 2013 and Peters & Stockin 2016 has been documented, with a further 23% annual decline since Peters & Stockin 2016 (n=26). This represents a 91% decline from Constantine 2002 (n=278). 95% of resights (n=16 individual fins) belonged to one nursery group only (refer to section 5.6)

As per Peters & Stockin 2016, it is recommended:

- For the current moratorium to remain in place, at least until population analyses are completed for the full North-East coast population. As local decline and significant vessel effects have been consistently reported over the last 20 years, an increase in any vessel activity around bottlenose dolphins has the potential to accelerate the decline to local extinction.
- For DOC to apply a multiple stakeholder inclusive (Higham et al., 2008) year-round management plan. The Bay of Islands is a complex area involving numerous stakeholders (commercial, private, cultural and others), requiring a management plan able to address all involved.
- For DOC to make provision for training of commercial permitted skippers and crew, yearly and ahead of peak season, to 1) reinforce both MMPR and local guidelines and restrictions in place and 2) ensure up-to-date and accurate education content is communicated on board permitted vessels
- For DOC to both support and monitor for accuracy local conservation education content available around bottlenose dolphins.

Additionally, it is recommended:

- For DOC to maintain exclusion zones as implemented in July 2019, and review location of the zones on a 3-yearly basis. As bottlenose dolphin behaviour in the Bay of Island does not seem to be substantially location based, exclusion zones must be placed in areas with a combination of high vessel traffic and high dolphin density, to minimize disturbance on the full range of behaviours.

- For DOC to maintain or increase the level of patrols as seen in the summer 2019-2020 season. Such patrols allow for the monitoring and education of private vessels, which is otherwise inexistent.
- For DOC to explore further management options explored to ensure the population is effectively protected, i.e Marine Mammal Sanctuary, MMPR review and/or locally specific guidelines.

"Critical issue 2: High and unsustainable calf mortality"

5 calves were observed over 27 months. 50% (n=2) of calves were estimated to have survived. No new calves were observed in the summer season of 2019-2020, with the last observation of a new neonate in December 2018. All calves were observed within the frequent user group (refer to section 5.9)

As per Peters & Stockin 2016, it is recommended:

- For the DOC to improve education on the MMPR and local guidelines to both private and commercial vessel operators in the Bay of Islands, with an emphasis on calf presence.
- Mandatory distances for permitted? -> keeping in mind any rules on calf presence basically means a rule on all their bottlenose encounters right now.

Additionally, it is recommended:

- For DOC to maintain exclusion zones as implemented in July 2019, and review location of the exclusion zones on a 3-yearly basis to match vessel traffic and dolphin density (see Critical issue 1). Such zones have the potential to create breaks in vessel pressure, and thus allow the more vulnerable individuals to survive their first years of life.
- For DOC to introduce locally specific guidelines applicable over all vessel types around calf presence, including increased distance to dolphins and reduced speed within 300m.

"Critical issue 3: Vessels and swim-with activities disturb/disrupt behaviours critical to bottlenose dolphin survival"

Vessel presence increased vessel expenditure behaviours and decreased energy acquisition behaviours, both in budget and bout length. Results also suggests a loss of mobility due to reduced travelling and observed reduced distribution. Behavioural changes observed involved the frequent user nursery group 94% (n=76hrs) of the time. No swims were observed from permitted or non-permitted commercial vessels, and average monthly swims from private vessels/land substantially decreased (99%, Appendix 3) from Peters & Stockin 2016. (refer to section 5.7).

It is recommended:

- For DOC to maintain exclusion zones and commercial swimming ban as implemented in July 2019. Appropriate exclusion zones have the potential to introduce time breaks in vessel presence around dolphins, and energy acquisition behaviours such as resting to take place uninterrupted.
- For DOC to introduce locally specific guidelines applicable over all vessel types. Private vessels were shown to be the predominant type present around bottlenose dolphins, with no other mitigation measures than the presence of a DOC patrol vessel. As they are less likely to be aware of MMPR, private vessels are likely to have an increased effect on bottlenose dolphin behaviour, making it necessary for mitigation measures to include them.
- For DOC to establish an education program associated with introduced local guidelines, to improve identification of calf presence by private vessels. Both local guidelines and education messages need to focus on simplicity for reliable results.

"Critical issue 4: Higher than sustainable vessel effort exerted on local population"

Vessel presence was reduced by 50% from Peters & Stockin 2016 (potential negative bias with unsampled peak season, see section 6.3). While an encouraging result this level of effort remains high compared to other areas of New Zealand. The maximum number of vessels recorded entering within 300m in one hour was 52, or almost 1 new vessel per minute. Vessel traffic was constituted of 82% of private vessels refer to section 5.8)

As per Peters & Stockin 2016, it is recommended:

- For the current moratorium to remain in place, at least until population analyses are completed for the full North-East coast population.
- For DOC to establish enforceable regulations for unpermitted commercial and private vessels.

Additionally, it is recommended:

- For DOC to maintain or increase the level of patrols as seen in the summer 2019-2020 season. Such patrols allow for compliance monitoring and education of all vessel types. This is particularly important for private vessels as 1) they are the prevalent vessel type with dolphins and 2) little bottlenose-related education content is available to private boaties in the Bay of Islands. Specifically, education on vessel speed and number around dolphins should be prioritised. The establishment of land viewing stations would also be a useful tool to reduce non-commercial effort around bottlenose dolphins.
- For DOC to maintain changes to permits as introduced in July 2019

"Critical issue 5: Poor compliance across all vessel types utilizing Bay of Islands waters"

Compliance was not investigated in this study. However on the water observations suggest poor compliance primarily from unpermitted commercial and private vessels.

It is recommended:

- For DOC to establish enforceable regulations for private and commercial vessels
- For DOC to provide or support the provision of marine mammal conservation education in the Bay of Islands

Overall, recommendations include a combination of enforcement and education over all vessel types on current marine mammal protection regulations, and the urgent introduction of local regulations specific to bottlenose dolphins. The creation of a Marine Mammal Sanctuary in the Bay of Islands would provide the framework to cover all elements reported here and is strongly recommended.

7. Future research

On the short term:

- Continuation of present study for 2 years, to allow for timeframes matching historical studies in the area and a true comparison. This will also align with the current permit timeframe.

On the longer term:

- Continuation of yearly photo-identification on long-term, at least until identifiable individuals numbers are comparable to Constantine 2002.
- Continuation of calf photogrammetry measurements on long term, until n numbers can prove or disprove a correlation between calf size and survival.
- Continuation of data collection on all marine mammal species occurring in Far North waters. This would allow this assessment o the potential effects of diverting current tourism

effort centered on bottlenose dolphins to other species, as well as monitoring populations. Distance sampling methodologies could be considered for species where photo-identification is less appropriate.

Valuable methodologies to explore:

- The use of acoustics in the form of fixed hydrophone(s) has the potential to bring insight into behaviour of bottlenose dolphins at night, as well as assess the levels of background noise in targeted areas.
- Collection of scat samples has the potential to bring insight into prey species and stress hormone levels.

Benefits such as consistency, comparability and long-term planning would arise from including all items described above into a yearly Far North marine mammal monitoring plan.

8. Conclusions & perspective

Bottlenose dolphins are the most encountered species in Far North waters. They are particularly seen in the Bay of Islands, where they have constituted the economic core of several dolphin-watching operations for over 20 years. The Bay of Islands is also a high vessel traffic area, with strong densities of both commercial and private vessels.

Disruption of critical behaviours by vessels, a local decline has been continuously reported in the Bay of Islands (Constantine 2002, Tezanos-Pinto 2013, Peters & Stockin 2016, this study). In the context of additional high calf mortality (Tezanos-Pinto et al., 2015, Peters & Stockin, 2016, this study) the loss of the Bay of Islands as useable habitat causes immediate concern for the overall North-East coast population.

Although management changes put in place in July 2019 have reduced the vessel effort around bottlenose dolphins, this study shows levels of effort remain high, critical behaviours are being disturbed, and the local decline has accelerated. Bottlenose dolphin numbers in the Bay of Islands are now at an all-time low, and critical action is needed to avoid local extinction. The establishment of enforceable local guidelines and increased education through the setup of a Marine Mammal Sanctuary is strongly recommended.

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11. Appendix 1

Definition of behavioural events of bottlenose dolphin groups in far North waters, New Zealand (Constantine 2002; Constantine et al 2004)

Behavioural event	**Definition**
Socialising	
Horizontal jump	At least one dolphin engaged in horizontal airborne forward progression of at least one body length while in dorsal position
Vertical jump	At least one dolphin engaged in vertical airborne forward progression of at least one body length while in dorsal position with abrupt lunges out of water with only shallow submerged
Noisy jump	At least one dolphin engaged in airborne forward progression with Maximum/flat body contact with the surface of the water upon entry
Head flop	At least one dolphin engages in partial breach above the surface of the water with side of head making sharp, noisy contact with surface upon entry
Top of body out	At least one dolphin orientated to hold top of body above the surface of the water
Tail out	At least one dolphin orientated to present and hold tail and/or flukes above the surface of the water
Upside down Swim	At least one dolphin orientated to Swim with ventral side towards the water surface
Bite	Teeth of one dolphin makes contact with any other individual

Behavioural event	Definition
Socialising	
Lobtail	At least one dolphin orientated in horizontal body position relative to the surface of the water. Dolphin makes contact with surface via a jerky whole body movement to flex tail. Individuals are likely to slap several times
Chase conspecific	Persistent following of one or more dolphin for a prolonged period
Pounce	At least one dolphin makes contact with one or more other individuals, with ventral to dorsal contract
Bubble blowing	At least one dolphin releases a large volume of air through its blowhole while submerged in one short burst
Surfing waves	At least one dolphin engaged forward progression in the direction of swell/waves
Bowriding/Wakeriding	swell/waves
Playing with kelp	One dolphin picking up and carrying any naturally occurring object, often on the dorsal fin
Belly away	At least one dolphin orientated to not display ventral side to one or more other individuals
Penis out	Dolphin penis visible and protruding from body
Body contact	At least two dolphins make contract. One engages in touching of the body (Connor *et al.* 2000) and includes biting, pectoral touch, body touch, or rolling together at the surface
Belly present	At least one dolphin orientated to display ventral side to one or more other individuals
Spyhop	Brief vertical or near vertical surfacing of the head, eye and rostrum above the water line followed by sinking return to water
Copulation	Two dolphin contact confirmed observation of sexual approach with ventral joining and intromission of conspecific
Possible copulation	Two dolphin contact between genital zone and intromission suspected but not observed
Nursing (rostro-genital contact)	confirmed observation of calf rostrum touching ventral surface of adult in area of mammary slits, with position held.
Foraging	
Chin out	At least one dolphin orientated with chin and rostrum present over the water line
Feeding	At least one dolphin observed feeding with confirmed visual of prey in mouth
Surface rushes	At least one dolphin engaged in fast and directional swimming on the surface with dorsal fin creating white-water splash
Synchronised swimming	Two or more dolphins matching speed and orientation in persistent forward movement
Horizontal flex	At least one dolphin orientated to perform Side flex or horizontal bending of the body for manoeuvring during feeding
Swimming on side	At least one dolphin orientated with lateral side towards the water surface
Fish toss	At least on dolphin tossing of fish using head, pectoral flipper or fluke where fish is thrown clear of the surface
Resting	
Logging	At least one dolphin observed stationary with no persistent movement at the surface for 5sec or more.

12. Appendix 2

Comparison of results between Peters & Stockin 2016 and Guerin 2020 (this study)

Criteria	Peters & Stockin 2016	Guerin 2020
Study timeframe	29 months	10 months
Number of dolphins identified	96	26
Discovery curve plateau	14 months	6 months
Dolphins identified within 10 months	80	26
Number of frequent users	19	16
Annual percentage decline since previous study	4.9%	22.9%
Vessels affected behavioural budget	Yes	Yes
Vessel affected behavioural bout length	Yes	Yes
Vessels affected behavioural transitions	Yes	Yes
Mean number of vessels present	11	1.2
Mean continuous minutes without vessels	11.3	20.2
Vessel type most present	Private (36%)	Private (82%)
Average swims from non-permitted platforms per month	37.2 (n=1080)	0.5 (n=5)
Please note, calf data for Guerin 2020 is based on a 27 months timeframe (October 2017 to March 2020)		
Number of calves recorded/months	0.4 (n=12)	0.2 (n=5)
Calf mortality	75%	50%